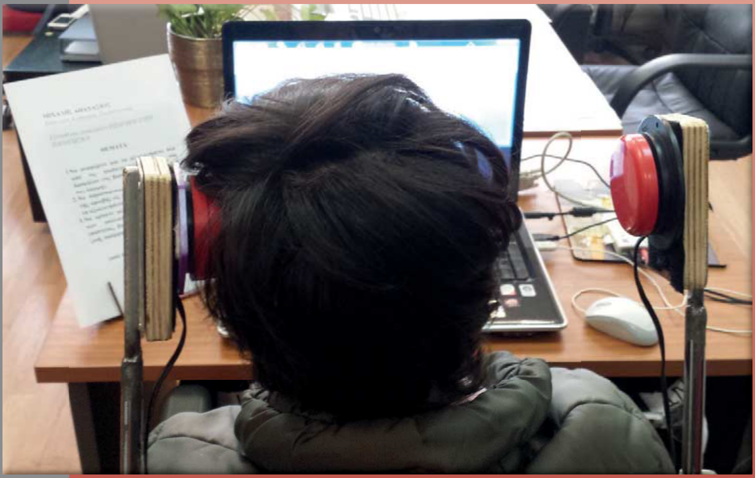
STUDIES IN HEALTH TECHNOLOGY AND INFORMATICS 306

Assistive Technology: Shaping a Sustainable and Inclusive World



Editors: Dominique Archambault
Georgios Kouroupetroglou

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Caring about others and the future is part of what makes us human, and it can be argued that improving the lives of people with disabilities improves the lives of all human beings. Most of what we do as a society for people with disabilities also improves life for others, and if we consider a person's entire life, a disability of some kind will affect almost everybody at some point.

This book, *Assistive Technology: Shaping a Sustainable and Inclusive World,* presents the proceedings of AAATE 2023, the 17th International Conference of the Association for the Advancement of Assistive Technology in Europe, held in Aubervilliers, France, from 30 August to 1 September 2023. For over 30 years, the biennial AAATE conference has focused on research aimed at improving the lives of people with a disability, and has become one of the main platforms for all stakeholders in the field. A total of 123 papers were submitted in the category intended for publication in these conference proceedings, and after a rigorous process involving review by at least three international reviewers, 74 were selected for inclusion here. Topics covered include service delivery of AT; AT for various groups such as older adults, children, and those with cognitive disabilities; mobility; privacy and security issues; and AT to promote inclusion and facilitate participation in education, culture, and work.

Providing a comprehensive and current overview, the book will be of interest to researchers, practitioners, manufacturers, decision-makers and providers, users of AT, and anyone else working in the field.

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ASSISTIVE TECHNOLOGY: SHAPING A SUSTAINABLE AND INCLUSIVE WORLD

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Assistive Technology: Shaping a Sustainable and Inclusive World

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Preface

We are happy to introduce AAATE 2023, the 17th International Conference of the Association for the Advancement of Assistive Technology in Europe, taking place in Aubervilliers, near Paris, from 30 August to 1 September 2023. Since the first conference was held in Maastricht in 1990, and every 2 years thereafter except in 2021, the AAATE conference has become, together with its twin conference ICCHP (International Conference on Computers Helping People with Special Needs), the main *rendez-vous* for all stakeholders interested in the field of digital accessibility and assistive technologies (AT) for people with disabilities: researchers, experts, practitioners, manufacturers, AT users, decision-makers, providers of AT and accessibility, as well as anyone else working in this field.

The topics discussed at this biennial conference have continued to evolve for more than 30 years, but the constant of AAATE, to borrow a mathematical term, is its focus on research which is aimed at improving the lives of people with a disability. This could be seen as a restrictive focus, but in reality it is a universal goal. Indeed, improving the lives of people with a disability simply means improving the lives of all human beings. There are two reasons for this. The first is that most of what we, as a society, do for people with a disability will improve the lives of everyone; for example, street accessibility for wheelchair users also facilitates the lives of young parents pushing prams, elderly people, delivery workers and many more. The second reason is that if we consider a person's entire life, and not just their situation at any given moment, disability will affect almost everybody at some point. Indeed, supporting people with a disability is part of what makes us human, that is, a species that cares about others and the future.

This last point may seem quite optimistic in the current global context, where human activities now endanger the survival of the entire species, but we are convinced that improving the lives of people with a disability – and consequently all people – is a key issue that will contribute to making our world more sustainable. In the same way, sustainability and inclusiveness are intrinsically linked, with both seeking to ensure the safeguarding of the most vulnerable members of society. This undoubtedly leads us to *Assistive Technology: Shaping a Sustainable and Inclusive World*.

One of the major changes witnessed in our domain of research has been the role played by end users; indeed, people with a disability should not merely be involved in the testing of prototypes designed to meet some specific need, it is essential to place them at the centre of the research and development process. Not only do people with disabilities best know their own needs, they also have great potential to be part of this process. Let us recall a certain Charles Barbier de la Serre, who invented the concept of raised-dot writing to facilitate night messaging, and whose name very few know two centuries later. There is also Louis Braille, who was blind, and who turned this tactile writing style into a reading system which revolutionised the education and lives of blind people all over the world. (Barbier's night writing system offered only the possibility of deciphering, making its usefulness extremely limited.)

The AAATE 2023 conference is hosted by University Paris 8-Vincennes-Saint-Denis at the *Centre de Conférences* of the Condorcet Campus.[1] This campus was founded in 2019 to provide new research infrastructure for the humanities and social sciences, and includes several buildings housing research labs, a large documentary centre known as the *Humathèque*, *L'Hôtel à projets,* where labs can have additional temporary offices for the duration of a project, *La Maison des chercheurs* providing short- and long-terms accommodation for invited researchers, as well as student housing and the very functional congress centre that is hosting the conference. More specifically, the conference is organised by the THIM team of the CHArt laboratory at the University Paris 8-Vincennes-Saint-Denis. THIM stands for *Technologies, Handicaps, Interaction et Multimodalités* (Technology, Handicap, Interaction and Multi-modalities). The team's research has focused on AT and accessibility for the past two decades. It is connected with the Master's programme *Technology and Disability*, which has been training students in AT development and assessment, as well as digital accessibility, since 2001.

As AAATE is intrinsically multidisciplinary, the conference has an original structure. Contributors were given the choice of contributing either an oral presentation, or an oral presentation combined with a paper to be published in the conference proceedings. This choice reflects the diversity of disciplines represented at the conference, as some fields value conference papers, provided they are peer reviewed, while others will only consider the publication of articles in scientific journals. Overall, 157 scientific presentations will be delivered in four parallel sessions during the three days of the conference. In addition, an Inclusion Forum will cover 17 sessions on education, 7 on policies and 24 on innovation.

Over 240 proposals were submitted in response to the call for contributions, demonstrating the research community's keen interest in these topics in Europe and beyond. Of these proposals, 123 were also submitted for publication in the conference proceedings. After completion of the review process, 74 of these were selected for the current proceedings, published by IOS Press in the series entitled *Studies in Health Technology and Informatics*. Each paper was reviewed by at least three reviewers from the International Scientific Committee, which is composed of 110 international experts from 32 countries around the world and reflecting the diversity of disciplines in our community. Many of the papers rejected for publication in the conference proceedings were subsequently reoriented to other categories of the conference, for oral presentation, or to the education, policy or innovation sessions.

At the time of writing this preface, two months before the conference, we have already registered attendees from 45 countries across five continents.

We are grateful to all the authors whose research efforts are published in this volume. We would also like to acknowledge the efforts of the International Scientific Committee, as well as that of the members of the Programme and Organisation Committees, who dedicated their time and effort to the realisation of this event. Finally, we would like to thank all conference participants for supporting the mission of AAATE.

July 2023

Dominique Archambault and Georgios Kouroupetroglou

[1]For more information about the *Condorcet* Campus, see https://www.campus-condorcet.fr/

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Using a Social Robot to Engage Older Adults Living in Residential Care Homes in Cognitive Training: Preliminary Results from the SHAPES Project

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Abstract. The employment of socially assistive robotics (SAR) is increasingly being considered a credible solution to support healthcare systems in dealing with an aging society. In this contribution, we explore the experience of older adults (n = 11) living in a residential facility with a cognitive training intervention conducted with the support of a SAR. Within the HORIZON2020 Project SHAPES, a mixed-method study has been conducted to collect preliminary evidence on users' engagement and acceptance of the proposed SAR-based intervention. The results suggest that the SAR-based cognitive training intervention conducted was accepted by all stakeholders. Data on enjoyment of participants indicate that users did not experience a "novelty effect" of the proposed innovation, but longer sessions are needed to confirm this result.

Keywords. Older adults, aging, cognitive decline, social robots, cognitive training

1. Introduction

Almost every country in the world is experiencing growth in the number and proportion of older persons in its population [1]. While population aging can be seen as one of the biggest achievements of modern medicine and public health measures, an aging society also poses important challenges for the sustainability of healthcare systems [2].

The employment of socially assistive robotics (SAR) is increasingly being considered a credible solution to support healthcare systems in dealing with an aging society (for a recent systematic review see [3]). Social robots can be considered 'relational artifacts' [4] that differ from other information technologies (e.g., smartphones, Alexa) since they can physically interact with real-world objects and people through verbal, non-verbal or affective modalities [5]. SAR refers in particular to the use of social robots to provide "the appropriate emotional, cognitive, and social cues to encourage development, learning, or therapy for an individual" [6; p. 1974]. In this

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view, a SAR is a system that employs social interaction strategies such as speech, communicative gestures and facial expressions to provide assistance in relation to a specific assistive or therapeutic context. Although research into the benefits of SAR is still at a preliminary stage, encouraging evidence suggests that robots may be useful as companions for older adults, not just to support them in domestic or everyday tasks, but also in improving their psychosocial outcomes (e.g., preventing cognitive decline) [7]. According to seminal evidence by Kim et al. [8], conducting cognitive training using robots may lead to more positive outcomes (e.g., brain activation) than training carried out in the traditional way, such as paper and pencil. This is because exposure to new technology is more difficult and challenging for seniors than using familiar devices, and the novelty effect may not only contribute to increased brain activity but may also enhance seniors' motivation to participate [9]. Despite current evidence showing promising results (for a recent systematic review see [10]), there are still multifaceted challenges in the application of SAR in cognitive training of older adults. One of such challenges is the deployment of SARs that are capable of consistently working in a noisy, dynamic real-world environment, thus making a significant contribution to a user's confidence and increase of users' positive perception of the robot [10].

1.1. Purpose and relevance of the study

The aim of the Smart & Healthy Ageing through People Engaging in Supportive Systems (SHAPES) HORIZON2020 project [11] is to integrate a broad range of technological, organizational, clinical, educational, and societal solutions to facilitate long-term healthy and active aging, contributing to the maintenance of a high-quality standard of life. In this contribution, we explore the experience of older adults living in a residential facility with a cognitive training intervention conducted with the support of a SAR. The study focuses in particular on the users' engagement and acceptance of the proposed SAR-based intervention. By using the robot in the daily living contexts of the end users (i.e., residential facility), this study can be considered relevant as it provides knowledge that is practical and has immediate application in a applied setting. The results of this study can be thus used to (1) inform further developments of the robotic platform to increase its acceptability for end users and (2) design more robust research protocols to collect reliable evidence on its impact in a real-life scenario.

2. Method

2.1. Participants

The study involved a convenience sample of 11 older adults (females n = 7; mean age = 75) living in a residential facility in the municipality of Bologna. The participants were selected among a pool of 17 participants, of whom six did not want to participate because either they did not want to interact with the robot (n = 5) or they considered the cognitive training unuseful (n = 1). To be included in the study, participants had to (a) live in the residential facility; (b) be able to understand and sign the consent form by themself; and (c) have never had used/interacted with a SAR before. The involved participants presented with an average level of limitations and restrictions in activities and participation as assessed by the WHODAS II (scoring: 0% = no limitations; 100% = severe limitations) of 46,2% (range: 31,25%-58,33).

2.2. Cognitive training and SAR

All participants were involved in a cognitive training intervention specifically developed for the scope of the current study by the SHAPES Consortium. The intervention included the following activities (a) riddles, (b) "create a story with the robot"; (c) "names, things and cities" (d) "find 5 elements belonging to a specific category" (e) given a specific event, find possible causes, (f) memories of places visited in the past (g) "ask the robot some curiosity about itself". Each session lasted about 45 minutes and included one of the aforementioned activities. The sample participated in the cognitive training activities all together to promote participants' social interaction and increase motivation (Figure 1). All the activities were delivered by a humanoid robot with the support of a researcher. The robot used was the ARI robot produced by PAL Robotics [12], which was controlled by a human operator during the training sessions.

The SHAPES technological solution originally tested consisted of three main components. The core is the ARI robot, which provided a suite of tools to enable real-time remote control. The robot itself was not provided with a voice layer, but only text-to-speech functionality. For this reason, a Chatbot has been integrated by Vicomtech [13]. In order to complete the description, most of the cognitive games were included with the Dianoia App [14], that could be accessed both from an external tablet or directly from Ari touchscreen.

Figure 1. Image of a typical cognitive training session involving a group of participants along with the operator and the social robot ARI.

2.3. Evaluation protocol

The study included three main phases. A baseline phase during which participants had the possibility to meet ARI and interact with it. At the end of this introductory meeting, participants were requested to sign the informed consent in case they accepted to take part in the intervention. In this first phase, those who signed the informed consent were administered a questionnaire to collect socio-demographic information.

The second phase included the cognitive rehabilitation intervention. In total, four cognitive training sessions were conducted over a period of 4 weeks (i.e., about one cognitive training session per week). At the end of each session, participants self-reported their levels of enjoyment of the activities using a 0-10 Likert scale (higher scores imply higher enjoyment). The third phase included two follow-up focus groups with the participants in the cognitive training activities (n = 6) and their formal caregivers (n= 4) to explore their overall experiences and collect feedback. On that occasion, two questionnaires were further administered. The General Attitudes Towards Robots Scale (GAToRS) [15] was used to assess the overall attitudes of older adults towards robots. The GAToRS includes 20 items and assesses four distinct factors (i.e., subscales): a) comfort and enjoyment around robots, b) unease and anxiety around robots, c) reasonable hopes about robots in general and d) reasonable worries about robots in general. All items were presented as statements and participants were asked to answer based on how much they agree with each statement. All items were anchored from 1 (“completely disagree”) to 7 (“completely agree”) [15]. The subscale scores were calculated by averaging the scores of the items in the subscale. The Technology Acceptance Model (TAM) questionnaire (Perceived Usefulness subscale) was used to quantify the informal caregivers’ perceived usefulness of SAR-based interventions. It included 5 items (i.e., statements). Scores ranged from 1 (Strongly disagree) to 5 (Strongly agree), with higher scores indicating higher perceived usefulness.

3. Results

3.1. Post-intervention results

Across the sessions, participants' self-reported enjoyment ranged from an average of 6 (SD = 3,7) of the first session to 10 (SD = 0) of the last session, documenting a stable increase in the interest in participating to SAR-based activities. The GAToRS showed an overall participants’ positive attitude towards the robots, with high scores in the “comfort and enjoyment around the robots” subscale (M = 5,05), and “reasonable hopes about robots in general” subscale (M = 5,2). The GAToRS also highlighted very low scores in the “unease and anxiety around robots” subscale (M = 1,6), but showed somewhat high scores in the “reasonable worries about robots in general” subscale (M = 4,5). Overall, the results from the post-intervention questionnaire suggest an overall positive users’ experience with the SAR-based cognitive training activities, which is also reflected in a positive attitude towards the use of SAR in general. Participants however reported some worries which were further explored in more detail in the focus group (see below).

3.2. Follow-up focus groups

The focus groups gave the possibility to participants to reflect on their experiences with the SAR. While formal caregivers were all positive towards the impact of SAR on the proposed training activities, half of the older adults were more skeptical. In detail, while the older adults seemed to have enjoyed the activities, they complained about the lack of intelligence (i.e., autonomy) of the robot as well as its limited behavioral repertoire. Both formal caregivers and older adults enjoyed the activity “create a story with the robot” which should be considered for a possible refinement of the proposed intervention.

3.3. Technology considerations

Although the chatbot creation support engine would have enabled the creation of interactive and complex dialogues, the result of the integration between the voice layer and the robot struggled to function properly. Several factors may have contributed: the need to train the voice-layer more for the Italian language; the noisy environment around the robot; the positioning of the robot's microphones too far away from wheelchair-bound participants; and the small amount of time left for the user between responding and processing the response. Because of this, ARI seemed to lack social skills, to talk to herself, and responds "I didn't understand" to almost any question, making the interaction frustrating and ineffective. To prevent this frustration from affecting the participants, it was decided not to use the voice-layer but to control the robot in real-time using text-to-speech provided by the ARI robot dashboard. In this way, ARI assumed the role of mediator between the controller and the end users.

As for the Dianoia app, it had many and various cognitive activities within it, pertaining to different categories of intervention. However, the need to have to print out PDFs of the activities made the exercise very tiring for participants who, given their age and medical conditions, struggled to read and write for a long time. For this reason, it was chosen to use the ARI text-to-speech to read and manage the exercises. This made it possible to better manage the activity, adapting to the users' times, as well as to make it more engaging. In addition, since some participants had different hearing difficulties, it would have been very useful to be able to customize the performance of the speech, ie. read more slowly, modulate the tone of voice, change the voice according to the user's preferences, scan words better.

4. Conclusions

The SAR-based cognitive training intervention conducted was accepted by all stakeholders. Data on enjoyment of participants suggest that they did not experience a "novelty effect" of the proposed innovation, but longer sessions are needed to confirm this result. The request to have a more "intelligent" and flexible robot, in our opinion, should be considered a positive result, in that it may imply the willingness of participants to keep interacting with an artificial agent over longer periods of time. In this view, future developments of ARI should consider the possibility to make it more engaging for older adults by increasing the complexity of its verbal behavior, for instance, by connecting it to advanced conversational AI platforms (e.g., ChatGPT).

References

[1] United Nations, Department of Economic and Social Affairs, Population Division. World Population Ageing, 2015; (ST/ESA/SER.A/390). ISBN: 978-92-1-057854-7.
[2] Harper S. Economic and social implications of aging societies. Science 2014;346(6209): 587-591, doi:10.1126/science.1254405.
[3] Abdi J, Al-Hindawi A, Ng T, Vizcaychipi MP. Scoping review on the use of socially assistive robot technology in elderly care. BMJ open. 2018;8(2), e018815, doi: 10.1136/bmjopen-2017-018815.
[4] Turkle S, Taggart W, Kidd CD, Dasté O. Relational artifacts with children and elders: the complexities of cybercompanionship. Connection Science 2006;18(4), 347-361, doi: 10.1080/09540090600868912.
[5] Breazeal C, Dautenhahn K, Kanda T. Social robotics. Springer handbook of robotics 2016;1935-1972, doi: 10.1007/978-3-319-32552-1_72.

[6] Matarić MJ, Scassellati B. Socially assistive robotics. Springer handbook of robotics 2016;1973-1994, doi: 10.1007/978-3-319-32552-1_73.
[7] Samaddar S, Desideri L, Encarnação P, Gollasch D, Petrie H, Weber G. Robotic and Virtual Reality Technologies for Children with Disabilities and Older Adults. In Computers Helping People with Special Needs: 18th International Conference, ICCHP-AAATE 2022, Lecco, Italy, July 11–15, 2022, Proceedings, Part II, Cham: Springer International Publishing p. 203-210. doi: 10.1007/978-3-031-08645-8_24.
[8] Kim GH, Jeon S, Im K, Kwon H, Lee BH, Kim GY, Na DL. Structural brain changes after traditional and robot-assisted multi-domain cognitive training in community-dwelling healthy elderly. PloS one 2015; 10(4), e0123251, doi: 10.1371/journal.pone.0123251.
[9] Łukasik S, Tobis S, Suwalska J, Łojko D, Napierała M et al. The role of socially assistive robots in the care of older people: to assist in cognitive training, to remind or to accompany?. Sustainability 2021; 13(18), 10394, doi: 10.3390/su131810394.
[10] Yuan F, Klavon E, Liu Z, Lopez RP, Zhao X. A systematic review of robotic rehabilitation for cognitive training. Frontiers in Robotics and AI 2021;8, 605715, doi: 10.3389/frobt.2021.605715.
[11] For more information visit: https://shapes2020.eu/
[12] For more information visit: https://pal-robotics.com/robots/ari/
[13] https://www.vicomtech.org/es
[14] https://www.scify.gr/site/en/impact-areas-en/assistive-technologies/dianoia-en
[15] Koverola M, Kunnari A, Sundval J, Laakasuo M. General attitudes towards robots scale (GAToRS): A new instrument for social surveys. International Journal of Social Robotics 2022;14(7), 1559-1581, doi: 10.1007/s12369-022-00880-3.

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Exploring AI Literacy Among Older Adults

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Abstract. Artificial Intelligence (AI) technology is increasingly being integrated into our daily lives and many aspects of society. AI is viewed as a new opportunity to promote independent living and well-being for older adults. AI literacy plays an important role in older adults' acceptance and use of AI-enabled products and services. However, to our knowledge, no research has investigated AI literacy among older adults. The study aims to address this gap by collecting and analysing data on older adults' knowledge and understanding of AI and their experiences and concerns regarding AI-enabled products and services. In total, 207 older adults, aged 60 years and over, participated in the study, including 182 who answered a survey and 25 who participated in semi-structured interviews. The results show a variety levels of AI literacy among the participants. Many are interested in learning more about AI so they can make informed decisions about AI-enabled products and services. This study has not only produced insights into AI literacy among older adults but also contributed to increasing the awareness of AI among the participants and has provided recommendations on measures to enhance older adults' AI competencies.

Keywords. Artificial intelligence, AI literacy, older adults, digital literacy

1. Introduction

Artificial intelligence (AI) is increasingly viewed as a new opportunity to overcome different challenges associated with ageing and promote independent living and well-being for older adults. AI-enabled technologies and solutions, such as social robots and smart homes, including voice assistants, have been developed to support older adults in living independently. Recent research has shown that age may affect people's experiences and attitude towards AI [1]. Compared to younger adults, older adults may have less knowledge of AI and experience of using AI-enabled products and thus face more challenges in accepting and using them.

AI literacy is regarded as a set of competencies that enable people to understand, use, monitor and critically reflect on AI applications without necessarily being able to develop AI models themselves [2, 3]. Ng and colleagues [3] argue that AI should be a part of technological literacy and propose that AI become a fundamental skill for everyone, not just computer scientists.

For older adults to fully benefit from the opportunities provided by AI technologies, they must have a basic understanding of AI and be able to make informed decisions about and interact efficiently with AI-enabled products and services. Although studies have investigated older adults' experiences and perceptions of

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specific AI-enabled products, such as voice assistants [4] and social robots [5], to our knowledge, no studies have focused on AI literacy among older adults. The research presented in this paper aims to address this gap by collecting and analysing data on older adults' knowledge and understanding of AI and their experiences of and concerns about AI-enabled products and services.

2. Related Work

2.1. AI Literacy

Research on AI literacy has mainly focused on the education domain, where courses and study programmes are provided at different levels of the education system to teach students the basics of AI, its possibilities, its limits and its potential social and economic impacts. In primary and secondary schools, AI-related topics have been integrated into the curriculum [6]. In higher education, research on teaching AI to students from backgrounds other than computer science and information technology, such as arts, medicine, business and teacher education, has also been published [7].

Despite the rapid increase in AI literacy education, defining AI literacy remains an ongoing effort [3]. According to Laupichler and colleagues [7], the most frequently cited definition of AI literacy is that of Long and Magerko [2]: "*a set of competencies that enables individuals to critically evaluate AI technologies, communicate and collaborate effectively with AI, and use AI as a tool online, at home, and in the workplace*. Based on their literature review of 30 peer-reviewed publications, Ng and colleagues [3] identify the following four aspects for fostering AI literacy: Know & Understand: know the basic functions of AI and how to use AI applications; Use & Apply: apply AI knowledge, concepts and applications in different scenarios; Evaluate: higher-order thinking skills (e.g. evaluate, appraise, predict, design) with AI applications; AI Ethics: human-centred considerations (e.g. fairness, accountability, transparency, ethics, safety).

We used these four aspects as the starting point for the study design and data analysis.

2.2. Older Adults' Experiences of AI-Enabled Products

Several studies have investigated experiences, perceptions and concerns regarding AI technologies and AI-enabled products among older adults, including Ambient/Active Assisted Living (AAL) technologies [8], smart home technologies [9] and voice assistants, such as Google Home and Amazon's Alexa [4, 10, 11]. These studies have shown that older users see the benefits of these technologies but also face many challenges, such as low technology literacy, lack of understanding of terminology and poor usability. Older users also have concerns about privacy and the level of control they have. For voice assistants, the quality of speech recognition, having to learn the right words to control the devices, difficulties in understanding how the devices work and where the information comes from, as well as difficulties in setting up the devices due to a lack of information in instruction manuals have been identified as challenges for older users. Kim and Choudhury [4] reveal that the older participants in their study worried about becoming lazy and inactive, which could negatively impact their quality of life. The studies have also shown older users' interest in learning and understanding and controlling their data, as well as their willingness to contribute to the design of technologies that can support independent living.

Shandilya and Fan [1] collect both quantitative data through a survey of 35 participants and qualitative data through semi-structured interviews with 15 participants aged 60 years or over. Their study shows that most participants have “some knowledge” of AI and are interested in learning about AI and using AI-enabled products, but their possibilities for learning are limited. They also have concerns about privacy and the impact AI will have on their intuitive decision-making skills. Although this study covers older adults’ knowledge of AI, most of the data focus on the participants’ experiences and perceptions of AI.

3. Method

The present study adopted a mixed methods approach. First, a survey was conducted to understand the general AI literacy among older adults. In addition to demographic information and digital competencies, questions in the survey were based on the four aspects of AI literacy identified by Ng and colleagues [3]. These aspects were mapped to questions and provided with examples to help respondents understand the questions. As the context of this research differs from the focus on AI literacy in formal education in [3], we reduced or removed aspects related to applying AI algorithms and creating AI applications. To accommodate older adults who may not be aware of AI, we provided examples of AI-enabled everyday technologies, such as a robot vacuum cleaner and recommendations of radio programmes based on programmes previously listened to. The survey was followed by a semi-structured interview aimed at gaining a deeper understanding of AI literacy among older adults by allowing participants to tell their own AI stories. In addition to a pilot study, we received feedback from an organisation for older adults on the formulation of questions and suggestions for suitable examples. The survey was revised accordingly before it was distributed.

The study utilized a convenience sampling method to recruit participants aged 60 years or older. Information about the survey and invitations to participate in interviews were distributed through organizations for older adults, senior centres and the researchers’ personal networks.

Survey data were collected anonymously and analysed using descriptive statistics, and the interviews were audio recorded and subsequently analysed using thematic analysis. The study was reported to the Data Protection Services in the Norwegian Agency for Shared Services in Education and Research (Sikt), which evaluated and approved the processing of personal data in this study.

4. Results

4.1. Participants

The survey yielded 182 responses from 90 female and 92 male participants. Twenty-five older adults participated in the semi-structured interviews, including 19 female and 6 male participants. The distribution by age is shown in **Table 1**.

Table 1. Age range of participants.

Age group	Survey	Interview
60–69	33	3
70–79	100	14
80–89	48	7
90–99	1	1

The participants represent many professional backgrounds in different sectors such as education, health, industry, and business. **Table 2** shows the smart devices they reported using. Some added that they use smart solutions, such as Apple Home and smart electricity consumption controls.

Table 2. Smart technologies used by participants.

Device	Number of participants in survey	Number of participants in interview
Robot vacuum cleaner	32	4
Voice assistant (Alexa, Google, Assistant, Siri, etc.)	49	4
Smart watch	57	1
Smart TV	106	1

4.2. Results from the Survey

Nine participants reported that they know nothing about AI, five reported having much knowledge, and the rest (N = 168) reported having heard of or having some knowledge about AI. Thirty-three participants reported that they understand how AI works to a large extent and 76 reported that they understand it to a small extent. Regarding whether they would like to learn more about AI, 73.1% responded "Yes" and only 2.2% responded "No". The responses about whether they are interested in understanding how AI works are similar.

More than half the respondents reported having experience of interacting with customer service chatbots (N = 101), fingerprint or face recognition to unlock smart phones (N = 111), a spam filter in emails (N = 115) and video and song recommendations, such as on Netflix, YouTube, Spotify and radio and TV programmes (N = 118). Some added that they use robot lawn mowers. About 48% of respondents (N = 84) reported that they are confident in using AI-enabled products. More than half the respondents learned to use them through searching the Internet (N = 113) and reading the user manual (N = 92).

Regarding why they do not use certain AI-enabled products, "Do no need" was the reason given by 89 participants, followed by concerns about privacy (N = 49) and safety (N = 40). According to 73.1% of respondents (N = 133), AI can be useful for older adults. About 31.3% (N = 57) trust AI. When asked whether they would trust AI more if they knew how it works, about the same number of respondents replied "Yes", while 100 participants responded "Maybe". About 42.3% of respondents (N = 77) stated that they do not feel comfortable with sharing their data with AI to improve its outcomes. Even more respondents (N = 88) shared that the current laws and regulations do not provide enough protection of personal information in AI-enabled products. More than half the respondents (N = 113) expressed concern about data security against malicious attacks in AI-enabled products and services. According to about half the respondents (N = 90), the current products and services that use AI for decision-making do not follow ethical standards.

4.3. Results from the Interviews

The results from the interviews are organized according to the following themes adapted from the four aspects of AI literacy [3]:

- Know & Understand: know the basics of AI and the main functions of AI-enabled products and services.
- Use: use AI-enabled products and services to achieve goals.
- Evaluate: evaluate AI-enabled products and services according to needs and the benefits of these products and services.
- AI Ethics: have awareness of AI ethics, data privacy and security.

4.3.1. Know & Understand

The interview data show that most participants had previously heard the term "artificial intelligence" and have heard about many AI-enabled products, such as robot lawn mower and vacuum cleaner, voice assistant and ChatGPT, from media and family/friends. Some reported having seen others using some of these products. Several participants have also noticed recommendations they receive on social media or online shopping websites. Some have used chatbots in customer service. One reported owning a smart speaker and three reported having used Siri on their phones or tablets. Four indicated that they own a robot lawn mower and a robot vacuum cleaner, respectively.

However, there is a high degree of variation in their knowledge of AI and understanding of how AI works. For example, some participants reported having heard of AI, while others were able to talk about some technical aspects of AI, such as that the recommendations one receives online or from social media are created by algorithms which record search activities:

> *It, in a way, records all your searches and gives you suggestions. For example, when I'm on Spotify and listen to an artist, then a week later or a while later, I get suggestions of similar artists.* (P7)
>
> *You can get those machines to also think for themselves and draw conclusions until they start to function in a way almost like a human.* (P10)

Some had read about AI to prepare for the interview and were able to give a more formal definition, such as "computer systems that can learn from their own experience and that can solve complex problems" (P9).

Many expressed that it is important to learn and know about AI so they can make better judgements concerning AI-enabled products and services: "You have to know enough about it to be able to be critical and opt out of what you can opt out of if it's negative" (P9).

Although most participants showed an interest in learning about AI, they also commented that it is challenging to keep up with rapid technological development in general and AI development specifically.

4.3.2. Use

Participants have various levels of satisfaction with the AI-enabled products and services they have used. The four participants who reported owning a robot lawn mower expressed that they are satisfied with it. Of the four participants who reporting owning a robot vacuum cleaner, only two are satisfied: "*I am very happy with my* *robotic lawnmower because then I can go away for weeks without thinking about the lawn*" (P21).

Five participants understand that it is possible and are also able to change the settings to adjust the recommendations they receive on social media or on online shopping websites so they can reduce the number of unnecessary recommendations and advertisements, while two stated that the settings are difficult to understand because of the technical language. The participant who owns a smart speaker reported challenges with speech recognition but has found ways to use it anyway. Another participant tried to use the voice assistant on the TV for searching but was unsuccessful and therefore went back to inputting search words in the search field manually.

Most participants who have used chatbots for customer service have not been satisfied. The main challenge is that users must formulate questions "correctly" for the chatbot to understand them. Only three reported that they have received satisfactory answers, but they also stated that they prefer to talk to a human in customer service: "You have to ask the questions so that they understand it. If you don't formulate yourself in terms of how they're programmed, then you'll just be passed on" (P12).

4.3.3. Evaluate

Most participants could evaluate AI-enabled products and services according to their needs, constraints and the potential benefits. Some participants explained why they have used or not used certain products:

> *I chose not to get myself a vacuum cleaner because I think it is better for me to do practical work so that I stay physically active.* (P8)
>
> *Something about bending down and straightening up – you're not as good as you were. I see that it can be beneficial, so I wish to have a robot vacuum cleaner.* (P5).

Some of them have done thorough research on the products before buying them. For example, P22 bought a robot lawn mower after reading a lot about it: "We bought it ourselves. We have read a lot about the types in terms of what kind of terrain you have and slopes and the capacity in relation to size" (P22).

Several participants shared their thoughts on the different needs of older adults and what kinds of AI-enabled products or services might be useful or not useful for them. For example, participants showed scepticism and were critical of installing voice assistants in the homes of people with dementia:

> *They [people with dementia] can get scared easily because they don't understand they have an aid in their home that is going to help them, but then they wonder if there are people inside their house when it starts talking. [...] I'm very sceptical about that [aspect] of artificial intelligence because they don't really understand what's going on.* (P4)

4.3.4. AI Ethics

The participants see the positive side of AI and acknowledge its benefits in helping with practical tasks at home. However, several participants also shared concerns about the risk of AI replacing humans in healthcare, which may result in a reduction in healthcare staff and lead to further reduced human contact, isolation and loneliness. Many emphasized the importance of human contact:

I'm so worried that politicians are overestimating this [AI] and think that it could replace humans and reduce healthcare staff even more [...] That's a tendency I am very afraid of because human contact is very important for everyone. (P9)

One participant mentioned that AI can be affected by the perceptions behind the data that are collected. In other words, if the data used by AI are affected by negative perceptions, such as racism and discrimination, that will affect the outcome of the AI-enabled product or service.

Several participants also shared concerns about privacy and data security in AI-enabled products and services as well as the risk of AI being exploited to spread fake information or to defraud older people.

5. Discussion

The results from the survey and interviews confirm some of the findings in [1]. Many participants in both studies report having limited knowledge of AI, although they have experience of using various AI-enabled products. They find it difficult to keep up with the rapid technological development and have concerns about their privacy and date security in AI-enabled products.

Our study covers a wider range of themes related to AI literacy than those reported in [1]. For example, we investigate older adults' considerations of AI ethics and their ability to evaluate AI-enabled products and services according to their needs. Further, we have gained an understanding of participants' thoughts and reflections concerning AI in healthcare, including the critiques and scepticism about the use of AI-enabled products and services in the homes of people with dementia.

Our study shows that older adults experience challenges, such as difficult terminology and poor usability, when using AI-enabled products and services and that they are interested in learning and understand the possibilities that AI technologies can offer in making informed decisions. These findings support the results from [8]. Both studies emphasize the importance of taking older adults' needs into consideration when developing AI-enabled products and services.

Although we achieved gender balance in the survey, we could not recruit as many male as female participants for the interviews. Another limitation is the study's reliance on self-reported data, which may not provide an accurate description of older adults' AI literacy, thus affecting the reliability of the results.

6. Conclusion and Future Work

This paper has presented a study focused on understanding AI literacy among older adults. The results show a high degree of variation in AI literacy among the participants and most of them are interested in learning. Some of them have (mixed) experience with AI-enabled products and services. Many discussed their decisions to use or not use AI products and services depending on their needs and the information about these products, which they gained through family and friends, media or searching online. The participants were able to reflect on the advantages and disadvantages of AI and discuss their concerns regarding contact with humans versus AI in healthcare and privacy and data security in AI-enabled products and services.

Further research should focus on developing a more systematic definition of the competencies in and objective measurement of AI literacy for older adults. In addition, studying AI literacy among older adults in different social and cultural contexts will provide a richer and broader understanding of their AI literacy.

This study has not only contributed to a better understanding of AI literacy among older adults but also raised participants' awareness of AI, as evidenced by the fact that those who intended to participate in the interviews began reading about AI and engaging in discussion with family and friends regarding AI-related products and challenges.

The results have shown that the involvement of older users in the design and development of AI technologies, particularly those targeting older populations, is essential for acceptance of the technologies. Further, governmental policy and strategies and resources in AI training to enhance competencies among older adults can help to bridge the gap in AI literacy between the young and older populations.

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References

[1] Shandilya E, Fan M. Understanding older adults' perceptions and challenges in using AI-enabled everyday technologies. arXiv:221001369. 2022. doi: https://doi.org/10.48550/arXiv.2210.01369.

[2] Long D, Magerko B. What is AI literacy? Competencies and design considerations. Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems; Honolulu, HI, USA: Association for Computing Machinery; 2020. p. 1–16.

[3] Ng DTK, Leung JKL, Chu SKW, Qiao MS. Conceptualizing AI literacy: An exploratory review. Computers and Education: Artificial Intelligence. 2021;2. doi: https://doi.org/10.1016/j.caeai.2021.100041.

[4] Kim S, Choudhury A. Exploring older adults' perception and use of smart speaker-based voice assistants: A longitudinal study. Computers in Human Behavior. 2021;124.

[5] Whelan S, Murphy K, Barrett E, Krusche C, Santorelli A, Dympna Casey. Factors affecting the acceptability of social robots by older adults including people with dementia or cognitive impairment: A literature review. International Journal of Social Robotics. 2018;10:643–68. doi: https://doi.org/10.1007/s12369-018-0471-x.

[6] Casal-Otero L, Catala A, Fernández-Morante C, Taboada M, Cebreiro B, Barro S. AI literacy in K-12: A systematic literature review. International Journal of STEM Education. 2023;10.

[7] Laupichler MC, Aster A, Schirch J, Raupach T. Artificial intelligence literacy in higher and adult education: A scoping literature review. Computers and Education: Artificial Intelligence. 2022;3.

[8] Wang S, Bolling K, Mao W, Reichstadt J, Jeste D, Kim H-C, et al. Technology to support aging in place: Older adults' perspectives. Healthcare. 2019;7(2). doi: https://doi.org/10.3390/healthcare7020060.

[9] Guan A, Dannewitz HC, Stratton L, Margrett J, Boot WR, Charness NH, et al. Perceptions, accessibility, expectations, and Concerns of smart home technologies among older adults. Innovation in Aging. 2019;3(Supplement_1):881–2. doi: https://doi.org/10.1093/geroni/igz038.3229.

[10] O'Brien K, Light SW, Bradley S, Lindquist L. Optimizing voice-controlled intelligent personal assistants for use by home-bound older adults. Journal of the American Geriatrics Society. 2022;70(5):1504–9. doi: https://doi.org/10.1111/jgs.17625.

[11] Pradhan A, Lazar A, Findlater L. Use of intelligent voice assistants by older adults with low technology use. ACM Transactions on Computer-Human Interaction. 2020;27(4). doi: https://doi.org/10.1145/3373759.

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Evaluating the Energy Requirements of Assistive Technologies for Older Adults

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Abstract. The successful adoption of assistive technologies for older adults requires considering and evaluating many different factors and dimensions such as effectiveness, usability, cost and equity of access, to name some of the most relevant. In line with this, the energy requirements to power such assistive technologies remains a hidden factor that might to some extent influence the success in their adoption and the user experience in a wider sense. Very often energy availability is taken for granted and its associated costs and operational requirements are mostly neglected. In this paper, the energy-related requirements of assistive technologies are analysed from a general perspective. This analysis is subsequently particularised for a use case within the SHAPES project, in the context of active and healthy ageing. This use case includes a wide variety of assistive technologies, namely: wearable devices, home sensors and a smart mirror, which provides connectivity and a set of software services. The energy requirements of all these technologies are evaluated and analysed to investigate their impact and relevance on the overall cost and user experience, following the proposed protocol.

Keywords. Assistive technologies, energy, wearable devices, smart mirror, evaluation, older adults

1. Introduction

The increase of energy demand of modern societies, the adoption of non-sustainable development models, and the recent geopolitical instability due to military conflicts and

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commercial wars has produced a global energy crisis characterised by a pronounced increase in energy prices [1]. The term energy poverty is commonly used nowadays, affecting certain population groups with limited income and resources, and particularly older adults. In 2016, the EU created the former Energy Poverty Observatory, that then became the Energy Poverty Advisory Hub [2,3], seeking an inclusive energy transition in the EU.

In this context, energy and its associated requirements and costs need to be considered as an important factor for the successful adoption of assistive technologies designed to improve the quality of life of older adults. The overall economic evaluation of cost-benefit, cost-effectiveness, cost-utility and cost minimization of assistive technologies [4], will therefore require and accurate assessment of such energy-related costs for a wide variety of technologies and the way in which they are used. The energy requirements of assistive technologies will also have an important influence in terms of user experience and sustainability of the solutions, considering installation, operation and maintenance requirements and costs during the life cycle of the product. Furthermore, energy availability will also affect the data integrity in many solutions incorporating sensors, and the overall quality of the resulting datasets. This will certainly be particularly relevant in battery-powered devices that require periodic battery replacement or recharging and the associated hardware for this purpose, being wearable technologies the most prominent case.

2. Energy-related Requirements for Assistive Technologies

In general, assistive technologies, as in most domains, require powering devices with electrical energy to match their consumption and ensure their operation. Any disruption in the energy supply might cause downtimes (unexpected or scheduled in certain circumstances), loss of data, malfunctioning, poor performance, damage, etc., that will affect user experience and even safety. In general, the development of assistive technologies should aim for solutions with:

- High efficiency, resulting in low energy consumption and operational costs for the user.
- High reliability, ensuring the continuity and safety of energy supply.
- Reduced maintenance, downtimes and operational burden for users.

In the following subsection, the energy-related requirements for assistive technologies are analysed from a general perspective considering the energy consumption, associated infrastructure and operational burden for the user.

2.1. Energy Consumption Requirements

Most assistive technologies employ electrical energy and will have an associated energy consumption, that can be measured in KWh or Wh. This consumption tends to be quite variable depending on how intensive is the use of the technology, whether is it used continuously or with a certain frequency of use. Furthermore, many solutions have different operating modes, that often entail different energy consumption levels. Hence, it is generally difficult to characterise the energy consumption of a certain device for a certain user, unless it is evaluated for a sufficiently long period of time, to obtain an average value of energy consumption that provides a representative value. Once this average value is obtained, the energy cost can be derived based on the electricity prices.

2.2. Infrastructure Requirements

Supplying energy requires an energy source such as the electrical grid for stationary solutions and batteries for portable devices. When using the electrical grid, wall plugs are necessary as well as the appropriate cables, that are generally shipped with the device. When installing new devices in a home environment, the availability and location of free wall plugs can be an issue. Furthermore, if some solution involves high power levels, the rating of the home wiring should be carefully checked to avoid electrical hazards, particularly in old installations.

On the other hand, in the case of battery-powered devices, when rechargeable batteries are used, a charger and associated cable is also required and supplied with the device. Despite the efforts in recent years towards standardisation, there is a wide variety of chargers and connectors in use in most homes, which also applies to assistive technologies. The progressive and growing adoption of the USB-C connector is positively improving this situation and the compatibility of chargers.

Finally, since many assistive technologies rely on data connectivity and cloud services. The use of home routers, smartphones with apps, network infrastructures and data centers also requires energy with an associated cost that is more difficult to establish.

2.3. Operational Requirements

Providing the energy supply to a device might require a certain degree of intervention from the user during operation and the life cycle of the solution. When assistive technologies rely on devices connected to wall plugs, this intervention is minimal. The device is only affected by energy shortages and disturbances as any other appliance at home, which will depend on the reliability of the electrical network.

In the case of battery-powered devices, the operational requirements will mainly depend on the type of battery used, and two different scenarios should be considered:

- Non-rechargeable batteries will require replacement once they are depleted. In this case, it will be interesting to know the duration, which will depend on the battery capacity and device consumption.
- Rechargeable batteries will require being recharged when their capacity is low. Recharging cycles will depend on the device consumption. The recharging operation will be characterised by how frequently the battery needs to be recharged and the charging time. This charging time, in many solutions, might imply a downtime in which the assistive technology cannot be used and data is not generated. This last aspect is important to be considered in sensor-based data-logging solutions and will affect the quality of the resulting datasets. Furthermore, the ageing of batteries after many cycles reduces their capacity and increases the frequency at which they need to be recharged.

In both cases, it will be desirable that the battery state of charge (SOC) and state of health (SOH) are monitored, providing notifications when batteries need to be replaced or recharged.

3. Proposed Protocol for the Evaluation of Energy-related Requirements

Considering the aforementioned energy-related requirements for assistive technologies, a protocol is proposed in this paper for the evaluation of solutions in this domain. This protocol aims to extract the energy-related characteristics of a solution. This information can then be used to perform a more accurate evaluation of the cost-effectiveness of the solution and to provide more precise information and training to the users. Finally, this analysis can also provide new insight into how to improve user experience.

The proposed protocol consists in completing the following steps:

1. Extraction of the energy-related characteristics and specifications of the device from the manufacturer information. This information will provide an initial estimation of energy consumption and operational requirements. This information might include: electrical rated values (voltage, current, frequency), battery type, capacity and autonomy, power consumption, etc. It will also provide the required infrastructure, including the required installation ratings, cables and chargers.
2. Energy consumption evaluation in the lab using specific instrumentation and accelerated tests. This will be performed in a controlled environment, considering different scenarios depending on the operating modes, frequency of use, user profiles, etc. This task requires specialised equipment and staff to be performed. Energy consumption models can be derived from the measured results to obtain a more accurate estimation of energy consumption and operational requirements.
3. Energy consumption evaluation in the real-life scenario and with real users. This task will require using measuring devices with data logging capabilities and keeping a record of battery duration, replacement and charging times in battery-powered devices: This task can be partially done by the user and will require a rather long time frame to obtain representative results and extract the average energy consumption and cost. This will provide the actual average consumption for a certain user and the operational requirements, particularly for battery-powered devices. Additionally, any events such as energy shortages and malfunctioning can be recorded as well as the impact they produce on the user and the device itself.
4. A simple open-question questionnaire, can be completed by the users to collect their energy-related concerns and opinions.
5. Finally, the accurate energy cost of an assistive technology solution can be obtained and can be used in the evaluation of the overall cost-effectiveness of the solution.

4. Energy Requirements Evaluation in a Use Case within the SHAPES Project

The SHAPES project (Smart & Healthy Ageing through People Engaging in Supportive Systems) is an innovation action that intends to build, pilot and deploy a large-scale, EU-standardised open platform for active and healthy ageing. The integration of a broad range of technological, organisational, clinical, educational and societal solutions seeks to facilitate long-term healthy and active ageing and the maintenance of a high-quality standard of life [5,6]. SHAPES is deploying 25 use cases with a wide variety of technologies that are being evaluated. Within these use cases, one of them has been selected

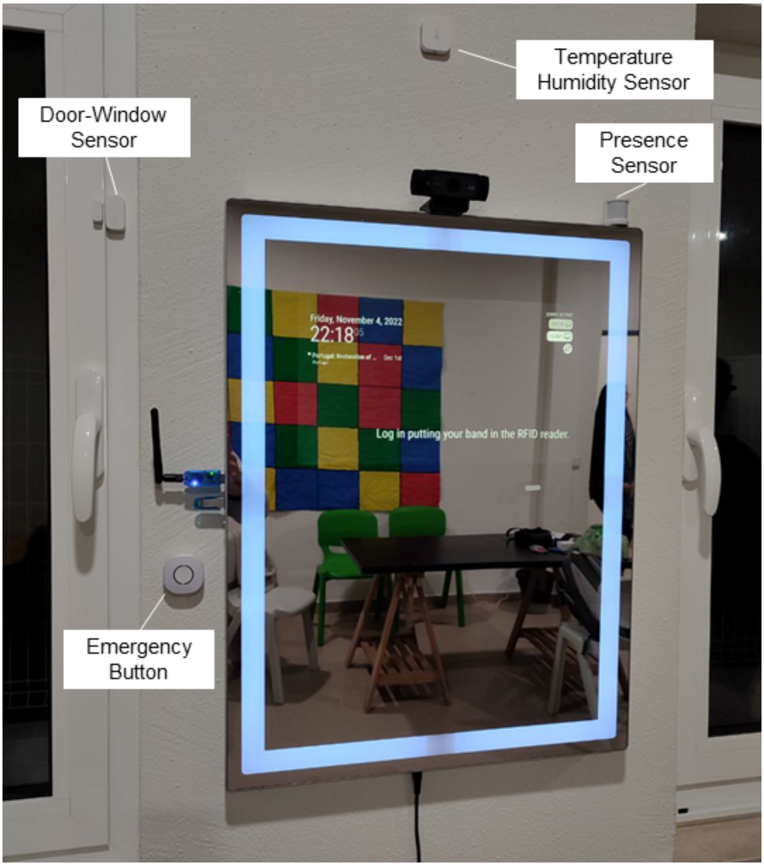

Figure 1. Smart Mirror, home sensors and emergency button in the use case under study

in this paper to perform an evaluation of the associated energy requirements. The use case is based on the use of a smart mirror as a comprehensive home solution for older individuals as shown in Fig. 1 [7]. The smart mirror provides several software services and interaction through a touch screen embedded in the mirror. Moreover, it provides Internet access and connection to the SHAPES platform core services. The software applications implemented include:

- Card-based RFID login service.
- Calendar, appointments and reminders.
- Videoconferencing service with relatives, friends and care professionals.
- Physical and cognitive training with remote supervision from care professionals.
- Home and activity monitoring.

The smart mirror is also connected to a set of battery-powered home sensors and wearable devices (see Fig. 1 and Fig. 2), including:

- Door and window open-closed sensors (Aqara MCCGQ11LM).
- Motion-Presence sensors (Aqara RTCGQ11LM).
- Temperature and humidity sensors (Aqara WSDCGQ11LM).

Figure 2. Wearable devices of the use case under study: activity smart band (left), emergency button (center) and fall detector (right)

Table 1. Energy requirements evaluation of the smart mirror in the selected SHAPES use case

Characteristic	Value
Rated Voltage	230 V AC
Rated Frequency	50-60 Hz
Power consumption (average)	30 W
Required wall plugs	1
Cable type	standard Schuko connector
Estimated energy cost	3.6 Euro/month

- Power consumption sensors (Gosund smart plug SP1).
- A fall detector wearable device (custom-made own development).
- An activity monitoring smart band measuring the level of activity, sleep, steps, calories and heart rate (Mi Smart Band 4).
- An emergency button (Shelly Button 1).

Overall, this use case provides a rich ecosystem of assistive solutions and, in this paper, a first approximation to the evaluation of the energy requirements has been performed based on the proposed protocol. In Table 1 results are provided for the smart mirror. Since this is a custom-made solution, the provided values have been obtained in the lab and the energy cost has been calculated based on the Spanish average energy price during the first 3 months of 2023, which was 0.167 Euro/kWh.

Regarding the battery-powered devices, the results of the study are presented in Table 2. Only the smart band and the fall detector have been considered because the home sensors and the emergency button have negligible requirements in terms of energy consumption and operational requirements.

Detailed results of the described use case and the different devices involved will be presented. Preliminary results, show an overall energy cost in the range of less than 4 € per month in the electricity bill, considering the current variability of electricity prices in Spain. The employed wearable devices have an autonomy of 1 day for the fall detector, 2 weeks for the activity smart bands (with 10-min sampling of variables) and 6 months for the emergency button. Such variability in the autonomy of the battery-powered wearable devices is due to the processing requirements of each solution. For instance, machine learning energy-intensive algorithms will require very frequent recharge of the device as a drawback.

Table 2. Energy requirements evaluation of the battery-powered devices in the selected SHAPES use case

Device	Smart Band
Characteristic	Value
Battery type	Li-Po rechargeable
Battery capacity	135 mAh
Recharging frequency	14 days
Recharging time	less than 2 hours
Consumption (average)	0,375 mA
Monitoring SOC	Yes, with notifications
Monitoring SOH	No
Charger cable type	Dedicated adaptor USB type A
Estimated energy cost	less than 0.01 Euro/month
Device	Fall Detector
Characteristic	Value
Battery type	Li-Po rechargeable
Battery capacity	400 mAh
Recharging frequency	1 day
Recharging time	less than 2 hours
Consumption (average)	16 mA
Monitoring SOC	Yes, with notifications
Monitoring SOH	No
Charger cable type	micro USB type B
Estimated energy cost	less than 0.01 Euro/month

5. Conclusions

With the current electricity prices, the energy cost has a non-negligible impact on the cost-effectiveness of assistive technologies for older individuals and particularly due to how energy poverty is affecting this group of the population. From an ethical point of view, it will be challenging for many assistive solutions to meet the expected and desired equity of access. Besides the cost, the user experience might also be affected due to the energy requirements of certain solutions, such as battery-powered wearable devices, where extended autonomy is sought in order to avoid the inconvenience of frequent recharging of batteries [8]. A proposed evaluation protocol is presented in this paper and is applied to a use case within the SHAPES project, with a rich ecosystem of solutions. This protocol will be applied to other use cases for further validation in the future.

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References

[1] IEA. World Energy Outlook 2022. Paris: International Energy Agency; 2022. License: CC BY 4.0 (report); CC BY NC SA 4.0 (Annex A). Available from: https://www.iea.org/reports/world-energy-outlook-2022.

[2] European Comission. Energy Poverty Advisory Hub [Internet]; 2023. Available from: https://energy-poverty.ec.europa.eu/index_en [cited 2023 May 21].

[3] Bouzarovski S, Thomson H, Cornelis M, Varo A, Guyet R. Towards an inclusive energy transition in the European Union: Confronting energy poverty amidst a global crisis. Luxembourg: EU Energy Poverty Observatory; 2020. ISBN 978-92-76-19635-8. Available from: https://energy-poverty.ec.europa.eu/discover/practices-and-policies-toolkit/publications/epov-report-towards-inclusive-energy-transition-european-union_en.

[4] Averi S, Kasteng F, Henning A, Kattel R. Scoping review of economic evaluations of assistive technology globally. Assistive Technology. 2021;33(sup1):50-67.

[5] SHAPES H2020 website [Internet]; 2023. Available from: https://shapes2020.eu/ [cited 2023 May 21].

[6] Seidel K, Labor M, Lombard-Vance R, et al. Implementation of a pan-European ecosystem and an interoperable platform for Smart and Healthy Ageing in Europe: An Innovation Action research protocol. Open Research Europe. 2022;2(85). Version 1; peer review: awaiting peer review. Available from: https://doi.org/10.12688/openreseurope.14827.1.

[7] Dorado J, Fernandez-Bermejo J, Santofimia MJ, Bolaños C, Unzueta L, Garcia M, et al. The SHAPES Smart Mirror Approach for Independent Living, Healthy and Active Ageing. Sensors. 2021;21(23). Available from: https://doi.org/10.3390/s21237938.

[8] Iqbal SMA, Mahgoub I, Du E, Leavitt MA, Asghar W. Advances in healthcare wearable devices. npj Flex Electron. 2021;5(9). Available from: https://doi.org/10.1038/s41528-021-00107-x.

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Using Wearable Devices in a Healthcare Facility: An Empirical Study with Alzheimer's Patients

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Abstract. Smart Wearables are considered a very promising solution for monitoring and helping people affected by cognitive decline or dementia and, in particular, Alzheimer Disease (AD). Nonetheless, the acceptability and wearability of such devices for AD patients pose certain challenges. To address this, an empirical study has been conducted with a group of patients with mild to moderate AD, wearing wristbands E4 by Empatica for a duration of three months. The experiment has been integrated into the regular healthcare activities, with active involvement from nurses and physicians. The paper reports the feedbacks of the caregivers and discusses wearability and acceptability issues.

Keywords. Dementia, Alzheimer's, wristband, bracelet, Assistive Technology, healthcare technology, nursing home, monitoring, caregiver

1. Introduction

Current trends of demographic transformation and ageing of population and their projections by 2050 [7] represent a challenge for the health and social systems of all countries. Today, among the chronic diseases of elderly people, dementia and, more specifically, the very common form of Alzheimer's Disease (AD), have a high incidence [15]. To maintain the autonomy of patients, while still offering the appropriate supervision, Assistive Technology and, in particular wearable devices, are considered among the most promising solutions [4]. For instance, with such devices, it is possible to understand whether the elderly leaves during a moment of amnesia, starts wandering, falls, or performs other abnormal (such as aggressive) behaviors [13]. Monitoring the behavior and detecting in advance possible issues has the potential to mitigate the stress and anxiety suffered by caregivers, improve clinical knowledge on the disease, enhance safety, promote the patients' autonomy, thus improving their quality of life [2][3][11].

In our pilot study, we monitored a group of AD patients ranging from mild to moderate levels of impairment, but still autonomous. They were hosted in a healthcare

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facility and wore a wristband to collect motion and physiological parameters such as heart rate and temperature. The primary objective of analyzing the collected data was to proactively identify potential abnormal behaviors and promptly alert caregivers when a crisis was anticipated. However, achieving accurate results relies heavily on the proper collection of data. For this reason, besides collecting sensors data, we focused our attention also on how the users experience the solution. In this paper, we describe the whole experimentation process, discuss the acceptability and wearability of the wearable device by the AD patients and possible future research directions.

2. State of the Art

Several wearable devices have been proposed for monitoring the quality of life in individuals. While these devices demonstrate their utility in monitoring various tasks, it is crucial to evaluate their practical impact on AD users.

A first survey about the acceptance of wearable technology by people with AD is presented in [10]: the authors evaluated wandering products by analyzing the literature and conducting interviews with six companies to understand possible wearability issues. However, in 2010, the marketplace was not ready to provide an ideal solution for AD patients, being the size of the components still too big, the devices too expensive, not safe, nor reliable.

In the context of wearable vital sign monitoring technologies for generic patients, the work in [14] surveys patient acceptability of such devices. Results show that acceptability is largely unreported: of the 427 studies screened, only seven observational studies consider patients experience, acceptability and comfort, but six of them were of low quality. Additionally, the duration of patient participation in these studies was extremely limited, ranging from a few hours to a maximum of 15 days. Such short durations are inadequate to draw conclusions regarding the continued acceptance of wearable devices beyond the initial interest and enthusiasm. Research on their usage with real AD patients and the acceptability of such devices remains very limited [1][8][9][12].

3. Methodology

In our pilot study, we adopted a user-centered approach that encompassed active involvement from healthcare facility managers, doctors, and caregivers throughout all phases of the research.

The E4 wristband by Empatica [6] was selected for its extensive range of embedded sensors, enabling the collection of potentially relevant data for monitoring AD patients. This medical device satisfies international standards in terms of risk, safety, usability, and quality. To ensure ethical compliance, we devised a research experiment protocol, which underwent thorough review and approval by the ethics committee of the healthcare facility.

Given the duration of the study (three months), the limited availability and cost of E4 devices, as well as potential impact on healthcare staff, five 70+ subjects with mild to moderate Alzheimer's Disease have been enrolled. The cohort consisted of three women and two men, and this number of patients was deemed manageable for this experiment for the healthcare staff. To ensure data anonymity, we did not participate in the selection process. Patients who were fully autonomous and independent, with electrosensitivity or allergies to latex, metals, or plastics, and those who exhibited aversion to wearing watches, or with a significant cognitive decline diagnosed by the ADAS-cog (Alzheimer's Disease Assessment Scale-Cognitive Subscale) were excluded from the selection.

Before starting the experiment, we setup all the needed tools and trained the nurses and physicians at the facility with instructions about the protocol. The facility was left completely autonomous in the management of the bracelets during the period of data collection. Caregivers distributed the bracelets to residents in the morning, immediately after the hygiene routine, typically between 6 and 10 am (typically after breakfast). The bracelets were collected in the evening, around 7 or 8 pm, just after dinner. During the evening and nighttime, the bracelets were connected to a PC for data upload and recharging.

At the end of the experiment, traditional technology acceptance models could not be directly applied due to the specific nature of the target individuals; thus, the assessment primarily relied on semi-structured interviews with nurses and physicians. These interviews followed the tandem interview model and involved three caregivers/doctors, to explore issues and gain further insights into the usage of the wearable devices. Our questions aimed at considering both the viewpoint of the patient (through the caregiver) and the points of view of caregivers/doctors. Questions were inspired by the Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST 2.0) measurement instrument [5].

4. Interviews

Part 1*: Questions to investigate the experience of the patient, his/her perceptions, emotions/anxiety, pain/discomfort, device acceptability*

QUESTION - How do patients feel about wearing the E4 band?
CAREGIVER: Well, it varies for each patient. One of the patients experiences difficulties with the device. This is meant to be worn on the left wrist, but she used to wear her own watch on that wrist and consistently complains about it. She tends to touch the E4 band and eventually manages to remove it. Another patient occasionally refuses to wear the E4 band due to discomfort. In fact, several patients complain about its discomfort and frequently attempt to loosen the band. Sometimes I found the device on their nightstand or even left somewhere in the clinic. However, when I explain to them that it is a doctor's request to wear the band, they cease their complaints. Personally, I believe they may become accustomed to the E4 band over time.
CAREGIVER: The E4 band is quite thick, and it requires a firm and tight fit on the wrist, which can be bothersome for our patients. Despite that, I must admit that patients do not complain excessively. Perhaps, this is because they trust us and are inclined to tolerate it in order to “make us happy”.

QUESTION - Did patients complain about the aesthetics of the device?
CAREGIVER: No, they don't seem to care about it. None of them has ever refused to wear the device due to its appearance or intrusiveness.

QUESTION - Did the solution cause any pain or annoyance while being worn? Did it lead to a state of stress and agitation?

CAREGIVER: No, it was just annoying, and this is the reason they often try to loosen it or remove it. Sometimes patients ask: “how long do I have to wear it?”, but they tolerate it quite well.

QUESTION - Did the solution allow the patients to perform all the routine tasks (from hygiene to leisure activities) without additional struggles?
CAREGIVER: Generally, they are able to perform their routine task. However, during the hygiene routine, the device needs to be taken off as it is not fully waterproof.

QUESTION: Can they take it off easily?
CAREGIVER: Yes, they can easily remove it. They manage to widen the band since they have thin arms, and the bracelet is relatively large. And also impactful in my opinion. I think that they see this big bracelet and they want to remove it.

QUESTION: This wristband does not have an emergency button? Would it be useful?
CAREGIVER: Having an emergency button would be of no use. The patients lack awareness, and they would likely play with it and trigger false alarms or insignificant alerts.

Part 2*: Questions to investigate the experience of the caregivers who were in charge of putting it on/off, recharging it, connect it to upload the data, interact with the patients*

QUESTION: Was the device intuitive and easy to use, including its charging system?
CAREGIVER: The device itself is relatively easy to use, and we are also in favor of the use of technology. But we had lots of issues: firstly, their thickness and difficulty in wearing it on; their short battery life also does not help as we must take the device off and on often. Lastly, during the charging process, the device does not automatically download the collected data, requiring someone to manually check it, which results in time loss.

QUESTION: Is the usage of bracelets feasible in the daily routines of the healthcare?
CAREGIVER: The usage of the bracelets is generally feasible during the day. However, the time required to connect the bracelets after dinner, as well as the time needed for charging and uploading data, does add some extra time to the routine.

QUESTION: Considering the specific wearable device, did you identify additional needs, not emerged before using it?
CAREGIVER: It would be interesting to have a waterproof device to monitor the hygiene time, which is a critical moment. Additionally, it would be beneficial to collect data to study the residents' reactions during cognitive stimulation activities offered at the facility.
CAREGIVER: One limitation of the device is that it does not allow us to check the battery level without removing it. Furthermore, a significant drawback of the device is the absence of a GPS sensor. This feature is crucial when dealing with patients affected by Alzheimer's as wandering is one of their major challenges.

5. Discussion

Acceptability/wearability are heavily influenced by the trust patients have in their caregivers and physicians. It is important to recognize that the usage patterns and behavior of patients in wearing the devices may differ from those of healthy and younger individuals. For example, AD patients may attempt to widen the watch band or remove the device, particularly in specific situations.

In addition to evaluating the acceptability and wearability from the perspective of patients, it is essential to consider the experiences and perspectives of the caregivers who are actively involved in the process. This includes assessing aspects such as the effort required from caregivers, the intuitiveness and ease of use of the tasks they handle, and the overall impact on the daily routine within the healthcare facility. A holistic evaluation method for such scenarios is needed.

Caregivers highlighted some overhead in the management of the wristbands that required extra-time and may feel overwhelmed by the usage of the technology. However, they acknowledge that if the data collected through the devices allow for the monitoring of relevant phenomena, the extra effort becomes acceptable. Specifically, there is a strong motivation from the healthcare facility to utilize technology in order to obtain objective data on individuals, enabling them to provide accurate reports not only to physicians but also to families.

Devices to be used with AD patients should be wearable in all conditions, including being waterproof for hygiene routines. The charging system and data downloading method should be straightforward, reliable, and autonomous, minimizing the burden on caregivers. The device should have a long-lasting battery life of several hours or even a few days, while also being lightweight. The placement of buttons should prevent unintentional actions, and the bracelet closure mechanism should be sufficiently complex to prevent users from removing it without assistance from an operator.

Finally, it is important to acknowledge the limitations of the present study. Firstly, the monitoring was conducted on a limited number of AD patients due to the restricted availability of devices. The results are based on a single sample of subjects who had mild to moderate AD and were exclusively of the Italian ethnic group. To enhance the generalizability of findings, future studies should include individuals at different stages of the disease and from diverse ethnic backgrounds. Despite these limitations, this study represents a significant advancement in the research of wearable devices for older individuals with dementia.

6. Conclusions

This paper presented the outcomes of an experimental study conducted in a nursing home, which involved the interaction of doctors, caregivers, and patients with a technologically advanced wearable device. Both patients and caregivers demonstrated a high level of acceptance towards the technology. However, the study also identified several critical aspects, suggesting areas for improvement specific to the context of use.

The development and conceptualization of wearable devices for health monitoring purposes have garnered significant interest in both the scientific community and the business sector [14]. However, there are still gaps in the design of wearable devices that can effectively meet the monitoring needs of elderly individuals and patients with dementia.

The experimentation and interviews conducted with caregivers and doctors emphasized the necessity for specific assessment methods when employing wearable devices with elderly individuals experiencing cognitive decline, as the evaluation process directly involves caregivers, as well as specific features for the wearable device itself.

Overall, the results of the experimentation are highly positive and opens up several future research directions.

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References

[1] Al-Naami B, Abu Owida H, Abu Mallouh M, Al-Naimat F, Agha M, Al-Hinnawi AR. A New Prototype of Smart Wearable Monitoring System Solution for Alzheimer's Patients. Med Devices (Auckl). 2021 Dec 2;14:423-433. doi: 10.2147/MDER.S339855. PMID: 34880687; PMCID: PMC8648277.
[2] Amato F, Bianchi S, Comai S, Crovari P, Grillo Pasquarelli MG, Imtiaz A, Masciadri A, Toldo M, Yuyar E. (2018). CLONE: a Promising System for the Remote Monitoring of Alzheimer's Patients: An Experimentation with a Wearable Device in a Village for Alzheimer's Care. In Proc. Goodtechs '18. ACM, New York, NY, USA, 255–260, doi:10.1145/3284869.3284906.
[3] Bellini G, Cipriano M, Comai S, De Angeli N, Gargano JP, Gianella M, Goi G, Ingrao G, Masciadri A, Rossi G, Salice F. Understanding Social Behaviour in a Health-Care Facility from Localization Data: A Case Study. Sensors 2021; 21(6):2147, doi: 10.3390/s21062147.
[4] Chakrabarti S, Biswas N, Jones LD, Kesari S, Ashili S. Smart Consumer Wearables as Digital Diagnostic Tools: A Review. Diagnostics 2022;12(9):2110, doi:10.3390/diagnostics12092110.
[5] Demers L, Weiss-Lambrou R, Ska, B. The Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST 2.0): An Overview and Recent Progress. Technology and Disability 2002;14(3) 101–105, doi: 10.3233/TAD-2002-14304.
[6] Empatica E4. Available from: https://www.empatica.com/research/e4/
[7] Eurostat (2020). Ageing Europe - statistics on population developments. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Ageing_Europe_-_statistics_on_population_developments
[8] Farina N, Sherlock G, Thomas S, Lowry RG, Banerjee S. Acceptability and feasibility of wearing activity monitors in community-dwelling older adults with dementia. Int J Geriatr Psychiatry 2019 Apr;34(4):617-624. doi: 10.1002/gps.5064.
[9] Kourtis LC, Regele OB, et al. Digital biomarkers for Alzheimer’s disease: the mobile/wearable devices opportunity. NPJ Digit Med. 2019;2(9), doi: 10.1038/s41746-019-0084-2.
[10] Mahoney EL, Mahoney DF. Acceptance of Wearable Technology by People With Alzheimer’s Disease: Issues and Accommodations. American Journal of Alzheimer’s Disease & Other Dementias 2010;25(6):527-531, doi:10.1177/1533317510376944.
[11] Masciadri A, Comai S, Salice F. Wellness Assessment of Alzheimer’s Patients in an Instrumented Health-Care Facility. Sensors 2019;19(17):3658, doi:10.3390/s19173658.
[12] Naslund JA, Aschbrenner KA, Barre LK, Bartels SJ. Feasibility of popular m-health technologies for activity tracking among individuals with serious mental illness. Telemed J E Health. 2015 Mar;21(3):213-6, doi: 10.1089/tmj.2014.0105.
[13] Olmedo-Aguirre JO, Reyes-Campos J, Alor-Hernández G, Machorro-Cano I, Rodríguez-Mazahua L, Sánchez-Cervantes JL. Remote Healthcare for Elderly People Using Wearables: A Review. Biosensors 2022;12(2):73, doi: 10.3390/bios12020073.
[14] Sprogis SK, Currey J, Considine J. Patient acceptability of wearable vital sign monitoring technologies in the acute care setting: A systematic review. J Clin Nurs. 2019 Aug;28(15-16):2732-2744, doi: 10.1111/jocn.14893.
[15] World Health Organization, 2022. Available from: https://www.who.int/news-room/fact-sheets/detail/dementia

Assistive Solutions for Person-Centred Integrated Care

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Mechanisms for the Participatory Governance of Technology-Mediated Health and Social Care

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Abstract. Increasingly, health and social care providers are adopting technology-mediated processes to optimise the delivery of care and to influence policy- and decision-makers. However, fragmentation persists in and between health and social care, impeding the provision of rounded person-centred care. Health and care delivery for an ageing population involves many diverse stakeholders with a range of motivations and agendas. The creation of a functional and sustainable network may promote the achievement of a well-functioning and integrated health and care sector. This work-in-progress paper outlines the evolution of an optimal governance model for the SHAPES network.

Keywords. Socio-technical framework, integrated care, healthy ageing, participation, trust, network governance, digital health networks

1. Introduction

Increasingly, health and social care providers are adopting technology-mediated processes to optimise the delivery of care, and to influence policy- and decision-makers. However, fragmentation persists in and between health and social care services, impeding the provision of rounded person-centred care. A range of large-scale challenges persist in health and social care sectors, such as the insufficient integration of health and care sectors, barriers to, or lack of, communication between different stakeholders, scarcity of opportunities for individuals to participate in, or influence, care decisions, and challenges in the implementation of policies or strategies [e.g. 1].

Health and care delivery for an ageing population involves a range of stakeholders with a diverse set of motivations, priorities, and concerns. The creation of a functional and sustainable network may achieve the desired outcome [2], such as a well-functioning and integrated health and care sector. Technology-mediated 'digital' health networks (DHNs) are one approach to bridging persistent divides between the health

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and care sectors, driven by active participation of key stakeholders to promote behavioural change [3]. Individuals may use DHNs to access health resources with information about specific illnesses, clinical trials or relevant services and support groups, which may promote the adoption of healthier behaviours or facilitate connections with others who can provide mutual emotional support. Moreover, DHNs may support collaboration between patients and healthcare professionals (HCPs), enabling patients' to actively participate in decision-making processes, e.g., about the treatment regimens [3,4]. For HCPs, DHNs facilitate interactions with colleagues, exchange of occupational knowledge and ideas, promotion of professional profiles or continuous professional/career development [4,5].

DHNs may also play a role in facilitating sectoral change, as exemplified by the Global Digital Health Network, which comprises the following core functions: dissemination of selected health topics and lessons learned through open meetings; knowledge management; repository of knowledge, tools and resources for the implementation of best practice; facilitating cross-sectoral collaboration at local, regional and global level; strengthening of professional skills and organisational capacities; advocacy work to engage policy and decision makers and lastly, to utilise the strengths of network members and to facilitate the participation, leadership and collective organisation of members. Yet, DHNs have also been associated with challenges relating to the quality of health information, spread of misinformation, adverse effects on the patient-physician relationship, and concerns about privacy and confidentiality [3,4]. Potentially, these functions and challenges are respectively amenable to being supported or ameliorated by good governance of DHNs.

This paper describes the development of a governance model for the on-going Horizon 2020 SHAPES 'Smart and Healthy Ageing through People Engaging in Supportive Systems' project (grant agreement number 857159) [6], which has taken steps to address these concerns through an iterative, co-creation approach that actively involves end-users, e.g., patients, HCPs, family members, researchers, SMEs, and legal and ethical experts. To best meet stakeholders' diverse needs, the SHAPES governance model is underpinned by a set of core values and principles, including: consensus orientation, rule of law, transparency, accountability, responsiveness, strategic vision, equity and inclusiveness, participation, effectiveness and efficiency, intelligence and information, and sound ethical conduct [e.g. 7–10].

In this paper we explore how a health network, mediated by a core platform and a technological ecosystem, can be governed to facilitate both the integration of the health and social care sectors, and the active participation of all relevant stakeholders. The development of the SHAPES governance model is an on-going future-oriented task. Thus, the outline below is a proposition of the SHAPES vision post-project.

2. Approach to developing the SHAPES Governance Model

2.1. Defining the nature of SHAPES

The development of the SHAPES governance model requires establishing the nature of SHAPES as an enterprise which, as will be seen below, is a multi-layered entity. This has involved a review of a range of possible governance models, and consultations with relevant stakeholders, including members of the SHAPES consortium and SHAPES advisory board as well as members of the public through dialogue workshops. In

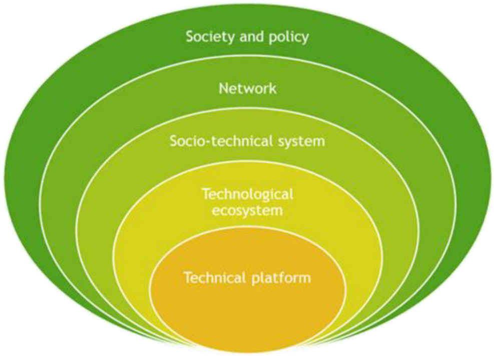

Figure 1: SHAPES Nested Governance Layers Model

addition, we will be conducting a pan-European survey to capture public attitudes to participation in health and care governance.

As illustrated in **Figure 1**, SHAPES exists at multiple nested levels as: i) SHAPES technical platform (STP), ii) SHAPES technological ecosystem (STE), sociotechnical system (STS), iv) SHAPES network (SN) and v) government and society (G&S).

In short, the first two layers incorporate 1) the STP which is the core platform enabling integration of and access to a range of digital solutions and services from 2) the (STE), which can be accessed through the SHAPES marketplace. The STS represents the local organisational system mediated by the STE and is the smallest unit where both rationale for, and value of, SHAPES can be demonstrated – that is operationally. The STS includes, for example, individual homes and local communities, H&SC institutions, health regions, amongst others. Members of the STS retain their existing governance structures and are responsible for compliance with, e.g., data processing and privacy regulations. SHAPES as an open social digital health network (SN) includes the full set of individual and institutional actors who are voluntary subscribers to the network. Membership and access profiles are based on the nature of network members, e.g. individuals or institutions, represented by a range of themed action groups (**Figure 3**). All layers relating to the SHAPES network also intersect with governmental and societal structures, rules and regulations.

2.2. Rationale for choosing a Network Administrative Organisation (NAO) network for SHAPES

Networks are complex, formal constellations of interdependent social actors and the ties that connect them. Public, private and third sector actors work collaboratively towards achieving a common goal [2,11–14] in spite of differing “objectives, values and priorities” [15,p.17]. Networks are becoming more common in response to policy problems that are too complex to be solved by a sole actor or organisation [2,12]. Networks, unlike more conventional, hierarchical, organisational structures, tend to be more flexible with flat hierarchies, and rely on collaboration and dialogue, social capital, norms and trust.

Network governance refers to “all governance strategies and interactions that take place within these governance networks” [12,p.4]. There are three basic types of

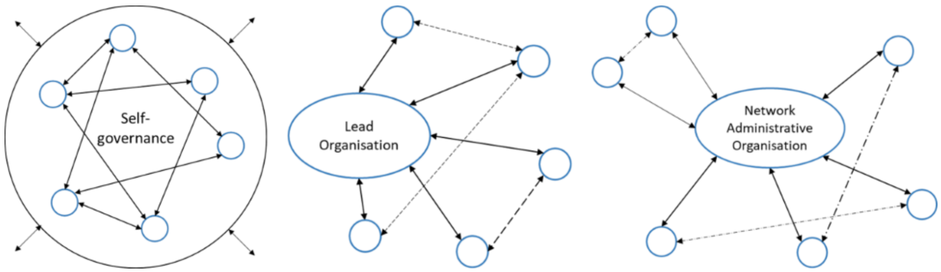

Figure 2: Types of network governance. Adapted from Kenis and Provan, 2009.

network governance: self-governance, lead organisation governance, and network administrative organisation (NAO) governance [13,16] (**Figure 2**).

Self-governance (SG) networks involve varying levels of formality. They are dense and highly decentralised arrangements governed exclusively by network members without a separate governing body. All members hold equal decision-making powers at network level. Moreover, members are equally responsible for both intra-network operations and relationships, and for interactions with external entities.

Lead organisation governance (LOG) networks are governed by a single lead organisation. One lead organisation from *within* the network, either chosen by network members or mandated by an external body, holds all decision-making powers and responsibilities. The lead organisation will coordinate, control, and make decisions about all major activities at network level, including organisational, administrative and financial decisions, and interactions with external entities. Interactions bteween network members tend to be scant.

NAO networks comprise elements of both participant-governed and LOG networks. NAO networks have a centralised power structure, and the NAO will be either created by the network members or mandated externally from *outside* the network. NAO networks usually have a board that involves all network members, or designated representatives. The NAO leads on operational decisions and the board is responsible for strategic decisions at the network level. Network members interact with both the NAO and with each other. Network members may decide on specific network activities or divide responsibilities between them. This means that no single entity holds all the power.

The choice of an NAO governance model as the most suitable and effective type of governance model for SHAPES was influenced by four key factors: network size, trust across the network, goal consensus and the nature of the tasks, i.e. need for network-level competencies. A network's success is dependent on the level of trust across the network, and the willingness to reciprocate among network members, which in time is expected to increase the density of ties across the network. SG models are suitable for small networks with high levels of trust, high goal consensus and low levels of network competencies. LOG models are more appropriate for medium-sized networks, with low levels of trust, low-to-moderate levels of goal consensus which are less likely to encourage collaboration, and moderate levels of network competencies. NAO models are best suited to medium to large sized networks, moderate levels of trust, moderate-to-high levels of goal consensus and high levels of network competencies [13].

The SHAPES consortium currently comprises 36 partners with more than 300 employees. SHAPES seeks to expand its member base post-project, and may draw on existing connections, such as a cluster of eight EU health and social care projects. The

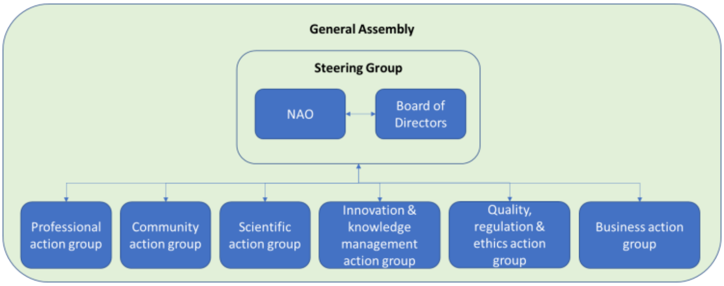

Figure 3: Governance structure of the SHAPES network

SHAPES consortium, which comprises a diverse set of experts, has been collaborating to achieve the goal of enabling older people to retain their independence and to age in place in spite of chronic illnesses and age-related limitations.

2.3. Benefits and challenges of network governance

Network governance models are associated with a range of benefits for network members, including i) economic benefits (e.g. reduced market transaction costs and pooling of resources through collaboration); ii) learning and innovation (i.e. improved learning processes through access to and exchanges of information, and internalisation of knowledge); legitimacy and status, conveyed through affiliation and endorsement from peers with higher status or with greater resources and lastly, greater effectiveness (i.e. improved service delivery and client satisfaction as a result of network structures and interactions) [e.g. 17].

However, the complexity of large networks comprising multiple, interdependent actors presents also presents a range of challenges for network effectiveness [14]. Challenges may derive from or relate to the diversity of stakeholders with conflicting goals and motivations, asymmetries of power and access to resources, access to information, members' compliance with or enforcement of network rules, conflicts between network members, and limitations in understanding of how governance is articulated in daily activities [*e.g.* 18,19].

2.4. Structure of the SHAPES NAO Governance Model

The SHAPES network governance structure will involve a steering group, a general assembly, thematic action groups at the European, national, regional and local level, as well as external stakeholders and supporters. The steering group will include the NAO and a board of directors (BoD). The NAO is a separate administrative entity established with the purpose to coordinate, monitor and sustain the activities of the SHAPES network. The BoD will be responsible for the strategic aspects of network governance.

The SHAPES Network will have six core thematic action groups (community, professionals, science, knowledge and innovation management, quality assurance, regulation and ethics, and business). These action groups will include both members of the public and thematic experts. Action groups will be hubs where elected representatives from national action groups will come together to collaborate and exchange knowledge, ideas, and best practice. Reports on these activities will inform the BoD, who will address the needs, challenges and desired changes identified by members of the action groups during regular network board meetings.

2.5. The composition of the SHAPES network

SHAPES is more than the sum of its members as it is designed to facilitate the provision of and the access to health and care services. This means that its governance model comprises both registered members, and stakeholders shaping the European health and care environment. Members can be patient organisations, health and care professionals, researchers, providers of technical solutions. Individuals can also join the network as users.

2.6. Interactions between network members at different levels of participation in health and social care governance

Figure 4 illustrates the interactions between the network members at different levels of participation in health and social care governance. The dark blue circle represents SHAPES' steering group (NAO and BoD). The NAO may employ staff performing the operational management and coordinating functions described above. The BoD will be elected by the SHAPES general assembly (GA) which will include all network members. The BoD will engage in the strategic management of SHAPES. The steering group will coordinate the thematic action groups, and each director will be responsible for at least one action group, according to their area of expertise. The light blue circle represents all SHAPES members. Active members can engage in the thematic action groups to represent their interests in the network. The white outer circle represents the network as a whole, including the contextual environment in which SHAPES will continue to evolve in interaction with, for example, national, regional and European authorities, experts involved in innovative health and care, related health care clusters and networks, as well as EU interest groups.

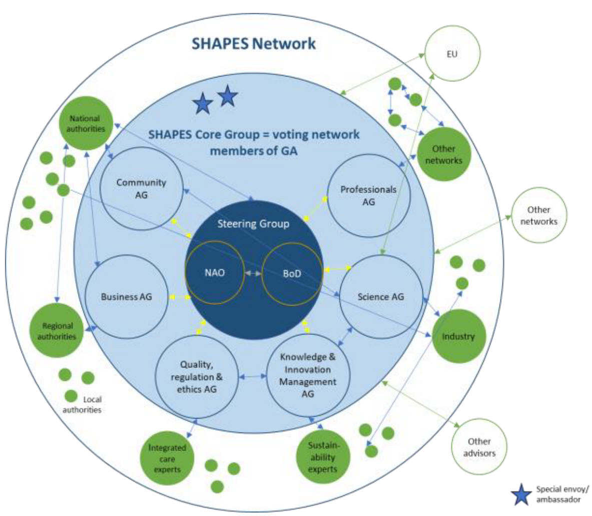

Figure 4: Levels of participation in the SHAPES network.
Graphic inspired by the Circular Economy Coalition Framework

3. Conclusion

This paper has presented an overview of the on-going work towards the development of a suitable model to govern the SHAPES network. As outlined above, the choice of an NAO network governance model as best fit for SHAPES was informed by network size, trust across the network, goal consensus and the nature of the functions to be performed by the network. As stated, there are a range of potential benefits that may incentivise both organisations and individuals to join the SHAPES network. Digital health networks may bridge the persistent divide between health and social care, facilitate inter-stakeholder communication, and afford stakeholders opportunities to influence decision-making. Nevertheless, DHNs present with a range of challenges that may hamper the successful implementation, expansion and long-term sustainability of the SHAPES network. The model and process of governing digital health networks may both ameliorate the challenges inherent in such networks, while supporting their goals. These challenges may be addressed and offset not only by good and efficient operations of the steering group, but also by giving primacy to the foundational values and principles of the governance model, and specifically expressing those through the governance operations. Putting these values and principles into practice, next steps will involve a pan-European survey to capture public attitudes towards the SHAPES governance model as a vehicle towards promoting greater participation in health and social care governance.

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References

[1] World Health Organization. WHO global strategy on people-centred and integrated health services. Interim report [Internet]. Geneva, Switzerland: World Health Organization; 2020 [cited 2023 Mar 5]. Available from: https://apps.who.int/iris/bitstream/handle/10665/155002/WHO_HIS_SDS_2015.6_eng.pdf?sequence=1&isAllowed=y.
[2] Kapucu N, Hu Q. The development of network governance and its relevance for public affairs education. J Public Aff Educ. 2021;27:267–275.
[3] Makena N, Adebesin F. Influence of health social networks on healthcare: a systematic literature review. 2022 [cited 2023 Mar 3]. p. 172–159. Available from: https://easychair.org/publications/paper/9Vsn.
[4] Lefebvre RC, Bornkessel AS. Digital social networks and health. Circulation. 2013;127:1829–1836.
[5] Mettler T. Contextualizing a professional social network for health care: Experiences from an action design research study. Inf Syst J. 2018;28:684–707.
[6] Seidel K, Labor M, Lombard-Vance R, et al. Implementation of a pan-European ecosystem and an interoperable platform for Smart and Healthy Ageing in Europe: An Innovation Action research protocol. Open Res Eur [Internet]. 2022 [cited 2023 May 21];2. Available from: https://open-research-europe.ec.europa.eu/articles/2-85/v1.
[7] Barbazza E, Tello JE. A review of health governance: Definitions, dimensions and tools to govern. Health Policy. 2014;116:1–11.
[8] Garattini L, Padula A. Clinical Governance in Italy: ‘Made in England’ for Import? Appl Health Econ Health Policy. 2017;15:541–544.
[9] Gray C. What is clinical governance? BMJ. 2005;330:s254.3-s254.
[10] Siddiqi S, Masud TI, Nishtar S, et al. Framework for assessing governance of the health system in developing countries: Gateway to good governance. Health Policy. 2009;90:13–25.
[11] Kapucu N, Hu Q. Network governance: concepts, theories, and applications. Routledge; 2020.

[12] Klijn EH, Koppenjan J. The shift towards network governance: drivers, characteristics and manifestations. In: Van De Walle S, Groeneveld S, editors. Theory Pract Public Sect Reform [Internet]. 1st ed. New York : Routledge, 2016.: Routledge; 2016 [cited 2023 May 21]. p. 158–177. Available from: https://www.taylorfrancis.com/books/9781317500124.
[13] Provan KG, Kenis P. Modes of network governance: Structure, management, and effectiveness. J Public Adm Res Theory. 2007;18:229–252.
[14] van Duijn S, Bannink D, Ybema S. Working toward network governance: local actors' strategies for navigating tensions in localized health care governance. Adm Soc. 2022;54:660–689.
[15] World Health Organization. Smart governance for health and well-being: the evidence. Kickbusch I, Gleicher D, editors. Copenhagen: World Health Organization; 2014.
[16] Kenis P, Provan K. Toward an exogenous theory of public network performance. Public Adm. 2009;87.
[17] Moretti A. The network organization: a governance perspective on structure, dynamics and performance [Internet]. Cham, Switzerland: Springer International Publishing; 2017 [cited 2023 Mar 20]. Available from: http://link.springer.com/10.1007/978-3-319-52093-3.
[18] Maron A, Benish A. Power and conflict in network governance: exclusive and inclusive forms of network administrative organizations. Public Manag Rev. 2022;24:1758–1778.
[19] Wegner D, Verschoore J. Network governance in action: functions and practices to foster collaborative environments. Adm Soc. 2022;54:479–499.

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Barriers to and Facilitators of Participation in Health and Social Care Governance: Categories and Cross-Cutting Themes from a Survey of SHAPES Project Partners

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Abstract. Good governance—aligned with human rights and rights-based care, participation, inclusion, and person-centredness—of digital care systems is integral to their ability to meet their objectives. To gain insight into existing governance structures and processes and participation experiences across Europe and lay foundations for the SHAPES Project's network governance (a healthy and active ageing Innovation Action consortium), our objectives included: 1) expand the list of known stakeholders, 2) explore how the range of stakeholders participate in health and social care governance, 3) develop an inventory of barriers and facilitators. Using an empirical, survey method, we consulted SHAPES Project partner organisations, with respondents invited to suggest specific participation barriers and facilitators. 16 organisations responded. Numerous additional stakeholders were identified. Circa 150 unique barriers and facilitators were reported, rationalised into 20 superordinate categories. Six cross-cutting themes were assembled: dimensionality and flux; power; opportunity and environments; interest, motivation, and choice; valuing governance participation, and duality. This work allows consideration of a wide range of stakeholders for the SHAPES collaborative governance model and future research, and for system design with the benefit of a detailed inventory of barriers and facilitators, and thematic contextualisation. Participation is modifiable and we suggest intervention targets and mechanisms.

Keywords. Governance, digital health, healthy ageing, participatory governance

1. Introduction

Health and social care (HSC) ecosystems range from national public systems of health service provision to digital health and social care systems which may variously link technology providers, care providers, embedded marketplaces, and the end user. The design of such systems in line with widely accepted enumerations of rights [1], and

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integrated care principles [2] is central to improving system quality, efficiency, and inclusiveness, and stakeholder experiences.

Complexity, risks, and opportunities for benefit are especially evident in even smaller-scale digitally enabled systems, as they may comprise multiple, interacting partners, divergent practices, novel technologies, use of personal data, and end-users in the general population or sub-populations with disabilities or health conditions.

As such, a laissez-faire approach will not suffice. To shape, steer, and manage strategy and operations, care systems and networks require governance and decision-making structures and processes. It should, in other words, have a set of values at its core and set of principles to effect those values [3–5]. These include *inter alia* consensus orientation, rule of law, transparency, accountability, responsiveness, strategic vision, equity and inclusion, participation, effectiveness and efficiency, intelligence and information, and ethical conduct. Governance ought to be founded on contemporary, human rights-based understandings of health and care [1,6,7] and meaningful inclusion and participation [8,9] of the relevant stakeholders, not least care recipients, family, and informal caregivers, whose needs indeed should be centred in any system.

Stakeholder diversity means that different, even competing, priorities are a reality, as are differential levels of, opportunities for, and access points to participation. By virtue of the existence of different levels of participation, expectations, opportunity, resources, and experiences, stakeholders may encounter a range of participation barriers or facilitators, many of which will be unique to particular stakeholder groups.

The SHAPES Project seeks to construct a digital, healthy ageing platform, ecosystem, and marketplace involving stakeholders from across the care spectrum [10], and will therefore require good governance to achieve its objectives. We aimed to acquire descriptive understandings of existing governance structures, processes, and experiences across Europe, from the standpoint of individual actors. We consulted various partner organisations across the SHAPES Project consortium via a governance participation consultation survey. Our principal objectives were to:

- expand the list of known, relevant stakeholders for consideration in the SHAPES collaborative governance model,
- explore how a range of stakeholders participate in HSC governance, and
- develop an inventory of related barriers and facilitators.

To tap into both the specific and the general or universal, we aimed to gather information from respondents' own countries, regions, or settings that they knew best, but also examples of factors that may be considered more abstract or theoretical, universal, or that they may have heard about in another region.

2. Method

Survey development was informed by prior findings from a dialogue workshop in the SHAPES Project. We structured the governance participation consultation survey as a matrix. Rows represented stakeholders in HSC governance. This included participants or stakeholders, ranging from people not engaged professionally in HSC systems, such as care recipients, family, and informal caregivers, to medical, social care, and administrative professionals and policymakers, to those in the wider ecosystem, such as academics. Any of the stakeholders could participate at more than one level of governance. Respondents were invited to add additional stakeholder categories, as appropriate. Columns represented levels of participation in HSC governance, ordered by the degree of participation any individual may engage in within their own national or regional setting, or in more abstract and universal terms. Categories of governance participation included: low; low but interested or concerned; moderate; high at micro/individual level; high at meso/management level (hospital, clinic, or care home management/administration); high at macro level through strategic decision-making in governance, and other. Respondents were invited to input specific barriers and facilitators into the matrix. An additional column permitted qualitative comment.

We distributed our consultation request with the survey matrix via email to partner organisations across the SHAPES Project network. SHAPES Project partners include academic and research institutions, SMEs (typically involved in technology development), care providers, and NGOs, including disabled persons/care recipient representative organisations. Responses were not fully anonymous, but sought at organisation level. Responses were collated, with numerical codes assigned to responses that explicated barriers or facilitators, which were in turn grouped into manageable categorisations. Cross-cutting themes were constructed using thematic analysis [11].

3. Results

We received N=18 consultation survey responses from across the SHAPES consortium. Respondents generally completed the survey on behalf of organisations (n=15). N=3 responded as individuals—all from the same institution as some of the present authors.

In addition to the stakeholder categories pre-specified in our survey, respondents added numerous additional stakeholder categories. These included specific stakeholders at care recipient, caregiver, HSC professional, care recipient's social network, care organisation, professional representative organisation, ICT organisation, health technology, higher education institution/research, governance professional, and regional administrative, and international network levels.

A large number of unique barriers and facilitators (circa 150) were reported by respondents to the consultation survey. With the application of qualitative, thematic analysis, barriers and facilitators were categorised into twenty superordinate categories. Categories included knowledge and awareness, capacity (personal), motivation and choice (personal), communication, inclusion, social role, resources–personal or professional, resources–organisational or systemic, power and its distribution, collective voice and action or solidarity, organisations and institutions, systems and services, access, legal & ethical contexts, social supports, technologies and tools, social, economic, and political environments, biases, inequalities, and inequities, and time. We outline these, along with exemplar barriers and facilitators within those categories, in table 1 below. A full list is available from the corresponding author and via https://osf.io/wjy87/ .

Table 1. Categories of Barriers and Facilitators to Participation in Governance

No	Categories	Barriers (Selected examples)	Facilitators (Selected Examples)
1	Knowledge and awareness	Strong but unstructured knowledge, lack of instruction (or knowledge) available to recipients on how to raise concerns in the correct, official pathway, lack of information on relative performance of HSC system.	Access to information, knowledge, education, training, evidence-based practice, caregiver having requisite experience and knowledge, experience of how the system works.
3	Capacity	Cognitive impairment.	Physical capacity, cognitive or decision-making capacity.

4	Motivation and choice	Influence of the socio-political environment, professionals' choice of enhanced services from an approved list only.	Free choice of one's personal physician, ability to seek a second opinion, healthcare systems allowing care recipients to decide.
5	Communication	Lack of clarity or communication about what (academic/research) recommendations actually influence policy, speed of the doctor's speech, conflict between stakeholders.	Two-way communication with HC providers, conflict may also function as a facilitator, allowing for leverage over decision making.
6	Inclusion	Perceived or actual tokenism.	Person-centredness, encouragement to be active decision maker, patient and public involvement (PPI), involving decision makers in technological R&D.
7	Social role	Care recipient.	Being and administrator, policymaker, or HSC professional.
8	Resources–personal or professional		Financial resources, social network.
9	Resources–organisational or systemic	Staff turnover due to grant-linked employment (research/academia).	Availability of trained personnel, specialised personnel.
10	Power and its distribution	Unequal distribution of power across social roles (e.g., physicians having more power at micro level than nurses), feeling disempowered.	Empowerment to implement change (which lies mostly with government and insurance companies).
11	Collective voice & action/solidarity		Labour union membership, professional organisations.
12	Organisations & institutions		International organisations.
13	Systems and services	Specialists operating in silos, insurers' control over pricing of procedures, linking reimbursement to frequency of activity (e.g., number of patients seen, rather than quality), restricted appointment times.	Well organised HSC systems, integrated care partnerships, integrated care itself, emphasis on prevention, correct navigation of care recipients through system, uploading of outpatient specialists of non- specialised visits; transparency regarding service quality.
14	Access to services	Physical barriers to service access, cost-related barriers (e.g., out of pocket costs), time-related barriers to access (e.g., waiting lists).	
15	Legal & ethical contexts and tools	Restrictive regulations (e.g., on reimbursement, or choice of services).	Regulations, guidelines (for technology use), advance care directive, developed policy.
16	Social supports	Caregivers not being supportive.	Access to online communities, caregiver support, spiritual support.

17	Technologies and tools		Connected health technology. Availability of ICT (e.g., health portals, symptom checkers), telemedicine, synchronous and asynchronous communication with HSC professionals, tools supporting integrated care, especially sharing information with social care and coordination of care of several kinds of professionals, electronic health record.
18	Social, economic, and political environments	Geographic inequalities.	Small size of a geographic or administrative region.
19	Biases, inequalities, and inequities	Age, gender, health status, disability status, citizenship or migrant status	
20	Time	Palliative care scenario dictating that limited time is available, length of time required to design, complete and report on trials.	Availability of time for participation. Protected time (if governance is part of a professional function).

A set of themes was assembled from the data. These themes were common, if not universal, across different respondents, stakeholder categories, or modes of participation. Themes are distinct from, but contextualise, the specific barriers and facilitators, or further our understanding of common and cross-cutting issues. Themes included: dimensionality and flux; power and imbalances thereof; opportunity and environments (incorporating structures, supports, inclusion and equity); interest, motivation, and choice; valuing governance participation, and duality of barriers and facilitators. We elaborate on each of these themes below, illustrating with sample responses.

Theme 1. **Dimensionality and Flux**. Care recipients' capacity, for example, may not fit a binary classification, instead operating on a spectrum, and/or varying over time, either upward or downward. Capacity exists in different forms, each of which may also fluctuate over time. Implementing participation or decision-making facilitators (e.g., assistive technology, advance care directives) may allow for change in terms of what forms of participation are available to people. *It may not always be clear to draw a line between a patient that is "dependent" vs one that is "independent". I appreciate this lies on a continuum, but it also may fluctuate from time-to-time within the patient (also patients may be dependent for some care needs, but not for others). – Respondent 'S'.*

Theme 2. Power and Imbalances Thereof. Power is a prominent determinant, mediator, and moderator of participation. Substantial power imbalances are evident between stakeholders. Care recipients, families, and informal caregivers typically have little power to make decisions or effect changes. At micro level, health professionals have decisional power in care contexts. Power is unevenly distributed across professions; physicians typically having the most, in care contexts and at more meso/administrative and strategic levels. Government bodies, legislatures, administrative bodies, and insurers typically have much more power than care recipients or professionals, especially at strategic levels. This also influences micro level activity, e.g., funding constraints or policy limitations on professionals' services. Individuals may be empowered in various ways, whether via professional bodies, trade unions, representative organisations, inclusion in decision making, initiatives such as advance care directives, or indirectly via improved knowledge, or service access and availability. *"Nurses are very often the ones that take care of the patient the most, who know their needs, struggles and monitor their well-being, they have quite respected position in a dialogue with the patient and the doctor, they can make minor changes in the care plan, however major decisions are still in the hands of the doctor." – Respondent 'O'.*

Theme 3. Opportunity and Environments (incorporating structures, systems, inclusion, and support). Opportunity relates to environmental factors, such as HSC environments, contexts in which governance participation might occur, social, economic, physical, and situational factors, inclusion, and supports. Numerous factors were identified in responses across the range of stakeholders and levels of participation. Often, environmental features intertwined with the theme of power—e.g., in hierarchies and power distributions. Opportunity may be expanded and bolstered by increasing stakeholder inclusion in decision making processes, and providing supports to stakeholders that enable participation. Such supports could take the form of social support, wider and more equitable access to care, assistive or eHealth technology, environmental adaptations (e.g., of the home), legal means, advanced care planning, and supports that target financial factors, from affordability of care and services, to supports or fiscal/economic change (non-exhaustive list). Interventions or facilitators that rebalance power relationships or empower stakeholders may also be considered as modifications in this domain. *"Enablers may include good levels of health literacy, good access to health services, access to appropriate aids (e.g., mobility aids, compliance aids), good relationships with healthcare professionals (HCPs), discussing decisions with friends/family and adaptions to living space. Barriers may include low levels of health literacy, poor access to health services, poor/untrusting relationship with HCPs, social isolation." – Respondent 'I'.*

Theme 4. Personal Interest, Choice, and Motivation. Issues relating to personal interest, choice, and motivation to participate, were evident across data and how it relates to involvement. Stakeholders naturally have the choice to participate where opportunities are available to them. They also have the choice to not participate, even where opportunities are available, with the only exception being those whose social or occupational role requires or mandates particular forms of participation, e.g., a policymaker making macro-level decisions, or consultant physician's involvement in daily, micro-level governance activities. Choice is mediated by motivation, and motivation is in turn determined not merely by personal factors, but also by features of the actor's environment. Motivation and choice are intertwined are intertwined with personal and environmental features, including but not limited to the information upon which choices are made, service access, availability of participation opportunities, inclusion and equality, technological supports, knowledge, and social supports. *"[Caregivers] lack capacity and motivation to be involved in decision making as their time and energy must be dedicated to immediate demands of caring" – Respondent 'S'.*

Theme 5. Valuing Participation in Governance. The overall tone and thrust of responses, and the wide range of barriers suggest that respondents value participation, at various levels and in various aspects of HSC systems. Similarly, respondents appeared to be interested in enabling participation and empowering stakeholders for participation. *"[The] financial model and overall concept of specialized (outpatient) care is not in favour of patients' empowerment and involvement." – Respondent 'E'.*

Theme 6. Duality. Duality emerged as an explanatory theme; a single factor may function as both a barrier and facilitator. Taking education as a particular example; it indeed may function as a facilitator. However, it may also operate as a barrier, contingent upon its accuracy, format, delivery, or ideological framework, boundaries, or content. Recipients of education which did not emphasise or value participation, inclusion, diversity, voice, or empowerment, may experience explicit or implicit barriers.

4. Discussion

Our governance participation survey aimed to explore how a range of stakeholders participate in HSC governance and to develop an inventory of related barriers and facilitators. This work provided a much-expanded list of relevant stakeholders in HSC, across different systems throughout Europe. This allowed a wide range of stakeholders to be considered in the construction of the SHAPES collaborative governance model and future research endeavours relating to digital health systems, integrated care, and participation in HSC governance. Survey responses generated circa 150 unique barriers and facilitators. Our method permitted collection of very specific barriers and facilitators (e.g., provision of specific assistive devices) and more general or universal factors (e.g., integrated care). Qualitative analysis enabled rationalisation into a manageable number of categories. Generation of cross cutting themes allowed contextualisation and understanding of universalities and common issues.

While respondents from across the spectrum of the consortium considered barriers and facilitators from the standpoint of care recipients and caregivers/family and from a range of countries and regions, the scope of responses could be somewhat limited by the non-participation in the consultation of person/patient-representative organisations. The process of designing a participatory governance model ought to be participatory itself, and therefore ongoing consultation with such organisations, a future large-sample, population-level survey of public attitudes, and dialogue workshop activities will go some way to bridging that gap.

This consultation allowed us to uncover detailed information about actors and stakeholders and how they currently, could possibly, may wish to, and could be enabled to, participate. Individuals differ in their functioning, motivation, or choices around whether, how, and when to participate. Similarly, environments—physical, social, economic, political, digital—differ; some are more or less enabling than others. Participation must be considered not as fixed, but as modifiable and extendable with appropriate intervention. Intervention to promote opportunities to participate—enablement—may take numerous forms. Examples of potential intervention targets or mechanisms include: information access; health literacy; digital literacy; actual and perceived empowerment; meaningful inclusion of care recipients, caregivers, and families in governance and decision making, including its design; technology provision; financial barriers to governance or to care itself; equity within systems and services; integration; facilitating collective action; social support; accessibility (e.g., universal design); and legal instruments.

5. Conclusion

A governance system should not only align with, but give effect to, humanitarian values, human rights, and rights-based care, should place emphases on participation, inclusion, and promoting person-centredness, and improve overall HSC experiences and outcomes. In the course of developing a collaborative governance model for the SHAPES Project, we effected broad consultation on diverse and isomorphic barriers and facilitators to participation in governance activities and processes, using empirical methods. This work permitted the development of a broad list of governance stakeholders from across Europe, an understanding of individuals' opportunities, of the role of technology in supporting participation, and of the factors that shape participation in governance, and an understanding of factors that contextualise or moderate participation and experiences. Values and rights, principles of enterprise governance of IT [12], network administrative organisation (NAO) models, and this work will be carried forward into the development of the SHAPES Project's collaborate governance model.

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References

[1] United Nations, Convention on the Rights of Persons with Disabilities, 2006.
[2] Hughes G, Shaw SE, Greenhalgh T. Rethinking Integrated Care: A Systematic Hermeneutic Review of the Literature on Integrated Care Strategies and Concepts, *The Milbank Quarterly*. 2020;98: 446-492. doi:10.1111/1468-0009.12459.
[3] Siddiqi S, Masud TI, Nishtar S, Peters DH, Sabri B, Bile KM, Jama MA. Framework for assessing governance of the health system in developing countries: Gateway to good governance, *Health Policy*. 2009;90:13-25. doi:10.1016/j.healthpol.2008.08.005.
[4] Barbazza E, Tello JE. A review of health governance: Definitions, dimensions and tools to govern, *Health Policy*. 2014;116:1-11. doi:10.1016/j.healthpol.2014.01.007.
[5] Garattini L, Padula A. Clinical Governance in Italy: 'Made in England' for Import?, *Appl Health Econ Health Policy*. 2017;15:541-544. doi:10.1007/s40258-017-0328-8.
[6] Degener T. A New Human Rights Model of Disability, in: Della Fina V, Cera R, Palmisano G, editors. The United Nations Convention on the Rights of Persons with Disabilities, Springer International Publishing, Cham, 2017:41-59. doi:10.1007/978-3-319-43790-3_2.
[7] Degener T. 10 years of Convention on the Rights of Persons with Disabilities, *Netherlands Quarterly of Human Rights*. 2017;35:152-157. doi:10.1177/0924051917722294.
[8] Rajan D, Brocard E, Poulussen C, Koch K, Nathan NL, Rohrer-Herold K, and Melihan-Chenin P, Beyond consultations and surveys: Enhancing participatory governance in health systems, *Eurohealth*. 2022;28:9-13.
[9] World Health Organization, Declaration of Astana: Global Conference on Primary Health Care: Astana, Kazakhstan, 25 and 26 October 2018. World Health Organization, Geneva.
[10] Seidel K, Labor L, Lombard-Vance R, McEvoy E, Cooke M, D'Arino L, Desmond D, Ferri D, Franke P, Gheno I, Grigoleit S, Guerra B, Krukowski A, Pešoutová M, Pietri I, Prendergast D, Maguire R, Manso M, Saris AJ, Sarlio-Siintola S, Silva T, Zarogianni E, MacLachlan M, SHAPES Consortium. Implementation of a pan-European ecosystem and an interoperable platform for Smart and Healthy Ageing in Europe: An Innovation Action research protocol, *Open Res Europe*. 2022;2:85. doi:10.12688/openreseurope.14827.1.
[11] Braun V, Clarke V. Using thematic analysis in psychology, *Qualitative Research in Psychology*. 2006;3:77–101. doi:10.1191/1478088706qp063oa.
[12] ISACA, COBIT 2019 framework: Governance and management objectives, ISACA, Schaumburg, IL, USA, 2018. www.isaca.org.

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SHAPES Marketplace: Transparency, Trust and Fair Competition in the Healthy Ageing Market

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Abstract. Access to digital health and care solutions and services that promote healthy ageing, independent living, and ageing in place is limited due to significant market barriers and challenges. The SHAPES project addresses the challenge of ageing populations by developing a sociotechnical ecosystem comprising a variety of health and care digital solutions, tools and services to enable and facilitate active, independent, and healthy ageing at home. Within the SHAPES project, the SHAPES Marketplace serves as a one-stop-shop for digital solutions and services designed for the Silver Economy that target the smart and healthy ageing and independent living markets. Delivering a dynamic catalogue of health and care digital solutions and services, the Marketplace promotes a transparent expansion of a trusted market offer on digital solutions and services for healthy ageing and independent living on a pan-European scale, thereby preventing vendor lock-in and enhancing the agile and fair competitiveness of the health and care industry, particularly in Europe. This paper introduces the SHAPES Marketplace and considers its function as a market driver to raise awareness on the benefits and impact of health and care digital solutions and services, as well as to shape the healthy ageing market, upholding the Systems-Market for Assistive and Related Technologies (SMART) Thinking Matrix to stimulate transparency, trust and fair competition.

Keywords. Marketplace, Silver Economy, market shaping strategy, SHAPES, co-creation, ageing population, older adults.

1. Introduction

Significant market barriers and challenges contribute to a low access to health and care digital solutions and services that support healthy ageing, independent living and ageing at place. Aiming to overcome these barriers and address the challenge of ageing populations, the Smart and Healthy Ageing through People Engaging in supportive Systems (SHAPES) project adopted a multidisciplinary approach to develop the SHAPES Platform, a sociotechnical ecosystem comprising a variety of health and care

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digital solutions and services to enable and facilitate active, independent, and healthy ageing at home [1]. The SHAPES digital solutions have the potential to empower older people to optimise their health, mental and physical wellbeing and participate in civic life, while maintaining independent and dignified lives at home and delaying or preventing the need for long-term institutionalised care. To facilitate access to the SHAPES digital solutions, a decision was made to create and launch the SHAPES Marketplace. The SHAPES Marketplace serves as a one-stop-shop for digital solutions and services for the Silver Economy, connecting demand and supply in a transparent way, enhancing the agile competitiveness of the European health and care industry.

This paper is structured as follows: chapter 2 presents the summarised overview of the state-of-the-art in healthcare digital marketplaces; chapter 3 describes the SHAPES Marketplace, addressing its design and development effort, as well as the fostering of transparency, trust and fair competition through relevant market shaping activities; the conclusion reinforces the SHAPES Marketplace's role in setting beyond state-of-the-art access to health and care digital solutions for older adults in the healthy ageing market, overcoming prevailing market barriers and challenges.

2. Landscape on Digital Solutions Marketplaces for Healthcare

Access to health and care digital solutions and services supporting healthy ageing, independent living and ageing at place is hampered by a range of market barriers and challenges. Among them are the fragmentation of the health and care industry market, a lack of awareness of the general public and knowledge gaps of the care workforce about existing trustworthy health and care digital solutions and their benefits, the absence of priority investments in digital health and care for older adults, the deficiency of harmonisation in regulation and standardisation initiatives concerning health and care digital solutions and the use of health data, the perception of elevated costs associated with the adoption and use of health and care digital solutions and the reluctance of health and social care professionals to accept and endorse the use of health and care digital solutions, tools, technologies and services.

Presenting a novel economic model, digital marketplaces are recognised for their capability to bridge demand and supply and establish efficiency and competitiveness, overcoming known market barriers and challenges. Indeed, the last two decades have seen the emergence of a number of marketplaces in Healthcare, offering solutions that typically include telemedicine, Electronic Health Records (EHRs), remote patient monitoring, clinical decision support tools, population health management and healthcare analytics. For this paper's scope, it is worth mentioning AppScript (https://www.appscript.net), Medigy (https://www.medigy.com), HealthXL (https://www.healthxl.com), and Elion (https://www.elion.health/marketplace).

Appscript offers virtual care platforms (e.g., remote consultations), EHR solutions, practice management software, patient engagement tools, telemedicine solutions, and remote patient monitoring solutions. However, these services are currently only available in the United States, the United Kingdom, and the United Arab Emirates. In addition, AppScript appears a marketplace restricted to particular solutions and does not consider accessibility aspects. Medigy is a generic platform that provides information on health-related events, healthcare IT consulting, Health Information Exchange solutions, EHR solutions, telehealth, patient engagement and education tools, healthcare analytics and reporting. Due to its generic nature, Medigy does not offer solutions tailored for the

Silver Economy, nor does it include accessibility features to better support citizens with disabilities. HealthXL is not a traditional healthcare marketplace, but rather a marketplace for "ideas". Although it does not advertise or sell digital products or services, it provides a forum for players in the healthcare industry to communicate with one another and work together on the development of digital healthcare solutions. As a result, it provides a marketplace for innovation, assisting organisations in identifying and assessing new healthcare solutions and encouraging engagement between the technology sector and the healthcare industry. Elion is an online marketplace that provides patients, medical practices, and other healthcare professionals access to a variety of healthcare solutions. Its offer includes EHR solutions, telemedicine platforms, and software for revenue cycle management. It lacks transparency in terms of vendor selection and quality control, it does not have a reputation system for the solutions and it does not include accessibility features.

Overall, it is missing a marketplace specifically designed to provide health and care digital solutions focusing on older adults and the segments of the Silver Economy. Recently, the ACTIVAGE Association (https://activage-association.org) started building a marketplace for seniors to find digital applications developed in the EU-funded project ACTIVAGE (https://www.activage-project.eu). The Association's marketplace provides seventeen applications that use the ACTIVAGE IoT Ecosystem Suite (AIOTES) technology. Still, there is the need for a truly global marketplace, facilitating the supply of innovative health and care digital solutions with common principles [2] that bring transparency, trust and fair competition to the market.

For the past two years, the SHAPES Marketplace has been co-designed with end-users, upholding accessibility and usability. Instead of imposing a specific technology, the Marketplace opens doors to suppliers worldwide, willing to abide to applicable regulations and the SHAPES ethics, terms of service and business conduct, which advocate transparency and trust and inspire fair competition [3].

3. The SHAPES Marketplace

The SHAPES Marketplace serves as a one-stop-shop for digital solutions and services targeting the smart and healthy ageing and independent living markets tailored for the Silver Economy. As such, it fosters a transparent expansion of the market offer to a pan-European scale, preventing vendor lock and enhancing the agile competitiveness of the health and care industry in Europe.

Directly connecting demand and supply, the SHAPES Marketplace brings benefits to both parties. For consumers (the demand), the Marketplace presents the benefit of including in a single platform trustworthy, secure and reliable digital that have been carefully chosen and adapted to meet their real needs, sustained by SHAPES's co-creation model, involving users in all stages to learn from their experience and expertise. For industry (the supply), the participation in SHAPES Marketplace provides a window to a large-scale customer base. Industry players in the market, including new entrants, welcome the opportunity of early market entry and access to large new markets at reduced costs, rapidly bridging the gap between product development and European-wide market access. Importantly, they benefit from SHAPES's outreach efforts in building reputation, trust and a support community, the SHAPES community.

3.1. Building the SHAPES Marketplace

The SHAPES Marketplace was attentively co-created with SHAPES end-users and key stakeholders, namely older adults across Europe and the SHAPES partners, including organisations representing older individuals and citizens with disabilities, health and social care providers, healthcare authorities, social science researchers and software developers, in order to empower older adults to fully participate in society. Design, development and validation of the SHAPES Marketplace were completed over the course of twenty-two months, using a co-creation methodology, involving focus groups, workshops and requirements elicitation, to ensure a collaborative innovation outcome.

Inclusive and universal design approaches were considered and the registration, search, purchase and rating processes were defined to facilitate navigation and user experience. Aside from attractive styling, the Marketplace's design was thought to maximise cultural acceptance and adequacy to its purpose (support healthy ageing) and context (health and care for older adults), delivering user-friendly and intuitive navigation through a plethora of person-centred digital solutions and services that support healthy ageing and independent living and forsake the "one size fits all" principle. Priority was applied to the digital accessibility needs and requirements of individuals with disabilities, abiding to the right to "seek, receive and impart information and ideas on an equal basis with others" stated in the CRPD [4]. Further, the SHAPES Marketplace dedicated a special attention to privacy and the protection of personal data [5], implementing rigorous security access policies and robust authentication and authorisation protocols, supporting user verification and cybersecurity measures.

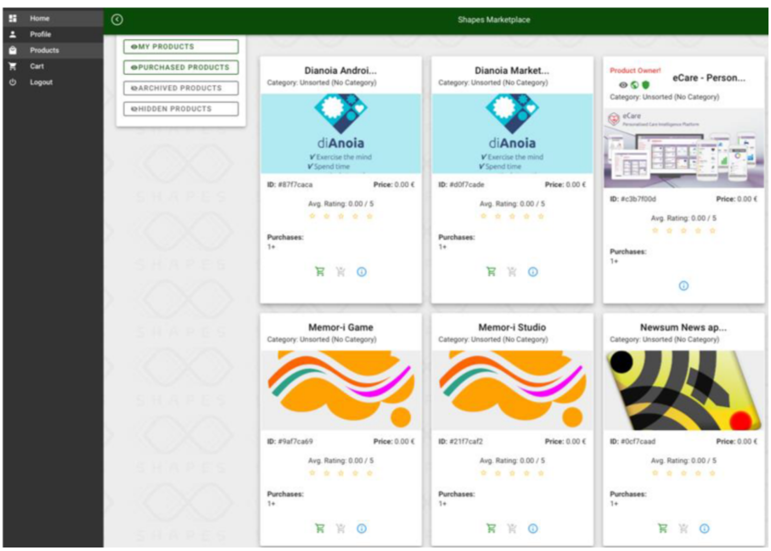

Figure 1. The SHAPES Marketplace products page.

The SHAPES Marketplace adopted open and widely used technologies to satisfy the applicable SHAPES user requirements, including accessibility requirements. Specific marketplace functionalities were organised in five customer-related use cases [6]: **Add a Product/Service**: Suppliers may add a product or a service to the marketplace, providing relevant information such as name, category, tags, description and images;

Update a Product/Service: Suppliers may update information about their products and services, including product documentation, prices, images, videos and licensing details; **Purchase Products/Services**: Customers may purchase products or services through a validated customer account, selecting and adding products to the cart and completing the purchase through the payment facility; **Engage Customers**: After purchasing a solution or service, customers may provide a review based on a 5-star grading system and leave a written comment. These ratings are reviews are accessible to all marketplace users; and **Approve Products/Services**: New or updated products or services in the SHAPES Marketplace must be approved by an administrator. Upon the approval, the product is added to the SHAPES Marketplace's product list, making it eligible for purchase. This mechanism safeguards the Marketplace against undesired or malicious actions.

Over time, the SHAPES Marketplace welcomed dozens of health and care digital solutions and services from device manufacturers and digital solutions providers, fostering a transparent expansion of the offer to the healthy ageing market.

3.2. Transparency, Trust and Fair Competition in the Healthy Ageing Market

The SHAPES Marketplace enables a broader and inclusive access to high-quality, accessible, affordable and available health and care digital solutions for older adults. It attentively selects the solutions that assure a direct involvement of end-users in their design, development and validation processes, as a first step to achieve customer trust in the Marketplace's offer. Following the alignment with true end-user needs, requirements and expectations, quality assurance is further bolstered by the solutions' adherence to prevailing standards, guidelines and regulations, as well by the suppliers' adoption of the SHAPES terms of service and ethical business conduct, rules that consolidate the trust-building process. Hence, the selection of suppliers and their digital solutions to be part of the SHAPES Marketplace serves a "seal of approval" that highlights the suppliers' reputation and the solutions' high-quality and trustworthiness, supporting consumers in understanding the market and making informed choices and purchases.

Important to the foundation of transparency in SHAPES pan-European networked community and Marketplace is the SHAPES governance model. Networks are formal but agile constructs comprising individuals or institutions from the public, private and third sector who collaborate to achieve a common goal [7, 8]. Successful networks rely on continuous collaboration and dialogue, social capital, norms and trust [9] to reconcile differing "objectives, values and priorities" [10]. SHAPES will be governed by a network administrative organisation governance model, a hybrid form of a self-governed network and a lead organisation governance network that ensures coordination and monitoring by an administrative entity responsible for operational decisions and a board of directors (network members), responsible for strategic decisions. The SHAPES governance model rests on a core set of values and principles that are consensus orientation, rule of law, transparency, accountability, responsiveness, strategic vision, equity and inclusiveness, participation, effectiveness and efficiency and sound ethical conduct [11].

By encouraging transparency of information and compliance to rules of conduct, the SHAPES Marketplace upholds fairness as a mechanism to increase long-term value for both sellers and buyers, based on quality, price and service. In this context, it endeavours to balance a stable and consistent capacity of supply and demand, ensuring adequate local access to a global and diversified offer that also enables consumers to entertain bespoke approaches, placing individual orders with local suppliers and improve the local economy dynamics [12]. The commitment is to deliver trustworthy health and care digital solutions and services across different (high, mid and low value) market segments and geographies. Importantly, the SHAPES Marketplace advocates affordability in that the pricing is attractive, accessible and cost-effective to consumers, while also enabling suppliers to reduce marketing and transaction costs and pursue innovation, the fundamental driver of continuous quality improvement and cost reduction [13, 14].

As a result, the SHAPES Marketplace tackles shortcomings such as the poor visibility of existing demand, the fragmentation of available offer and the absence of quality standards to support robust procurement, through the sharing of information and benchmarking on health and care solutions' characteristics, price, quality, performance, benefits and impact. Overall, the transparency brought to demand and supply encourages the participation in the SHAPES Marketplace, revitalising trust and fair competition.

3.3. A Market Shaping Strategy for the SHAPES Marketplace

The SHAPES Marketplace leverages a significant amount of know-how, knowledge, co-creation experience and digital innovations produced as part of the SHAPES Project to join capabilities, resources and the community to nurture healthy ageing and reshape the market. It is the conviction of the SHAPES partners that the SHAPES Marketplace contributes to setup a well-functioning market, encouraging suppliers to provide high-quality innovative health and care digital solutions and services for older adults, that truly meet and satisfy their current and emerging needs, while upholding affordability. As SHAPES improves the levels of health and digital literacy, targeted consumers are aware, informed, educated and empowered to act as custodians of their own health and care.

The SHAPES Marketplace thus benefits from a systems-thinking approach [15] that frames the market shaping effort of all SHAPES partners in overcoming issues and constraints and in better aligning incentives across all stakeholders in the market. This approach is illustrated by the SMART Thinking Matrix (Figure 2), characterising a well-functioning market as one where the buyer experiences a wide range of affordable user-centred products and services and the seller benefits from the interoperability across the different market sectors to avoid fragmentation [16].

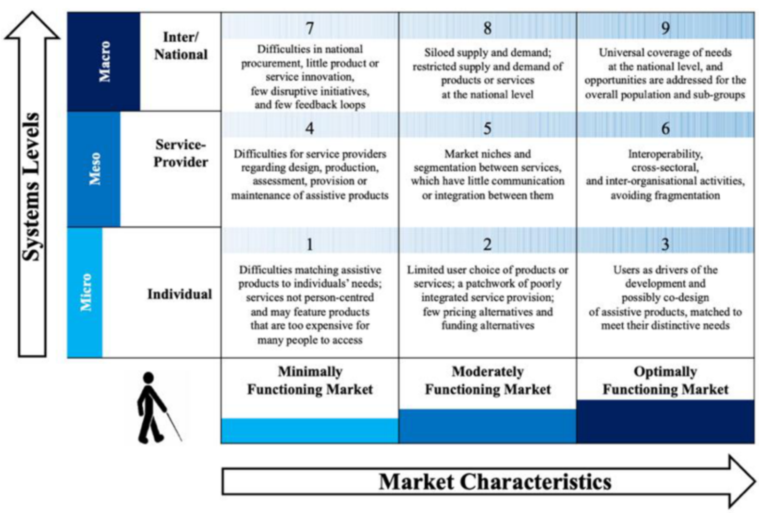

Figure 2. SHAPES SMART Thinking Matrix. Source [16]

Indeed, successful market shaping initiatives - those achieving socially relevant outcomes - typically address the reduction of transaction costs (market integration and interaction), the increase of market information (improve visibility, transparency and trust levels in the market) and/or the balance of supplier and consumer risks (sharing of risks encourages active market participation) [17, 18]. Through the SHAPES Marketplace, prevailing transaction costs decrease, as a result of the consolidated supply and demand in a one-stop-shop with ample market visibility and easy-to-use purchasing mechanisms that facilitate market access for all players. Further, the Marketplace's transparency policy leverages the available market information on the demand (needs, characteristics, patterns) and the supply (specifications, price, quality, performance, benefits and impact), fostering predictability, improved planning and stable prices, thus promoting higher levels of acceptance and trust among suppliers and consumers. Finally, it is possible to sustain a balance of (financial) risks for suppliers and consumers, as the Marketplace encourages active market participation based on purchasing and delivery commitments (no erratic procurements and no late payments), while upholding ethically-sound terms of service and business conduct.

In SHAPES, market shaping efforts involves the active engagement of the SHAPES community (policy- and decision-makers, service providers and end-users) on a long-term commitment to foster the sustainability of the SHAPES Marketplace by bringing together suppliers and customers to consolidate existing and forecast supply and demand, deliver visibility to support informed decision-making and investments, strengthen acquisition, set affordable pricing and improve information sharing on the characteristics, quality, price and efficacy of available health and care digital solutions supporting healthy ageing, independent living and ageing at place [19]. In addition, information, education and communication campaigns generate awareness and knowledge about the need, importance and impact of health and care digital solutions, training end-users on the appropriate use of these innovations and educating policy-makers on healthy ageing priorities, sustainable funding models and the SHAPES Marketplace.

4. Conclusion

Linking demand and supply in an omnichannel, the SHAPES Marketplace already aggregates more than forty health and care digital solutions and provides access to a considerable amount of know-how and knowledge on European health and care systems and the experiences of older adults' lifeworld across Europe. The Marketplace also delivers real-world data on the health, care and quality of life of an ageing population across Europe, basing its analysis on data from the European Health Interview Survey. Embracing a more competitive and efficient market, the SHAPES Marketplace addresses existing market barriers and challenges by:

- Contributing to viable and sustainable policies supporting healthy ageing, independent living and ageing at place, by promoting the adoption and use of appropriate, accessible, affordable, scalable and sustainable person-centred health and care digital solutions;
- Facilitating the procurement and acquisition of health and care digital solutions for older adults by providing the SHAPES Marketplace as a one-stop-shop delivering trusted high-quality, accessible, affordable and available digital solutions, tools, technologies and services;

- Providing informational resources and datasets associated with healthy ageing, independent living and ageing at place in order to improve the levels of health and digital literacy and the awareness towards the Silver Society themes.

The SHAPES Marketplace promotes the widespread adoption and uptake of health and care digital solutions for older adults across Europe and engages a community of suppliers and consumers in specific care procurement and care delivery commitments that yield economies of scale, while preserving transparency, trust and fair competition. Influencing innovation, regulations and policy, the SHAPES Marketplace has the potential to enact change on the delivery of care to ageing communities and to contribute to a more universal, democratic and inclusive access to health and care in Europe.

References

[1] Seidel K, *et al.* Implementation of a pan-European ecosystem and an interoperable platform for Smart and Healthy Ageing in Europe: An Innovation Action research protocol [awaiting peer review]. Open Res Europe 2022;2:85. Available from: https://doi.org/10.12688/openreseurope.14827.1.
[2] European Union. Communication on enabling the digital transformation of health and care in the Digital Single Market; empowering citizens and building a healthier society. 2018; SWD 126 final.
[3] European Union. Communication on the Mid-Term Review on the implementation of the Digital Single Market Strategy A Connected Digital Single Market for All. 2017; COM 228 final.
[4] United Nations. Convention on the Rights of Persons with Disabilities. 2016.
[5] European Union. Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (GDPR). Available from: https://eur-lex.europa.eu/eli/reg/2016/679/oj.
[6] The SHAPES Consortium. SHAPES Marketplace. D7.4. April 2023.
[7] Kapucu N, Hu Q. Network governance: Concepts, theories, and applications. 2020. Routledge.
[8] Provan KG, Kenis P. Modes of network governance: Structure, management, and effectiveness. Journal of Public Administration Research and Theory. 2007;18(2):229–252. Available from: https://doi.org/10.1093/jopart/mum015.
[9] Labor M, *et al*. Mechanisms for the Participatory Governance of Technologically-Mediated Health and Social Care. AAATE 2023; Conference Proceedings. Forthcoming.
[10] World Health Organisation. Smart governance for health and well-being: The evidence. 2014. p. 17.
[11] Barbazza E, Tello JE. A review of health governance: definitions, dimensions and tools to govern. Health Policy. 2014 May;116(1):1-11. doi: 10.1016/j.healthpol.2014.01.007.
[12] The SHAPES Consortium. SHAPES Market Analysis and Strategy Definition. D7.1. April 2023.
[13] Møllgaard P, Overgaard P. Market transparency and competition policy, Working paper, Copenhagen Business School, Department of Economics, Frederiksberg, 2001;6. Available from: https://hdl.handle.net/10398/7567.
[14] Rivers P, Glover S. Health care competition, strategic mission, and patient satisfaction: research model and propositions. J Health Organ Manag. 2008;22(6):627–641.
[15] MacLachlan M, Scherer MJ. Systems thinking for assistive technology: a commentary on the GREAT summit. Disability and Rehabilitation: Assistive Technology, 2018;13(5): 492-496. doi: 10.1080/17483107.2018.1472306.
[16] MacLachlan M, *et al.* Intersections between systems thinking and market shaping for assistive technology: The SMART (Systems-Market for Assistive and Related Technologies) thinking matrix. International Journal of Environmental Research and Public Health, 2018;15(12):2627. doi: https://doi.org/10.3390/ijerph15122627.
[17] Holloway C, *et al*. A review of innovation strategies and processes to improve access to AT: Looking ahead to open innovation ecosystems. Assistive Technology, 2021;33:sup1, p. 68-86. doi: 10.1080/10400435.2021.1970653.
[18] Savage M, *et al*. Applying market shaping approaches to increase access to assistive technology in low- and middle-income countries. Assistive Technology, 2021;33:sup1, p. 124-135, doi: 10.1080/10400435.2021.1991050.
[19] World Health Organisation. Global strategy on digital health 2020-2025. 2021. Licence: CC BY-NC-SA 3.0 IGO.

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A Study on Standard for Safety Requirements for Care Robots

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Abstract. Recently, care robots are being developed that incorporate robotics into assistive products that focus on daily care for the physically disabled or elderly with reduced physical function. However, although care robots can reduce the physical burden of human intervention, they can also be dangerous depending on their situational awareness. This study describes a standardization that defines safety requirements for care robots and includes verification methods to test their safety requirements. As an example of the application of this standard, a standard for the safety and performance method of a feeding robot is shown. This standardization study is expected to contribute to the spread of care robots in the future.

Keywords. Care Robot, safety, standard, requirement

1. Introduction

The classification and terminology of assistive products are addressed explicitly in the ISO 9999 standard [1]. The standard defines an assistive product as "optimizing a person's functioning and reducing disability." In other words, an assistive product can optimize a person's functioning or reduce disability. With the recent development of robotics, many assistive devices are incorporating robotics to improve their functionality. The terms robot and robotics are well-defined in ISO 8373 [2].

A robot is defined as "programmed actuated mechanism with a degree of autonomy to perform locomotion, manipulation or positioning," and robotic technology is defined as "practical application knowledge commonly used in the design of robots or their control systems, especially to raise their degree of autonomy" [2]. Since IEC/TR 60601-4-1 defines a medical robot as a "robot intended to be used as medical electrical equipment or system," an assistive robot can be defined as a "robot intended to be used as an assistive product" [3]. Similarly, a care robot is a "robot intended to be used for caring persons with disability or elderly persons."

These care robots are intended to support the care, nursing, and physical activities of the care recipient, easing the burden of caregiving, and improving the quality of life of the elderly or disabled and their families. The care robots are developed around basic activities such as Feeding, Personal toileting, Hoist, and Posture-changeable robots.

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However, there are still no clear definitions, products classifications, and safety standards for care robots, so their dissemination has many difficulties.

In this study, we propose a standard that defines safety requirements specific to care robots and includes verification methods to test safety based on the safety requirements. As an example of applying this standard, we show a standard of safety requirements and performance tests for feeding robots.

2. Care robot

2.1. Definition of care robot

Care or care service is defined as "the act of providing physical or mental assistance to the elderly or disabled who have difficulty maintaining daily activities on their own." Thus, a care robot can be defined as "a robot to assist activities of daily living for persons with disability or the elderly who have difficulties in daily life".

2.2. Types of care robots

Care or care service is defined as "the act of providing physical or mental assistance to the elderly or disabled who have difficulty maintaining daily activities on their own." Thus, a care robot can be defined as "a robot to assist activities of daily living for persons with disability or the elderly who have difficulties in daily life" (Figure 1) [4].

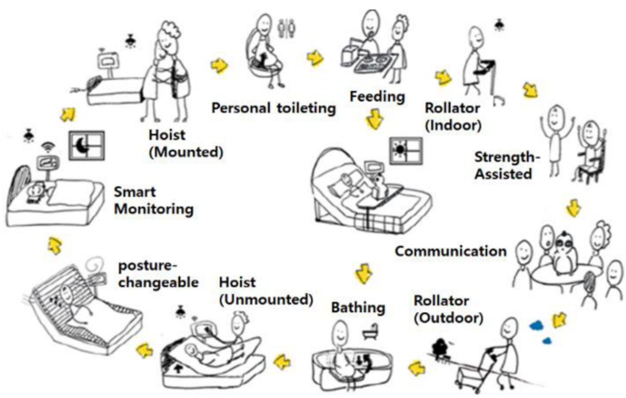

Figure 1. Types of care robots [4].

3. Safety standards for care robots

ISO 8373 defines a robot as "programmed actuated mechanism with a degree of autonomy to perform locomotion, manipulation or positioning." Based on this definition, a care robot can be considered a robot as "an assistive device or drive mechanism for daily living with a degree of autonomy." Based on this definition, the necessary safety requirements and tests were investigated, analyzed, and reflected in the standard.

3.1. Structure of care robot standards

The structure of care robot standards is divided into a common (general) safety standard, individual (particular) safety standards, care data standards, and care robot degrees of autonomy. The common safety standard for care robots covers general safety requirements that should be applied to care robots. In contrast, the individual care robot standard covers requirements that are difficult to apply in general in consideration of the characteristics of individual care robots and must be considered for each item. The care data standard and the care robot degree of autonomy standard are separate standards that can be referenced for care robots [Fig2].

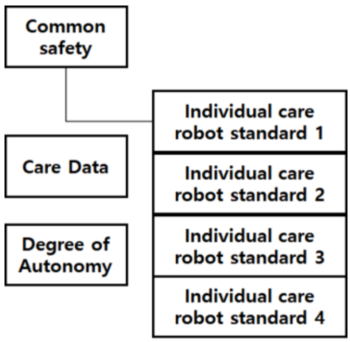

Figure 2. Hierarchy of care robot standards.

3.2. General requirements

For risk analysis and management of care robots, the procedures of ISO 14971 or ISO 12100 are applied [5,6]. In addition, for care robots classified as medical devices, IEC 62366-1 is used to identify hazardous situations [7], and for care robots with embedded programs, IEC 62304 is used [8]. In particular, for care robots with degree of autonomy, the loss of the user's situational awareness is considered a hazard [9].

Multifunctional care robots with two or more functions must meet the safety and performance requirements in individual standards according to the primary function proposed by the manufacturer. Functions other than the primary function shall be classified as minor and meet common safety requirements.

If the care robot supports wired and wireless communication (Wi-Fi, Bluetooth, USB, RS-232, LAN, etc.), it must be designed for availability, confidentiality, and integrity within the risk management process.

3.3. Safety requirements for care robots

Safety requirements are categorized into electrical safety, mechanical safety, cleaning and disinfection, environmental factors, and hazardous materials.

Electrical safety is required to comply with national safety certification requirements. If there are no national safety certification requirements, at least meet the requirements for leakage current, withstand voltage, and over temperature. In addition, built-in batteries, emergency stop, protectives stop, and electronics compatibility are required [Table 1]. Mechanical safety requirements are provided for the structure, pinching, squeezing, and restraint to ensure that the user of the care robot is not at risk of mechanical harm.

Requirements for hazardous substances are provided for parts of the robot that come into contact with the human body. The allowable values of hazardous substances are based on the Korean certification (KC) standard for children's products [10].

To prevent harm from noise, the standard requires a maximum noise level of no more than 50 dB in sleeping environments, 65 dB indoors, and 85 dB outdoors. In addition, the standard requires classification for water resistance according to IEC 60529 [9].

Table 1. Electrical Safety Requirements for care robots

Item	Requirements
Built-in battery	- Care bots that use batteries must have a battery status indicator. In addition, all circuits connected to the battery must be protected against overcurrent for user safety. - The internal battery must meet the following requirements a) Batteries must not ignite, explode, or leak while using the robot. b) All batteries must be completely sealed. If there are exposed terminals, they must be of opposite polarity and spaced at least 6 mm apart. c) Battery terminals and connections must be sealed to prevent short circuits. d) Lithium-ion batteries must meet IEC 62133-2 [15].
Emergency stop	- The care robot shall be equipped with one or more emergency stop devices, and the emergency stop shall meet the following requirements a) The emergency stop device must reduce the risk to an acceptable level. b) The E-Stop device must be easily accessible to the user. c) The E-STOP device must be colored red. d) The E-STOP device shall be marked on or near its surface with the symbol IEC 60417-5638 or the word STOP [16]. e) Once activated, the emergency stop device shall remain stationary until a user action is taken to restart it.
Protection stop	- The care robot shall have a protective stop function if required by risk management. The protective stop function shall comply with the following requirements a) The protective stop must reduce the risk to an acceptable level. b) A program embedded in the care robot must automatically restart the protective stop. However, the user must initiate the restart manually if the automatic restart poses an unacceptable risk.

4. Example of feeding robot

This section introduces the individual requirements of a feeding robot. The shape of a feeding robot is shown in Fig 3. The safety of the feeding robot is further tested for impact energy, static load, and repetitive durability. The performance of the feeding robot is further evaluated through pose accuracy (ISO 9283) [11], continuous use time, and feeding assistance success rate.

Figure 3. Feeding Robot.

5. Conclusion

Recently, various research projects on care robots have been started and are in progress. However, due to the lack of relevant standards, there may be problems with the steps for licensing or certification for future productization. Therefore, we developed a standard for safety requirements for care robots in this study.

The requirements for electrical safety and mechanical safety, which are safety requirements for medical devices, were investigated and applied. The mechanical risk factors defined by robots were additionally reflected by referring to ISO 13482. In addition, since care robots use robotics and the primary users are non-experts, the risk of situational awareness loss was considered by referring to IEC 80601-2-78, an international standard for rehabilitation robots, and cybersecurity was also added. Performance issues will be addressed in individual standards for care robots to be developed in the future.

In a situation where standardization of safety evaluation of care robots is actively needed, it is expected that securing product safety and consumer trust through normal development will be very important for the successful settlement and expansion of the care robot industry. Furthermore, the developed standards can be used for licensing and establishing policies for care robots, and manufacturers will be able to ensure safety in the development stage of care robots.

The addition of robot and robot technology definitions, automatic toileting systems, power assist units for assistive products for walking, and feeding robots to ISO 9999 has paved the way for developing and institutionalizing international standards for care robots. Therefore, it can be promoted as an international standard based on the current standards. In addition, we will also develop standards for individual care robot items so that care robots currently under development can be released to the market with guaranteed safety and performance.

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References

[1] ISO 9999:2022, Assistive products - Classification and terminology.
[2] ISO 8373:2021, Robots and robotic devices - Vocabulary.
[3] IEC/TR 60601-4-1:2017, Medical electrical equipment - Part 4-1: Guidance and interpretation - Medical electrical equipment and medical electrical systems employing a degree of autonomy.
[4] Song, WK, Kwon, SC, and Ahn, GO. Research on planning to establish a foundation for care services including robot technology. Korea: National Rehabilitation Center; 2018. p. 13.
[5] ISO 14971:2019, Medical devices - Application of risk management to medical devices.
[6] ISO 12100:2010, Safety of machinery - General principles for design - Risk assessment and risk reduction.
[7] IEC 62366-1:2015 Medical devices - Part 1: Application of usability engineering to medical devices.
[8] IEC 62304:2006+AMD1:2015 Medical device software - Software life cycle processes.
[9] IEC 60529:1989/AMD2:2013/COR1:2019, Degrees of protection provided by enclosures (IP Code).
[10] Korean Agency for Technology and Standards, Special Act on The Safety of Children's Products, Annex 6 (Toys-21.7.1), 2022. Available from: https://www.kats.go.kr/content.do?cmsid=530&mode= view&page=&cid=22221
[11] ISO 9283:1998 Manipulating industrial robots-Performance criteria and related test methods.

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Exploring the Potential of Conversational Interfaces for Care of Older Adults: Insights from Stakeholder Workshops

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Abstract. This study aimed to explore the utilisation of conversational interfaces (CIs) by local care service providers (CSPs) and their potential applications in improving the quality of life for older adults. Two workshops were conducted with stakeholders to gather insights and requirements. Although currently not yet utilised by CSPs, stakeholders expressed their openness towards CIs and believed that older adults are very likely to appear receptive to them. Loneliness and isolation were identified as significant challenges, even among older adults living in care institutions. Key requirements for chatbots included complementarity to in-person interactions, user-friendliness, 24/7 availability, and seamless integration into daily life. Ethical considerations, data privacy, and security were emphasised, also highlighting the importance of transparency and limited data retention. Various use cases were discussed, such as assistance, self-management tools, and reminders. The financing issues remained inconclusive, but health insurances showed their potential interest in solutions targeting loneliness.

Keywords. AAL, Active Assisted Living, conversational interface, user interface, chatbot, older adults, technology acceptance

1. Introduction

Conversational interfaces (CIs) have a long history, dating back to the 1960s with the development of ELIZA, a computer program for natural language communication between humans and machines [1]. However, it is only in recent years that CIs, in the form of chatbots, have gained widespread attention and adoption, thanks to significant advancements in machine learning and artificial intelligence, particularly in the field of natural language processing [2] [3] [4] [5]. These advancements have greatly improved

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the capabilities of CIs, enabling more natural and human-like interactions. By leveraging chatbot technology, healthcare professionals and caregivers can provide personalised and accessible support to older adults, addressing their needs and concerns in a timely manner. CIs are being utilised as virtual companions, assisting in everyday tasks, providing mental health support, facilitating behaviour change, and promoting overall well-being [6] [7] [8] [9] [10] [11] [12] [13].

In light of these advancements and potential benefits, it is essential to explore the various applications and requirements of CIs in healthcare for older adults. This research aims to shed light on the topic by conducting workshops and engaging with stakeholders who are interested in utilising CIs to improve the well-being of older adults. By understanding the perspectives and needs of these stakeholders, effective strategies for the implementation of CIs can be identified in healthcare settings and contribute to the ongoing efforts in enhancing the quality of life for older adults. To gain a better understanding of potential CIs in use, which applications care service providers (CSPs) are interested in, and what requirements exist, two workshops were conducted with representative stakeholders. The workshops implementation and their outcomes are presented in the following sections.

2. Methodology

To gather insights on the use of CIs in CSPs business environments, a stakeholder group was invited to participate in two user-centered design workshops, each lasting for two hours. The workshops followed the world-café method, which encourages group discussions and peer-to-peer knowledge-sharing [14] [15]. Before the workshops, conversation starters and various introductory questions were prepared and shared with the stakeholders to guide and structure the discussions. All conversations were held in the local language (German). Notes written by the participants, as well as written logs about the conversations were collected during the workshops.

The stakeholder group consisted of:

- Chief operating officer (female) of a local assistance and care service provider with 820 institutionalised care places and over 200 apartments. The company employs more than 1,000 people.
- Chief executive of a local association (male) for ambulant assistance and care services, consisting of counselling, treatment care, basic care, evening/night care, meals on wheels, psychiatric care, housekeeping, family support, etc. The tasks are covered by more than 100 employees who made more than 100,000 visits to clients at home in 2021.
- A representative of a local association (male), which fosters a resource-oriented old-age policy and the active participation of the generation of 60 years and older. Among other activities, they are utilising their Office for Older Person Affairs to contribute to the age policy of their city.
- A lecturer (female) in the domain of social work and law, specialised in social work (mental disorders, addiction) and counselling methodology in social work and person-centred dialogue.
- A lecturer (female) from the domain for rehabilitation and healthy ageing.

The last participant was not present during the first workshop. All stakeholders were recruited from the contact network of the project team and all stakeholders offered their time without charge.

3. Results

Although all stakeholders indicated that they are rather open to the idea of utilising CIs, none of the stakeholders were using them in their professional environment. While there could be several potential applications assisting the professional caregivers, all workshop stakeholders were mainly focused on the question of how CIs could be used to improve the quality of life of older adults. The shared opinion is that nowadays many older adults are open to CIs. Their estimation was that currently 4 out of 10 older adults would already show their acceptance towards chatbots, and they were also convinced that the acceptance rate is expected to increase over time.

Among the concerns and needs, isolation or loneliness were ranked as a major challenge. It was pointed out that even older adults living in care institutions often find themselves stricken from loneliness. Therefore, they indicated that CIs addressing loneliness could be an attractive avenue.

As a result, based on the stakeholder inputs during the two user-centered design workshops, the view of potential and requirements of chatbots can be summarised as follows:

a) Chatbots represent a highly promising complement to in-person interactions, rather than a complete replacement.
b) Chatbots can be utilised at home or in other settings.
c) Chatbots offer round-the-clock availability.
d) The threshold for seeking assistance from a chatbot is lower compared to asking a real person for help.
e) The implementation of chatbots should incorporate playful elements to ensure engagement and avoid monotony.
f) Chatbots should possess an intuitive and user-friendly interface, keeping simplicity as a priority.
g) Voice interfaces are attractive, when reliable enough.
h) The inclusion of the local language and in dialect is crucial for effective expression of emotions.
i) Older adults should be able to seamlessly integrate chatbot usage into their daily lives.
j) It is important to distinguish between individuals who are oriented and those who may require support as their cognitive abilities decline.
k) The use of a chatbot itself can be considered an intervention.

The workshop participants identified ethics and data privacy as important aspects to consider, or to derive requirements from. In summary the focus was laid on the following:

l) Scepticism may be expressed by individuals when it comes to sharing their personal data.
m) Comprehensive information about ethical considerations related to chatbot usage should be provided to older adults.
n) Emphasis should be placed on transparency regarding data usage.
o) Privacy should be ensured by clarifying who has access to data.
p) Robust measures for data security and cyber security should be implemented.
q) The option for users to delete their history or profile should be provided.
r) Data should be stored for a limited period of time.

When the participants discussed potential use cases, the following have been mentioned:

s) Games
t) Tests
    - dementia assessment game
    - assessment support to determine self-care abilities.
u) Assistance
    - conversations
    - proactive companion for older adults
    - supplement for cognitive-behavioural therapy (not psychoanalysis)
    - support in everyday life (rather than ambitious therapy)
    - feedback in everyday life
v) Self-management tool
    - daily positive moments diary (capturing delightful/surprising moments)
    - interactive mood diary - app detects worsening situations (like a "health app")
    - providing information about good times during difficult periods
    - future-oriented events: Prompting users to plan and share positive events in the next three days.
w) Reminders
    - cherished memories (possibly through photos)
    - for medication/therapy appointments, with input from relatives/professionals.
    - trivial reminders (e.g., watering plants, taking medication)

The conversation on who would finance the operation of such CIs was inconclusive. However, it was agreed that institutions and organisations would only buy such a system when a clear impact on their business can be measured. Moreover, it was assumed that health insurances would be very interested in obtaining a tool that could help to combat loneliness.

4. Discussion

The estimation of CIs acceptance (4 out of 10) by the workshop participants must be analysed and compared to other findings in literature. In a previous study [16] , adults over 60 years of age were asked about a chatbot for health data collection, usability and satisfaction and reported relatively high perceived ease-of-use (5.8/7), usefulness (4.7/7), and usability (5.4/7). These positive earlier findings are consistent with our conclusions from the workshop and may indicate a cautious assessment by the workshop participants. However, it is important to consider the fact that older adults who are institutionalised are generally no longer able to meet the demands of daily living. Therefore, there may be a bias in our workshop data towards a larger proportion of older adults with severe limitations, such as those suffering from dementia, who may have difficulty expressing themselves. This view is represented in item “j)”. The user interface must be adapted to the needs of the user.

Another requirement related to the user interface is the usage of simple language (“f), h)”) and being of a playful nature (“e)”). These aspects are in line with the results of other publications [17] [18] [19]. Among other requirements, the latter publication also emphasises the value of lowering initial barriers, which was also identified as a potential of the technology by the workshop participants (see “d)”).

In the beginning of the workshop, the participants pointed out that even among institutionalised clients, loneliness is a major problem. One expectation is that chatbots could be part of a solution by becoming an intervention themselves (“k)”). This could be realised in various ways, e.g., by offering games (“s)”) or as part of assistance (“u)”) in the form of a virtual companion or as a substitute for conversations. The validity of the idea to combat loneliness and isolation by conversational agents is supported by [20].

Although not directly mentioned by the workshop participants, the ability of the chatbot to become a virtual companion, or to react in an empathic way when emotional support shall be provided, derives a further requirement: it is to be expected that acceptance will be increased if the chatbot becomes more empathetic. This challenge could be tackled by utilisation of such technologies like sentiment analysis and affective computing [21].

The potential value of CIs for such use cases as supplement for cognitive-behavioural therapy, especially for mental health and depression support, has been demonstrated in [22] [23].

5. Conclusion

Stakeholders are open to utilising CIs to improve the quality of life for older adults. Although none of the stakeholders currently use CIs in their professional environments yet, they believe many older adults are already receptive to them, and even more end-users are expected to open up in the coming years. Loneliness and isolation were identified as major challenges, even among older adults living in care institutions. Key requirements for chatbots include being complementary to in-person interactions, user-friendly with playful elements, available round-the-clock, and capable of seamless integration into daily life. Ethics, data privacy, and security are important considerations, emphasising transparency, privacy, and limited data retention. Potential use cases include games, assessments, assistance, self-management tools, and reminders. Financing remains rather inconclusive, but health insurances may be already interested in tools that address loneliness.

To make the idea of a smart diary a reality, it will be implemented and validated in the near future. The smart diary will combine the advantages of the highly regarded “6 min diary” [24] with an innovative reminder feature. Although there is a potential for similar concepts in the field of CIs applications, we are aware that there are also technical challenges to overcome, such as emotion recognition and dialogue management. In addition, the business cases that ensure economic viability need to be further refined.

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References

[1] Weizenbaum J. ELIZA-a computer program for the study of natural language communication between man and machine. Communications of the ACM. 1966;9:36–45.

[2] Rapp A, Curti L, Boldi A. The human side of human-chatbot interaction: A systematic literature review of ten years of research on text-based chatbots. International Journal of Human-Computer Studies. 2021;151:102630.

[3] Ram A, Prasad R, Khatri C, Venkatesh A, Gabriel R, Liu Q, Nunn J, Hedayatnia B, Cheng M, Nagar A, et al. Conversational ai: The science behind the alexa prize. arXiv preprint arXiv:1801.03604, 2018.

[4] Caldarini G, Jaf S, McGarry K. A Literature Survey of Recent Advances in Chatbots. Information. Jan 2022;13:41.

[5] Abdul-Kader SA, Woods JC. Survey on chatbot design techniques in speech conversation systems. International Journal of Advanced Computer Science and Applications. 2015;6.

[6] Abd-Alrazaq AA, Rababeh A, Alajlani M, Bewick BM and Househ M. Effectiveness and safety of using chatbots to improve mental health: systematic review and meta-analysis. Journal of medical Internet research. 2020;22:e16021.

[7] Gentner T, Neitzel T, Schulze J, Buettner R. A Systematic Literature Review of Medical Chatbot Research from a Behavior Change Perspective. In: 44th IEEE Annual Computers, Software and Applications Conference (COMPSAC). 2020.

[8] Mathur P, Khanna A, Cywinski J, Maheshwari K, Papay F, McCoy L, Naylor A, Burns M, Guha A, Khare A, Singh G, Reddy S, Cha J, Anand A, Habboub G, Lee J, Thomas J, Tiwari A, Mummadi S, Vachon T. Artificial Intelligence in Healthcare: 2020 Year in Review, 2021.

[9] Miner AS, Laranjo L, Kocaballi AB, Chatbots in the fight against the COVID-19 pandemic. NPJ digital medicine. 2020;3:65.

[10] Maher CA, Davis CR, Curtis RG, Short CE, Murphy KJ. A Physical Activity and Diet Program Delivered by Artificially Intelligent Virtual Health Coach: Proof-of-Concept Study. JMIR Mhealth Uhealth. Jul 2020;8: e17558.

[11] Iancu I, Iancu B. Interacting with chatbots later in life: A technology acceptance perspective in COVID-19 pandemic situation. Front Psychol. Jan 2023;13:1111003.

[12] Lu G, Kubli M, Moist R, Zhang X, Li N, Gächter I, Wozniak T, Fleck M. Tough Times, Extraordinary Care: A Critical Assessment of Chatbot-Based Digital Mental Healthcare Solutions for Older Persons to Fight Against Pandemics Like COVID-19. In: Proc. of Sixth International Congress on Information and Communication Technology, Singapore, 2022.

[13] Stieger M, Allemand M, Lachman ME. Effects of a digital self-control intervention to increase physical activity in middle-aged adults. Journal of Health Psychology. 2023;0:13591053231166756.

[14] Löhr K, Weinhardt M, Sieber S. The “World Café” as a participatory method for collecting qualitative data. International journal of qualitative methods. 2020;19:1609406920916976.

[15] Schiele H, Krummaker S, Hoffmann P, Kowalski R. The “research world café” as method of scientific enquiry: Combining rigor with relevance and speed. Journal of Business Research. 2022;140:280-296.

[16] Wilczewski H, Soni H, Ivanova J, Ong T, Barrera JF, Bunnell BE, Welch BM. Older adults' experience with virtual conversational agents for health data collection. Frontiers in Digital Health. 2023;5.

[17] Weber P, Mahmood F, Ahmadi M, von Jan V, Ludwig T, Wieching R, Fridolin: participatory design and evaluation of a nutrition chatbot for older adults. i-com. 2023;22:33-51.

[18] Fadhil A, Schiavo G. Designing for Health Chatbots. CoRR. 2019;abs/1902.09022.

[19] Ryu H, Kim S, Kim D, Han S, Lee K, Kang Y. Simple and Steady Interactions Win the Healthy Mentality: Designing a Chatbot Service for the Elderly. Proc. ACM Hum.-Comput. Interact. Oct 2020;4.

[20] Ring L, Barry B, Totzke K, Bickmore T. Addressing Loneliness and Isolation in Older Adults: Proactive Affective Agents Provide Better Support. In: 2013 Humaine Association Conference on Affective Computing and Intelligent Interaction, 2013.

[21] Shum HY, He XD, Li D. From Eliza to XiaoIce: challenges and opportunities with social chatbots. Frontiers of Information Technology & Electronic Engineering 2018;19:10-26.

[22] Sweeney C, Potts C, Ennis E, Bond R, Mulvenna MD, O’Neill S, Malcolm M, Kuosmanen L, Kostenius C, Vakaloudis A, Mcconvey G, Turkington R, Hanna D, Nieminen H, Vartiainen AK, Robertson A, Mctear MF. Can Chatbots Help Support a Person’s Mental Health? Perceptions and Views from Mental Healthcare Professionals and Experts. ACM Trans. Comput. Healthcare. Jul 2021;2.

[23] Kaywan P, Ahmed K, Ibaida A, Miao Y, Gu B. Early detection of depression using a conversational AI bot: A non-clinical trial. PLoS ONE. 2023;18(2):1-27.

[24] Lorenz T, Algner M, Binder B. A positive psychology resource for students? Evaluation of the effectiveness of the 6 minutes diary in a randomized control trial. Frontiers in psychology. 2022;13.

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Smart Nursing: The Use of Technology to Support Homecare Nurses with Their Care of the Elderly

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Abstract. The demand for homecare services is on the rise, while simultaneously there is a shortage of homecare nurses who are burdened with increasingly heavier workloads. The introduction of assistive technologies has the potential to assist elderly individuals as well as (informal) caregivers. This study aims to facilitate nursing care with technology, within the framework of a proper daily structure for elderly people. Initially, a needs assessment was performed with homecare nurses to identify the most relevant daily structure patterns. Subsequently, a prototype comprising of a test setup and a mobile application was developed, followed by a case study involving participation from homecare nurses, informal caregivers, and patients. Both subjective experiences and standardized outcome measures (System Usability Scale, Usefulness Satisfaction and Ease of Use Scale and User Experience Questionnaire) revealed highly positive attitudes towards the test setup and application. Future research endeavours should focus on scaling up the technology and expanding its availability to other caregivers.

Keywords. Assistive technology, sensors, elderly, homecare nursing, daily structure.

1. Introduction

The aging population continues to increase significantly. In the European Union, the number of people aged 75-84 years is projected to expand by 56.1%, while the number aged 65-74 years is projected to increase by 16.6% between 2019 and 2050 [1]. The demand for home care is increasing while at the same time high-quality care is still the main goal of caregivers. Homecare nurses experience very high workloads and stress levels [2, 3]. Furthermore, homecare nurses encounter many difficulties when providing services at home, for instance objective measurements are important for clinical reasoning, but it is often a challenge to gather such data about patients [4].

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Lack of daily structure is a widespread problem for elderly people for whom home care is needed. The implementation of technology in healthcare can support the elderly as well as (informal) care providers. A lot is possible today; technological evolutions are happening at a quick pace [5]. Electronic sensors are becoming more accurate, and processors are becoming faster at a steady rate. This creates opportunities for new applications around IoT-devices (Internet of Things) such as using a smartphone to control lights, keeping track of the contents of the fridge, controlling the thermostat or even operate and manage washing machines remotely. Each of these are technologies that make life easier for people, not only at the level of providing information, but also at the level of assisting. Smart algorithms using artificial intelligence can consequently offer many solutions in healthcare using the data collected by these sensors [6]. Benefits from technology including smart homes have been demonstrated in literature [7], showing improvements in safety and insight in the risk of falling [8] and indoor mobility [9] etc. Assistive technology can lead to more comfort, new healthcare opportunities and more efficiency and quality of care [10, 11].

In general, nurses are positive about new technologies in care. They consider it important that technology contributes to better quality of care. When nurses are involved in the selection and introduction of new technologies, it increases the likelihood that technology will actually be used. Nurses mainly expect these technologies to increase the quality of life and self-reliance of the client, they do not expect an effect on physical strain, workload and attractiveness of the profession. In contrast, nurses do show a fear of losing their jobs due to increased use of technology [12]. However, clinical reasoning by nurses will always remain crucial in care and cannot easily be replaced by technology.

The aim of this study is to facilitate nursing care through the use of technology within the framework of a proper daily structure for elderly people. To achieve this goal, the following questions were formulated:

1) Which are the most relevant daily structure patterns that require monitoring?
2) How can a prototype for stimulating day structure be developed which integrates the most relevant nursing problems and linked interventions? How can nurses access recorded data in a simple and intuitive manner?
3) How do homecare nurses, patients and informal caregivers experience the feasibility of the developed test setup to monitor patients and support them during their daily care?

2. Methods

This study can be divided into three phases. Firstly, in order to acquire a comprehensive understanding of the most significant daily structure patterns, a needs assessment was executed. Secondly, drawing from the findings of the needs assessment, an iterative design process was implemented, leading to the development of a prototype for monitoring daily patterns and an application for straightforward and user-friendly access to recorded data. Finally, a pilot case study was conducted to investigate the feasibility of using the prototype and application in a real-world setting.

2.1. Needs assessment

In a previous study conducted by our research team, a needs assessment was performed among elderly individuals displaying potential signs of dementia and their informal caregivers. The aim was to identify the daily activities that posed the greatest challenges for them. The current study turns its attention to home care nurses, as they play a critical role in supporting these challenging daily activities and hence can offer valuable insights into improving elderly care. One of the goals of this assessment was to investigate the specific needs of homecare nurses in relation to their care for the patients and regarding the visualisation of patient data. However, the patient and informal caregivers remained central throughout all considerations during the project. The needs assessment itself consisted of two parts: an online questionnaire and in-depth interviews.

2.1.1. Participants

Home care nurses were recruited via multiple homecare organisations in the Limburg region of Belgium as well as through a call on social media. The inclusion criterion was to be employed as a nurse in the home care sector working with elderly people. Nurses who indicated in the questionnaire they would like to participate in an in-depth interview were contacted for the interview. The questionnaire was administered between January 2021 and March 2021 after which the interviews were conducted between March 2021 and April 2021. Within these periods the data collection for both the questionnaire and interviews continued until data saturation was reached.

2.1.2. Survey and semi-structured interviews

An online questionnaire was developed containing 33 questions in the following domains: demographic (3 questions), workload (3 questions), technology use (11 questions), patterns of daily structure (13 questions), information processing (3 questions). For the in-depth interviews, an interview guideline was prepared to further investigate the most important patterns related to daily structure. For each pattern it was explored which parameters should be measured, which nursing problems and interventions are related to the pattern and how technology can support them. Furthermore, it was investigated how homecare nurses should receive the information provided by the technology.

2.2. Test setup and application

Following the needs assessment and an analysis of critical patterns and parameters, a comprehensive selection of sensors and technologies was made. Factors of particular importance included: interoperability, affordability (open-source whenever possible) and privacy. The input and feedback from nurses were taken into account to ensure alignment with their requirements and preferences.

To ensure the application in which nurses viewed the patient data was sufficiently user-friendly, an iterative design process was followed in which nurses were closely involved through focus groups. Home care nurses were recruited via the researchers' network and through healthcare organizations. Guidelines were developed to be used during the focus groups in which the first prototype of the test setup and application were shown and discussed. There were two rounds of focus groups, in between which the application prototype was incrementally improved. The focus groups were conducted between March 2022 and May 2022 and continued until data saturation was achieved.

2.3. Case study

For the case study, a close collaboration with the healthcare organization Wit-Gele Kruis Limburg was established. Two patients receiving care from their organization were recruited together with their regular nurses. Inclusion criteria for the patients were: living alone, at home or in an assisted living facility, being over 65 years of age, being able-minded, having an informal caregiver and the presence of one or more potential/current nursing problems according to Gordon's patterns or the Omaha system. To create a simpler and more easily controlled environment, the exclusion criteria were living together or the presence of large pets. For the home care nurses the inclusion criterion was to take care of the included patient and willing to participate in this study.

The test setup was installed and used for 3 consecutive months. Both standardized assessments and semi-structured interviews were performed. For the standardized assessments, the System Usability Scale (SUS), the Usefulness, Satisfaction and Ease of Use scale (USE) and the User Experience Questionnaire (UEQ) were used (filled in by the nurses). The semi-structured interview was conducted with the patient (n=2), informal caregiver and homecare nurses. Interviews were conducted at the start and end of the 3-month period. The SUS, USE and UEQ were taken at the end of the 3-month period. Every week, the nurses and informal caregivers were contacted by telephone to ask about their experiences and answer questions.

2.4. Ethical considerations

This study was approved by the Medical Ethical committee of Hasselt University. All participants have been informed both orally and in writing and have signed an informed consent document.

3. Results

3.1. Needs assessment

For the needs assessment the online questionnaire was completed by 143 homecare nurses, of which 6 homecare nurses participated in the in depth-interview. The mean age was 49.5 years with 66% having over 10 years of working experience. The homecare nurses' workload can be considered fairly high as on average (across 140 nurses) a score of 7 out of 10 was given (with 10 being the highest conceivable workload). Attitudes towards technology were positive in 60%, and negative in 8% of the homecare nurses. Out of several metrics of interest, the sleep and rest pattern was perceived to be the most important, followed by diet and metabolism, activity, health perceptions/maintenance, and cognition/perception. Over 86% of the homecare nurses indicated that the electronic patient file is the preferred channel for receiving information from technology, while 37% also consider an application on a smartphone or tablet to be a good way.

3.2. Test setup and application

3.2.1. Test setup

Based on the needs assessment, the sleep and resting and activity pattern were selected as focus for the test setup. A diverse mix of moderately affordable sensors were selected that were for the most part easily available on the commercial market. Clients and their living quarters were equipped with the following technologies: a smart watch (measuring steps, heart rate and sleeping pattern), a sleeping mat (measuring sleep and breathing pattern), a smart scale, movement sensors, door sensors (front door, refrigerator door), a seating mat and a tablet. A smartphone and internet connection were provided in case they were not already present.

With privacy and security in mind, the data these sensors provided was collected and aggregated on a network storage device that was located on premise. Home care nurses could consult this data for the patients in their care, using a tailor-made mobile application. Restricted access to the patient data was ensured via a login system and a secure encrypted connection. An additional tablet device was provided for the patient and their informal caregiver.

Information provided to the nurses consisted of (detailed) sleep information, periods of activity and inactivity, weight and heart rate information, and information about living habits in general (movement between and presence in rooms, and number of times the fridge was opened). Figure 1 schematically demonstrates the test setup.

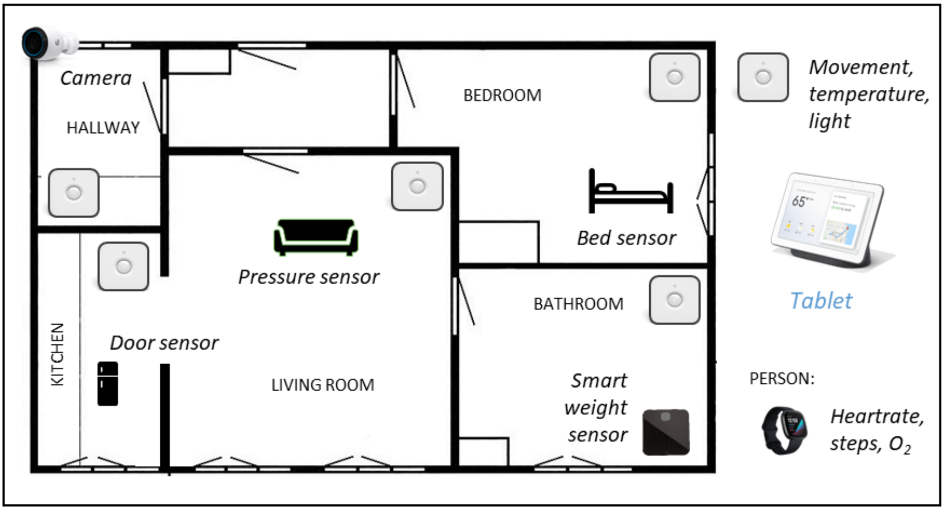

Figure 1. Overview of the test setup.

3.2.2. Application

Initially, a non-functional design of the application including several screens and dummy data was made. This first version was presented to 13 nurses in total during 3 focus groups. Feedback for each screen was collected, consisting of good elements, things that could be improved, items which were redundant and missing elements. Based on these insights a second version of the design was created and presented to another group of 9 nurses total in a second round of 2 focus groups.

Starting from this design, a working prototype was produced that could display the collected data. During the pilot cases more data and visualizations were added to the application, and several changes were implemented based on user feedback. Figure 2 gives an overview of the process and some screenshots of the application.

Figure 2. Iterative design process of the application, including some screenshots.

3.3. Case study

The test setup was installed in 2 patients' homes and the experiences of 5 nurses and 2 informal caregivers were mapped. The information from the sensors (on top of the usual information obtained while conversing with the patients) often became a useful starting point for more detailed enquiries, and more evidence-based decisions during home care. Several participating nurses indicated they gained a clearer understanding of the patients' general physical health and well-being. Patients reported that the test set up had no noticeable impact on their daily life. The sensors were inobtrusive except for the smart watch. They were also curious about the results regarding their sleep, resting and activity pattern. The information provided by the nurses gave them a more accurate insight into these patterns. Informal caregivers reflected that when abnormalities were observed by the nurses, they were contacted. Overall, the informal caregivers experienced no perceptible disadvantages from the test setup.

The mean SUS score was 87.5 (stdev 15) and the scores ranged between 70 and 100. The UEQ uses 6 scales: attractiveness, perspicuity, efficiency, dependability, stimulation and novelty. On all of these, the test setup and application had a positive evaluation (figure 3A). Compared to the benchmark dataset of the UEQ (containing data on 21.175

individuals from 468 studies concerning different products, the test setup and application scored 'good' on dependability and 'excellent' on the other 5 scales. Regarding the USE questionnaire, the mean scores on a seven-point scale were 5.1 for usefulness, 5.6 for ease of use, 6.2 for ease of learning and 5.7 for satisfaction (figure 3B).

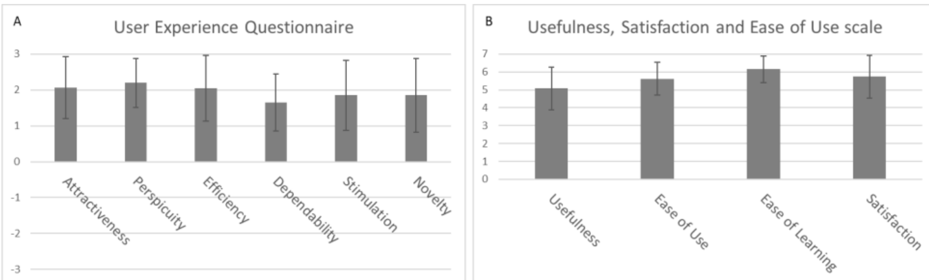

Figure 3. Results of A) the User Experience Questionnaire (UEQ) and B) the Usefulness, satisfaction, and ease of use (USE) scale.

The application of data analysis techniques and artificial intelligence can be a valuable asset for homecare nurses. Various unsupervised learning approaches (Isolation Forest, kNN, PCA analysis, and others) enable the detection and flagging of potential anomalies, which may not be immediately apparent when homecare nurses interact with the visualized data in the application. They can then perform a more in-depth inspection of the potentially anomalous events.

4. Discussion, future work, and conclusion

The main aim of this project was to facilitate nursing care using technology within the framework of a proper daily structure for elderly people. With a focus on the sleep, rest and activity pattern, a test setup and application were developed in collaboration with homecare nurses. The relevance of the two selected patterns has also been demonstrated in literature [13]. Homecare nurses as well as patients and informal caregivers were all positive about the test setup and application as demonstrated by the questionnaires and interviews. During the study, several other healthcare providers were interested in the data, including the physiotherapist, GP and informal caregiver. In the future we should look at how the test setup can be made available to multiple additional disciplines and what information should be made available to each.

Based on our interviews with home care professionals, it turned out the parameters of importance for monitoring patients can be quite diverse and differ significantly on a case-by-case basis. While collecting requirements from home care nurses, some other parameters of interest were discussed, for which we could not obtain proper sensors or platforms in time. A non-exhaustive list of "smart" products that may create added value in specific cases are: a smart medication dispenser, a smart blood pressure sensor, a smart cup or pitcher that measures liquid intake and a smart toilet that measures quantity and/or quality of excreta. Note that all these products should have an API accessible to third parties to be able to be integrated with our platform; some of these products were available, but only within a closed software ecosystem that could not be integrated.

An interesting avenue in which to continue this project in the future is scaling it up to accommodate a (significantly) higher number of patients, home care nurses and informal caregivers and increase the test period duration. We are currently outlining a follow-up project in which we want to address potential upscaling challenges such as cost per patient, cost for the operator of the platform, simplicity of installation, ease of use, data storage, privacy, security, and data analysis.

In summary it can be stated that a system to give home nurses a more detailed insight about patients' daily structure is very valuable in supporting them in the context of patient care.

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References

[1] Eurostat. Ageing Europe. Looking at the Lives of Older People in the EU, 2020th ed. Luxembourg: Publications Office of the European Union; 2020.
[2] Perez-Francisco DH, Duarte-Climents G, Del Rosario-Melian JM, Gomez-Salgado J, Romero-Martin M, Sanchez-Gomez MB. Influence of Workload on Primary Care Nurses' Health and Burnout, Patients' Safety, and Quality of Care: Integrative Review. Healthcare (Basel). 2020;8(1).
[3] Unger C. Introducing a Resiliency Bundle for Home Care Nurses. Home Healthc Now. 2022;40(4):202-8.
[4] Scheper MvV, M. Data-ondersteunde gezondheidszorg en innovatie. De mogelijkheden van big data, remote sensing en artificiële intelligentie binnen het klinisch handelen van de gezondheidszorgprofessional. Instituut voor Gezondheidszorg (IVG).
[5] Ghorbani F, Ahmadi A, Kia M, Rahman Q, Delrobaei M. A Decision-Aware Ambient Assisted Living System with IoT Embedded Device for In-Home Monitoring of Older Adults. Sensors (Basel). 2023;23(5).
[6] Chen H, Zhang Y, Wang L. A study on the quality evaluation index system of smart home care for older adults in the community --based on Delphi and AHP. BMC Public Health. 2023;23(1):411.
[7] Aggar C, Sorwar G, Seton C, Penman O, Ward A. Smart home technology to support older people's quality of life: A longitudinal pilot study. Int J Older People Nurs. 2023;18(1):e12489.
[8] Piau A, Mattek N, Crissey R, Beattie Z, Dodge H, Kaye J. When Will My Patient Fall? Sensor-Based In-Home Walking Speed Identifies Future Falls in Older Adults. J Gerontol A Biol Sci Med Sci. 2020;75(5):968-73.
[9] Wu CY, Dodge HH, Reynolds C, Barnes LL, Silbert LC, Lim MM, et al. In-Home Mobility Frequency and Stability in Older Adults Living Alone With or Without MCI: Introduction of New Metrics. Front Digit Health. 2021;3:764510.
[10] Comprehensive Scoping Study on the Use of Assistive Technology by Frail Older People Living in the Community Department of Health and Ageing.; 2008.
[11] Marasinghe KM, Chaurasia A, Adil M, Liu QY, Nur TI, Oremus M. The impact of assistive devices on community-dwelling older adults and their informal caregivers: a systematic review. BMC Geriatr. 2022;22(1):897.
[12] de Veer AJE FA. Ervaringen van verpleegkundigen en verzorgenden met nieuwe technologieën in de zorg Utrecht: NIVEL; 2009.
[13] Wrede C B-JA, van Gemert-Pijnen L. . How to create value with unobtrusive monitoring technology in home-based dementia care: a multimethod study among key stakeholders BMC Geriatr. 2022;Nov 30;22(1):921

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Evaluation of Commercially Available Fall Detection Systems

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Abstract. Falls are a serious problem in the hospital setting and home environments. However, this problem does not only affect the elderly, but also people who have had surgery, have disabling problems, have associated diagnoses (such as poor eyesight, confusion, etc.) or are dizzy or have walking aids. The aim of research was to find, compare and implement fall detectors especially for the hospital environment. This paper summarizes possible fall detectors. Various technological solutions were selected for testing, including wearable technologies as well as contactless technologies based on PIR detectors and mmWave technologies. The selected fall detectors were tested in living laboratory of HEALTHLab.vsb.cz and then in Hospital AGEL Třinec - Podlesí. The best result of the testing was the use of two Vayyar Home Care devices in one room, thus achieving a detection accuracy of 92.50 % and a sensitivity of 92.50 %.

Keywords. fall detectors, mmWave sensors, contact - (less) detection

1. Introduction

Falls of elderly and postoperative patients are the biggest concern in this field, which can worsen the patient's condition and postpone discharge of the patient from the hospital[1, 2,3]. In medical facilities, falls are a big problem, also because of the need to examine the patient after a fall. Such treatment can be expensive and very expensive [1,4].

To facilitate the identification of threats in patients, the nurse can use a comprehensive fall prediction tool to reduce patient risk of falling. Determining how to predict a fall is key factor for prevention [4,5,6,7] where fall risk assessments are different for pediatric patients [8,9,10] . Fall prevention strategies very often starts after the first fall, not before. This is a key reason why some fall prevention procedures fail consistently to reduce the overall fall injury index over time [7].

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2. Fall detection

For the detection of falls, it is possible to use a camera solution and a solution that does not require camera solution, such as PIR sensors or sensory mats or floors. In this work were tested: mmWave sensor, sensory pads, PIR sensors, smart watches and glasses. Where the selected sensors are further tested in a real environment.

2.1. mmWave sensors

Sensor based on mmWave create a narrow electromagnetic beam,which works on the principle of FMCW (frequency continuous modulated wave) radar technologies. Information transmission is possible over a wide frequency band greater than 500 MHz [11,12,13,11,14,15]. An example of a commercial device is Vayyar Home Care [16] and Hikvision [17] .

2.2. Accelerometer-based

Accelerometer-based fall detectors are used to detect positions that can lead to falls [18,19]. Falls can be monitored using wearable devices[16] or using accelerometers in mobile phones [19].

2.3. PIR sensors

A passive infrared sensor (PIR) is a sensitive sensor to infrared radiation that emits from the heat of the person, animal or other object being sensed. The sensitivity of the sensor depends on several variables: the direction of movement relative to the the sensor, on the thermal insulation of the clothing ,ambient temperature, the dimension of the sensed object, the weather [20,21].

2.4. Sensory pads

The most comprehensive method of bedside presence detection is the Sensor Pad. Commonly available types of sensory pads include bed pads or floor pads. All types of pads can be designed either wirelessly or with a cable. Sensory pads can be divided into: For use on a mattress [20, 21] and for use under the mattress [22, 23].

3. Materials and Methods

This section will cover the tested fall detection devices. The PIR detector category is represented by the eLsa multifunctional detector. Furthermore, the category of radar systems is represented by the solution of the Israeli company Vayyar Care with the Vayyar Home device. The SensFloor capacitive floor serves as a benchmark for the entire testing. In addition, a presentation mat from the same manufacturer and two wearable devices, namely Apple watch 5 and Serenity Eyewear, are used.

3.1. eLsa

Activity sensing using eLsa is built to provide solutions for private home care and nursing home buildings. This device uses PIR sensors, and it is activated when the patient enters the room. So, both the upper and lower parts of the detector are activated. If the patient falls, the detector placed upper lose sense of activity and only detector at the bottom senses the activity so it evaluates the fall [22].

3.2. Vayyar Home Care

Vayyar Home Care [16] device eliminates the need for video cameras, buttons and wearable devices. Vayyar Care uses radar to monitor a room continuously, in all conditions, in darkness, in elevated humidity (up to 95 % humidity), in temperatures from 0°C to 40°C. The device is capable of detecting a fall within a range of 3.9624 m forward and 1.9812 m sideways, larger rooms may require more equipment to function properly [16].

3.3. SensFloor

SensFloor [23] is composed of a thin sensory pad that is installed underneath the conventional floor covering, similar to noise insulation. This sensor floor monitors every movement of people on it in real time. The fact, that no sensitive data is attached to individual tracks makes the recording 100 % anonymous. The sensory floor is based on a textile mat, with a microelectronics insert that wirelessly sends information about the status of each sensor field to a central receiver. The SensFloor Mat is from the same company as the SensFloor and works identically [23].

3.4. Glasses by Serenity Eyewear

Serenity Eyewear glasses by Ellcie Healthy [24] has a built-in gyroscope and accelerometer with the addition of an infrared sensor. If a fall occurs, the glasses will send a message to the family or caregivers. Data from individual sensors is analysed using artificial intelligence. The algorithm automatically adapts to each user [24].

3.5. Apple watch

If an unwanted situation should occur, i.e. a fall, the watch reacts in several ways. If the patient is moving after a fall the watch only triggers an alert for the patient to respond to. If the watch detects that the patient has been motionless for about a minute, it will start a 30-second countdown, vibrating the wrist and triggering an alert [25].

4. Experiment setup

Experiments were selected in from different test environment. The first is living laboratory (HEALTHLab.vsb.cz). Then hospital conditions were used for testing. In the home environment, the fall detectors were tested in two rooms. Namely, a room with a bed due to the fact that this room will substitute the hospital room for testing. Next, the bathroom was chosen because it is one of the riskiest rooms for the occurrence of falls. The

Figure 1. (A) Room with events, (B) Bathroom with events. (1). Get out of bed,(2) Fall at the closet,(3) Getting out of bed, (4) Looking out the window, (5) Slumping by the wall next to the window, (6) Falling near the sink, (7) Shower, (8) Slumping by the towels. (V) Vayyare Home Care device.

figure 1 shows the locations for testing detectors with events in room and bathroom in HEALTHLab.vsb.cz.

For the scenario design, were proposed list of scenarios. The scenario for testing detectors in VŠB-TUO living laboratory was chosen to best reflect the normal course of the day with as many falls as possible. At the beginning of testing, the subject enters the room and lies down in bed. After a predetermined amount of time, he gets out of bed, try to change his clothes from the closet followed by a fall, the subject remains lying on the floor for a minimum of one minute to achieve the time for recall assistance Subsequently, the subject gets up and returns to the bed to make it. After making the bed, he will go to look out the window where he will simulate slumping against the wall. He then moves to the bathroom where he goes to the sink where he simulates falling. He then picks himself up and walks into the shower. On its way out of the shower, it slumps against the wall next to the towel holder. Events are numerically ordered and recorded in the Figure 1.

In this experiment, all the technologies listed in Chapter 3 were used. Testing at hospital AGEL Třinec-Podlesí, using two Vayyar Care devices for better detection quality. Testing was done in the hospital room in Cardiology. Figure 2 shows the layoutof the room. A ceiling location at a height of 2.96 m was chosen to install Vayyar device. In Figure 2 (B), the position of the Vayyar is marked with the place No. 1. And it was also placed on the wall to a height of 1.5 m above the ground, marked with the place No. 2. The height was measured to the centre of the device and the device was properly fixed to the wall. The scenario for testing was also chosen to best reflect the normal course of the day with as many falls as possible.

The scenario for testing was designed to reflect areas with a high incidence of falls. The scenario begins with the test subject arriving from the bathroom, indicated in Figure 2 by the place No. 1. This is followed by the fall defined above as a stumble indicated by the place No. 2. Next, the test subject moved to the window indicated by the place No. 3. He then moves to the bed where place No. 5 of the fall begins. The subject falls from the bed into the aisle between the beds by a predefined fall. After the time limit has elapsed, the person sits down at the table for a moment. He then moves to place No. 7 where the subject stumbles. He then goes to the wardrobe to get his belongings, where he stays for a while and returns to the bed again and performs the last fall, indicated by place No. 10, between the bed and the wall.

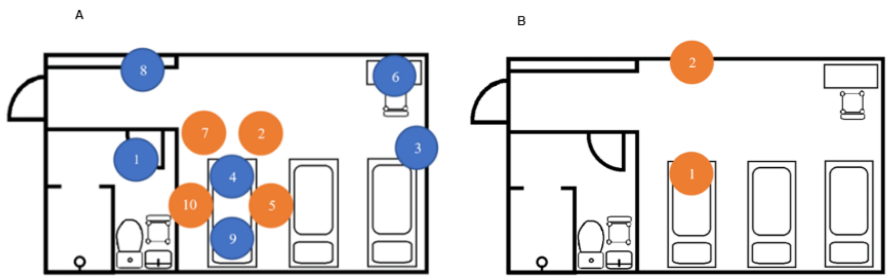

Figure 2. (A) Locations of events in hospital room, (B) Location of equipment.

4.1. Testing group

A total of 20 participants attended testing in HEALTHLab. For each, weight (average weight,77 kg), height (average height, 179 cm), age (± 1 STD), BMI (average BMI, 24.072), and waist circumference (average waist circumference, 89 cm) were recorded. Gender was not considered important for this testing and was not recorded for that reason. For testing in a hospital setting, one person was tested.

4.2. Data analysis

Several analysis parameters were used to validate the results. The number of all correct fall detections divided by the entire amount of data is used to compute accuracy, Eq. 1. The number of positive predictions divided by the total number of positives yields the sensitivity, Eq.2.

$$Accuracy = TP/(TP+FP+FN)100\% \quad (1)$$

$$Sensitivity = TP/(TP+FN)100\% \quad (2)$$

5. Reasults HEALTHLab

A total of 80 falls were performed in the HEALTHLab, according to a described scenario. During testing, there were occasions when unintentional fall detection occurred during movement. The only device that experienced these errors was glasses Serenity Eyewear. These false detections were common when putting on the glasses or when lying down in bed.

5.1. Results for testing in hospital

A total of 40 falls were performed in short-term testing. Based on the results, the Vayyar device was selected for testing.

Table 1. : Total score of all devices, VŠB-TUO.

Device	Total of all performed	Detected	Sensitivity	Accuracy	Average delay
SensFloor	40	40	100.00 %	100.00 %	4s
SensFloor Mat as fall detector	20	15	75.00 %	75.00 %	11s
Vayyar on the ceilling 45°	40	27	67.50 %	67.50 %	1 m 6 s
Vayyar on the wall	40	29	72.50 %	72.50 %	1 m 9 s
Vayyar on the ceiling	40	30	75.00 %	75.00 %	1 m 8 s
Combined score, Vayyar room	40	37	92.50 %	92.50 %	1 m 9 s
Vayyar sum	120	86	71.66 %	71.66 %	1 m 8 s
eLsa	80	10	12.50 %	12.50 %	1 m 44 s
Apple Watch	80	3	3.75 %	3.75 %	1 m 3 s
Serenity Eyewear glasses	80	50	62.50 %	58.14 %	2 s

Table 2. : Reasults from detection in the hostipal room.

Device	Fall detected	Detected stumble	Total detected	Total sensitivity	Total accuracy
Vayyar on the wall	12 out of 20	17 out of 20	29 out of 40	72.50 %	72.50 %
Vayyar on the ceiling	11 out of 20	17 out of 20	28 out of 40	70.00 %	70.00 %
Combined score of two devices	17 out of 20	20 out of 20	37 out of 40	92.50 %	92.50 %

6. Discussion

Of all the fall detection devices tested in HEALTHLab, the Apple Watch 5 and eLsa performed the worst. These devices detected fewer than 11 falls out of a total of 80 falls as shows Table 1. One of the possible reasons for the low sensitivity of falls in watches is the detection algorithm and in PIR sensor is the limitation PIR technology . The only device that detected a false positive fall was Serenity Eyewear, with a total of six false positives. The Vayyar device was evaluated both alone and as a combination of two devices for in-room testing. When the Vayyar device was used alone, the detection yielded around 30 detected falls out of 40, when the two Vayyar devices were combined, the detection was more accurate and detected around seven more falls.

In hospital were used two Vayyar deviced for testing, in a configuration of separate detectors placed in different locations in the room and a joint detection configuration based on the simultaneous use of both Vayyar detectors. The joint detection configuration using two detectors demonstrated higher detection success rates, which is consistent with the findings from testing in a telemetry apartment of two Vayyar devices in one room. For the use of two Vayyar devices, a detection accuracy of 92.50 % and a sensitivity of 92.50 % were found. For the use of one Vayyar detector in either the apartment or the hospital room, the accuracy and sensitivity are found to average 71.66 % and 71.66 % respectively.

Table 2 shows the results for each facility. In addition, a combined correlated to reflect whether at least one of the devices detected a crash with a given serial number. When the device was placed on the ceiling of the hospital room, the sensitivity was 70 %. Placing it on the wall achieved a higher value of 72.5 %. The best result was achieved by the combination of two devices, which showed a sensitivity of 92.5 %. The median response times of the two devices were almost identical. The wall-mounted Vayyar achieved a median response time of 1 m 2 s and the ceiling-mounted Vayyar had a mean response time of 1 m 1 s.

7. Conclusion

Falls pose a significant risk to patients, often prolonging hospitalisation and recovery time. For this reason, efforts are made to eliminate this adverse event to a minimum. Based on the experimental measurements performed, future research will focus on the influence of anatomical differences of the test subjects and their effect on the quality of fall detection. Areas of development will take focus on detection systems that are able to detect non-contact falls in rooms occupied by more than one person. This is because it is common in hospital and social service environments for a single room to be occupied by more than one person.

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References

[1] Morris ME, Webster K, Jones C, Hill AM, Haines T, McPhail S, et al. Interventions to reduce falls in hospitals: a systematic review and meta-analysis. 2022;51(5):afac077.

[2] Heng H, Jazayeri D, Shaw L, Kiegaldie D, Hill AM, Morris ME. Hospital falls prevention with patient education: a scoping review. 2020;20(1):140. Available from: https://doi.org/10.1186/s12877-020-01515-w.

[3] Bouldin ELD, Andresen EM, Dunton NE, Simon M, Waters TM, Liu M, et al. Falls among adult patients hospitalized in the United States: prevalence and trends. 2013;9(1):13-7.

[4] Callis N. Falls prevention: Identification of predictive fall risk factors. 2016;29:53-8. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0897189715001056.

[5] Najafpour Z, Godarzi Z, Arab M, Yaseri M. Risk Factors for Falls in Hospital In-Patients: A Prospective Nested Case Control Study. 2019;8(5):300-6. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6571495/.

[6] Baek S, Piao J, Jin Y, Lee SM. Validity of the Morse Fall Scale implemented in an electronic medical record system. 2014;23(17):2434-40.

[7] Hendrich A. Inpatient Falls: Lessons from the Field; 2006. Available from: https://psqh.com/mayjun06/falls.html.

[8] Franck LS, Gay CL, Cooper B, Ezrre S, Murphy B, Chan JSL, et al. The Little Schmidy Pediatric Hospital Fall Risk Assessment Index: A diagnostic accuracy study. 2017;68:51-9.

[9] Chromá J. Risk of falling in pediatric nursing. 2016;7(4):542-8. Available from: http://cejnm.osu.cz/doi/10.15452/CEJNM.2016.07.0027.html.

[10] Hill-Rodriguez D, Messmer PR, Williams PD, Zeller RA, Williams AR, Wood M, et al. The Humpty Dumpty Falls Scale: A Case-Control Study. 2009;14(1):22-32. Available from: https://onlinelibrary.wiley.com/doi/10.1111/j.1744-6155.2008.00166.x.

[11] Oppermann I, Hämäläinen M, Iinatti J. UWB Theory and Applications. Wiley; 2004.

[12] Khan F, Ghaffar A, Khan N, Cho SH. An Overview of Signal Processing Techniques for Remote Health Monitoring Using Impulse Radio UWB Transceiver. 2020;20(9):2479. Available from: https://www.mdpi.com/1424-8220/20/9/2479.

[13] van Berlo B, Elkelany A, Ozcelebi T, Meratnia N. Millimeter Wave Sensing: A Review of Application Pipelines and Building Blocks. 2021;21(9):10332-68. Conference Name: IEEE Sensors Journal.
[14] Mokhtari G, Aminikhanghahi S, Zhang Q, Cook DJ. Fall detection in smart home environments using UWB sensors and unsupervised change detection. 2018;4(3):131-9. Available from: https://doi.org/10.1007/s40860-018-0065-2.
[15] Huang X, Cheena H, Thomas A, Tsoi JKP. Indoor Detection and Tracking of People Using mmWave Sensor. 2021;2021:e6657709. Publisher: Hindawi. Available from: https://www.hindawi.com/journals/js/2021/6657709/.
[16] Vayyar Care: Fall Detection Exclusively with Alexa Together [Internet]; 2022. [cited 2022 Feb 01]. Available from: https://vayyar.com/care/.
[17] HIKVISION SOLUTION - FALL DETECTION RADAR; 2023. Available from: https://www.tridis.be/en/hikvision-solution-fall-detection-radar.
[18] Palmerini L, Klenk J, Becker C, Chiari L. Accelerometer-Based Fall Detection Using Machine Learning: Training and Testing on Real-World Falls. 2020;20(22):6479. Number: 22 Publisher: Multidisciplinary Digital Publishing Institute. Available from: https://www.mdpi.com/1424-8220/20/22/6479.
[19] Stampfler T, Elgendi M, Fletcher RR, Menon C. Fall detection using accelerometer-based smartphones: Where do we go from here? 2022;10. Available from: https://www.frontiersin.org/articles/10.3389/fpubh.2022.996021.
[20] Singh A, Rehman SU, Yongchareon S, Chong PHJ. Sensor Technologies for Fall Detection Systems: A Review. 2020;20(13):6889-919. Conference Name: IEEE Sensors Journal.
[21] Rahman MM, Islam MM, Ahmmed S, Khan SA. Obstacle and Fall Detection to Guide the Visually Impaired People with Real Time Monitoring. 2020;1(4):219. Available from: https://doi.org/10.1007/s42979-020-00231-x.
[22] eLsa in home care - Activity sensing, Fall prevention - MariCare; 2022. Available from: https://maricare.com/en/solutions/home-care.
[23] Solutions; 2022. Available from: https://future-shape.com/en/.
[24] Home - Ellcie Healthy; 2023. Available from: https://ellcie-healthy.com/en/home/.
[25] Use Fall Detection with Apple Watch [Internet]; 2023. [cited 2023 May 18]. Available from: https://support.apple.com/en-us/HT208944.

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Privacy-Aware and Acceptable Video-Based Assistive Technologies

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Blind Modalities for Human Activity Recognition

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Abstract. Human Activity Recognition (HAR) has attracted considerable interest due to its ability to facilitate automation in various application areas, including but not limited to smart homes, active assisted living, and security. At present, optical modalities such as RGB, depth, and thermal imaging are prevalent in the field due to the effectiveness of deep learning algorithms like Convolutional Neural Networks (CNNs) and the abundance of publicly available image data. However, unconventional modalities such as radar, WiFi, seismic and environmental sensors are emerging as potential alternatives due to their capacity for contactless long-range sensing in spatially constrained environments and preservation of visual privacy. This work gives an overview of the HAR modalities landscape and discusses works that apply these emerging modalities in new and unconventional ways to inform researchers and practitioners about challenges and opportunities in the field of HAR.

Keywords. human activity recognition, person-centric sensing, blind modalities

1. Introduction

Human Activity Recognition (HAR) is a field of research concerned with the extraction and analysis of behavioral information from person-centric sensory data, enabling applications in Active Assisted Living (AAL), healthcare monitoring, smart environments, human-robot interaction, autonomous driving, or security and surveillance [1].

The widespread adoption of HAR in AAL, healthcare, or smart environment applications has the potential to improve the lives of countless people. Yet, real-world implementations frequently fail due to privacy concerns among target users [2]. In private environments, in particular, a strong attitude of rejection towards HAR systems exists, which can be attributed to the dominant type of technology being used for data acquisition. The remarkable advances in computer vision and deep learning of the past decade have resulted in current state-of-the-art HAR systems being mostly vision-based, with cameras serving as the primary source of data [3]. From a purely technical perspective, the preference for cameras is justified by the high information density in images that eases the implementation of fundamental tasks. However, this characteristic also makes the success of camera-based HAR systems highly context-dependent. For example, while cameras are generally tolerated in public environments when used for healthcare or safety applications (e.g., recognition of medical emergencies or traffic monitoring), cameras are strongly rejected when used for surveillance (e.g., face detection and tracking) [4]. System location also plays a crucial role in user acceptance. The idea of having a camera-

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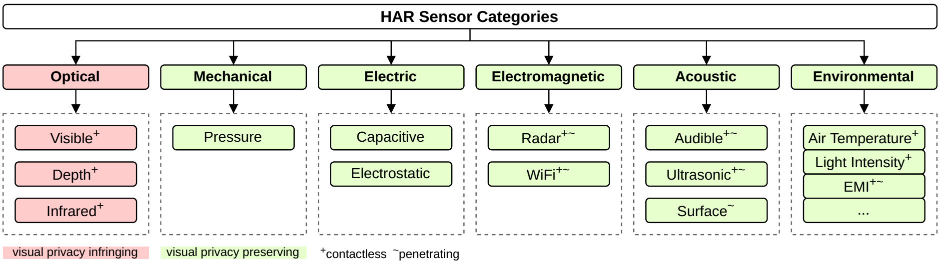

Figure 1. Modified HAR modality taxonomy adapted from [1], with *blind modalities* highlighted in green.

based HAR system at home, regardless of the application, is a no-go for many people [4], as the mere presence of a camera-like object can induce the negative feeling of "being watched". Cameras can carry a negative connotation and be perceived as intrusive or surveilling [5]. Consequently, the perceived usefulness of cameras in HAR systems is outweighed by privacy concerns leading to rejection [6]. Already, this situation has led to the widespread disappearance of conventional RGB cameras from privacy-sensitive HAR applications and their substitution by depth or thermal cameras, which are perceived to offer a greater level of privacy protection [7]. Unfortunately, this perception is contrasted by works on person identification in depth and thermal images, or domain translation between modalities [8], which raise questions about the extent to which depth and thermal cameras can truly protect visual privacy. The scientific literature on technology acceptance in HAR applications paints a clear picture, however. Among all available technologies, cameras are least accepted in both public and private environments [4,9,10]. This finding is concerning as it shows that state-of-the-art HAR systems are not meeting target users' needs, and while camera-based HAR systems are most capable at present, widespread adoption is unlikely to occur with this technology.

2. Blind Modalities

To achieve adoption in private environments, we must move away from cameras and explore alternative modalities that align with target users' needs. Existing research on technology acceptance in HAR applications identified the protection of visual privacy as a key criterion for system acceptance [4]. Consequently, non-optical "non-seeing" *blind modalities* lend themselves as an alternative. As visualized in Figure 1, the HAR modalities landscape offers a wide range of alternative modalities that can protect visual privacy in HAR applications (highlighted in green). Yet, research interest is comparatively low still [1]. Certain *blind modalities* even have technical advantages over cameras, which can extend the capabilities of HAR systems and enable new applications. Unlike cameras, *blind modalities* such as radar, WiFi, or surface acoustic do not require line of sight and can penetrate walls, enabling through-wall HAR [11]. Combined with long operating ranges, this characteristic allows unobtrusive monitoring of large areas with a single device, minimizing system complexity and cost. While previous work has already demonstrated the potential of *blind modalities* in the context of privacy-sensitive HAR applications, camera-based HAR systems are still superior in their sensing versatility and accuracy. This can be attributed to open problems such as the absence of off-the-shelf sensing hardware, lack of publicly available training data [1], challenges with fusion and processing of data in multi-modal sensing due to data heterogeneity and asynchrony

[12], signal mixing in multi-person scenarios [13] or poor modal generalization to new environments [14].

2.1. Radar

Initially developed for the military, radar technology has found its way into a broad spectrum of non-military applications. Today, high-performance radar systems are essential tools in geology, meteorology, and astronomy. Traffic monitoring and navigation on land, at sea, in the air, and in space are also key application areas. However, the application of radar technology to HAR is a relatively recent development promoted by the emergence of compact, low-cost radar systems designed for civilian applications[2]. The interest in radar technology, as a modality in HAR applications, is growing as potential advantages over cameras are being recognized [15]. Radars can protect visual privacy as only positional information is extracted from the scene, making this technology suitable for privacy-sensitive HAR applications [1,16]. Moreover, radars are illumination invariant and functional even in scenarios with limited visibility (e.g., smoke-filled room) [17]. Another advantage is the ability to penetrate walls, which allows the monitoring of large indoor areas with a single device and the realization of cross-room HAR applications that are impossible with cameras [18,11].

Radar-based HAR works can be classified by data representation dimensionality: 1D (time series), 2D (time-Doppler, time-range, range-Doppler map), and 3D (time-range-Doppler map). Most works use 2D representations (time-Doppler maps) processed with CNN-based architectures [15]. One early example is [19], where humans and seven simple activities are classified using CNNs trained on CW time-Doppler maps. Trommel et al. use a similar approach for human gait classification [20]. A common approach in radar-based HAR is the use of time-Doppler maps to exploit velocity information [15]. However, slow or orthogonal movements produce weak signals that are hard to detect and classify. Erol et al. [21] and Shao et al. [22] address this problem with the use of time-range maps. Furthermore, other authors have proposed using 3D representations (time-range-Doppler maps) to jointly process complementary information in 2D representations. An example is the Google Soli system [23,24], which uses a hybrid CNN and RNN network for highly accurate short-range hand gesture recognition on smartphones. Erol and Armin extend the use of 3D representations to full-body activities [25,26]. Finally, multi-representation approaches were proposed for processing complementary information. Jokanovic et al. [27,28] demonstrate how multi-representation learning on radar data can improve HAR system recognition accuracy.

2.2. WiFi

When a human moves through the electromagnetic field of a WiFi device (e.g., WiFi router or smartphone), the characteristics of the signal change depending on the activity performed. WiFi-based HAR is based on this observation [29]. The simple signal attenuation caused by a human body can be measured using the Returned Signal Strength Indicator (RSSI). Furthermore, more complex signal characteristics can be observed in the Channel State Information (CSI). Since most WiFi devices process this information as part of their operation, no custom hardware is required, contrary to radar appliactions. RSSI and CSI, can be extracted from common WiFi devices using modified drivers [30].

[2]Infineon Position2Go, https://www.infineon.com/dgdl/Infineon-Position2Go_development_kit-PB-v01_00-EN.pdf?fileId=5546d46267c74c9a0167cabc70cd0120, Accessed: 02.05.2023

Together with the ability to penetrate walls, the large operating range of WiFi (35m indoor and 250m outdoor [31]) enables the realization of large-scale indoor HAR applications with a single device. Moreover, WiFi is also lighting invariant and does not violate visual privacy [32].

One of the earliest examples of WiFi-based HAR is found in [33], which demonstrates how statistical features extracted from RSSI time series can be used for intruder detection and tracking. As WiFi signals are strongly affected by the environment, dynamic changes in the environment can degrade system performance [33]. Kosba et al. address this problem in their work on motion detection [14] and present a system (RASID) that is robust to dynamic changes in the environment. Furthermore, Sigg et al. demonstrate RSSI-based recognition of four simple activities [34] and, in a follow-up work, extend their approach to include a localization component [35]. Most modern WiFi-based HAR approaches use CSI instead of RSSI due to its coarse resolution and lack of stability [36]. In the first work on CSI-based HAR [37], Wang et al. present a system (E-eyes) for detecting complex stationary and mobile activities in a home environment. Another CSI-based HAR system (CARM) is presented in [38,32], addressing generalization to new environments with a location-independent activity model. As first demonstrated in [39], CSI is also suitable for the recognition of "abnormal" activities (e.g., falls). Wang et al. present a CSI-based fall detection system (WiFall). Building on this, a CSI-based fall detection system (FallDeFi) is presented in [40], which uses Short-Time Fourier Transform (STFT) to extract time-frequency features from CSI and outperforms both RT-Fall [41] and CARM [32].

2.3. Surface Acoustic

When a human performs physical activities, structural vibrations are generated in the environment that propagate throughout floors and walls. Depending on the activity performed (e.g., walking, running, or falling), characteristic vibration patterns are generated, on the basis of which one can recognize the activity performed [42]. Surface acoustic-based HAR is based on this observation. For the recording of structural vibrations, seismic sensors such as accelerometers [43] and geophones [44] are commonly used. These can be embedded in the environment or attached directly to a person [45]. Because wearable sensors are often perceived as intrusive or stigmatizing [46,47], contactless surface acoustic-based HAR, where seismic sensors are embedded exclusively in the environment, is regarded as the superior method. Like radar and WiFi, seismic sensing is illumination invariant, visual privacy-preserving, and enables long-range applications [48].

In one of the first works on surface acoustic-based HAR [42], Alwan et al. present a fall detection system based on the observation that "abnormal" activities such as falls generate significantly different vibration patterns than regular activities. In [44], Huang et al. present a modern surface acoustic-based real-time fall detection system (G-Fall) that can detect two different types of falls (trip and slip). Clemente et al. [49] present a similar surface acoustic-based real-time fall detection system that in addition allows the identification of persons based on footstep-induced structural vibrations. In [50], Tsukiyama presents an AAL system that can recognize "abnormal" behavior based on water consumption in a single-person household. A similar approach is taken in [51], where structural vibrations of a sink are used to detect hand-washing activities. Similarly to [50], Pan et al. [52] also address the recognition of "abnormal" behavior patterns in single-person households by monitoring electricity consumption and structural vibrations. The majority of prior works on surface acoustic-based HAR are limited to single-person scenarios due to the problematic signal mixing in multi-person scenarios [13,53]. This problem is addressed in a recent work on person identification based on footstep-induced structural vibrations in multi-person scenarios by Fagert et al. [54], which proposes a new approach for signal decomposition that treats a composite signal as a product of basis functions (individual footstep patterns).

2.4. Environmental

The term "environmental sensors" describes a large and diverse set of sensors for the measurement of different physical quantities in the local environment. Today, environmental sensors are essential components in most electronical devices and are thus ubiquitous in our daily lives [55]. Common examples include environmental sensors for measuring temperature, pressure, humidity, or light intensity. Less visible yet ubiquitous examples include environmental sensors for measuring light spectra, power consumption, magnetic fields, electromagnetic interference (EMI), flow rates, or gas concentrations. In the context of smart environments (Internet of Things (IoT)), environmental sensors are increasingly used for HAR applications due to their non-intrusive nature [56]. A unique aspect of HAR applications in this context is that activities are often recognized indirectly, through the interaction with objects in the environment (e.g., recognition of food preparation through the measurement of microwave-induced EMI), instead of measuring physical quantities of the human body directly [12]. Furthermore, because individual environmental sensors are limited in their sensing versatility and thus can only cover a relatively small spectrum of activities, uni-modal systems are rather uncommon. HAR systems for smart environment applications are typically multi-modal systems that integrate a large number of heterogeneous modalities for enhanced recognition capabilities. In their comprehensive work on general-purpose sensing in smart environments, Laput et al. present such an environmental sensor-based HAR system [12]. The system integrates nine discrete environmental sensors with twelve different sensor dimensions and achieves camera-like sensing versatility and accuracy. In a follow-up work, Laput and Harrision address the practical feasibility of large-scale general-purpose sensing [48].

3. Discussion

Blind modalities such as radar, WiFi, seismic and environmental sensors are emerging as potential alternatives to cameras in HAR applications due to their capacity for contactless long-range sensing in spatially constrained environments and preservation of visual privacy, which has been identified as a key requirement for user adoption in privacy-sensitive applications. Furthermore, *blind modalities* enable new applications such as through-wall HAR and tracking while reducing system complexity and cost compared to camera-based solutions that require per-room deployment. Despite the demonstrated potential, widespread adoption has yet to occur. This can be partly attributed to open problems such as the absence of off-the-shelf sensing hardware, lack of publicly available training data, challenges with fusion and processing of data in multi-modal sensing due to data heterogeneity and asynchrony, signal mixing in multi-person scenarios or poor modal generalization to new environments. Future work has to address these open problems to make *blind modalities* a viable alternative to optical modalities in practice, which currently remain superior in their sensing versatility and accuracy.

4. Conclusion

In this work, we highlighted the inherent problems that arise when using camera-based HAR systems in privacy-sensitive HAR applications commonly found in smart home or AAL settings, leading to limited user adoption. We have established the concept of *blind modalities*, which offer a visual-preserving alternative to optical modalities. Finally, on the basis of selected prior works, the challenges and opportunities related to applying *blind modalities* to HAR applications were discussed.

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References

[1] Fu B, Damer N, Kirchbuchner F, Kuijper A. Sensing Technology for Human Activity Recognition: A Comprehensive Survey. IEEE Access. 2020 01;PP:1-1.

[2] van Heek JO, Wilkowska W, Ziefle M. Cultural Impact on Perceptions of Aging, Care, and Lifelogging Technology: A Comparison between Turkey and Germany. International Journal of Human-Computer Interaction. 2021;37(2):156-68.

[3] Strohmayer J, Kampel M. A Compact Tri-Modal Camera Unit for RGBDT Vision. In: 2022 the 5th International Conference on Machine Vision and Applications (ICMVA). ICMVA 2022. New York, NY, USA; 2022. p. 34-42. Available from: https://doi.org/10.1145/3523111.3523116.

[4] Arning K, Ziefle M. "Get that Camera Out of My House!" Conjoint Measurement of Preferences for Video-Based Healthcare Monitoring Systems in Private and Public Places. In: Geissbühler A, Demongeot J, Mokhtari M, Abdulrazak B, Aloulou H, editors. Inclusive Smart Cities and e-Health. Cham: Springer International Publishing; 2015. p. 152-64.

[5] Kirchbuchner F, Grosse-Puppendahl T, Hastall MR, Distler M, Kuijper A. Ambient Intelligence from Senior Citizens' Perspectives: Understanding Privacy Concerns, Technology Acceptance, and Expectations. In: De Ruyter B, Kameas A, Chatzimisios P, Mavrommati I, editors. Ambient Intelligence. Cham: Springer International Publishing; 2015. p. 48-59.

[6] Claes V, Devriendt E, Tournoy J, Milisen K. Attitudes and perceptions of adults of 60 years and older towards in-home monitoring of the activities of daily living with contactless sensors: an explorative study. International journal of nursing studies. 2015;52 1:134-48.

[7] Wang X, Ellul J, Azzopardi G. Elderly Fall Detection Systems: A Literature Survey. Frontiers in Robotics and AI. 2020;7. Available from: https://www.frontiersin.org/article/10.3389/frobt.2020.00071.

[8] Fabbri M, Borghi G, Lanzi F, Vezzani R, Calderara S, Cucchiara R. Domain Translation with Conditional GANs: from Depth to RGB Face-to-Face. In: 2018 24th International Conference on Pattern Recognition (ICPR); 2018. p. 1355-60.

[9] Offermann J, Wilkowska W, Ziefle M. Cultural Impact on Perceptions of Aging, Care, and Lifelogging Technology: A Comparison between Turkey and Germany. International Journal of Human-Computer Interaction. 2020 09.

[10] Beach S, Schulz R, Downs J, Matthews J, Barron B, Seelman K. Disability, Age, and Informational Privacy Attitudes in Quality of Life Technology Applications: Results from a National Web Survey. ACM Trans Access Comput. 2009 may;2(1). Available from: https://doi.org/10.1145/1525840.1525846.

[11] Khawaja W, Koohifar F, Guvenc I. UWB radar based beyond wall sensing and tracking for ambient assisted living. IEEE Annual Consumer Communications and Networking Conference (CCNC). 2017:142-7.

[12] Laput G, Zhang Y, Harrison C. Synthetic Sensors: Towards General-Purpose Sensing. In: Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems. CHI '17. New York, NY, USA; 2017. p. 3986-99.

[13] Fagert J, Mirshekari M, Pan S, Zhang P, Noh HY. Vibration source separation for multiple people gait monitoring using footstep-induced floor vibrations. Structural Health Monitoring 2019. 2019.

[14] Kosba AE, Saeed A, Youssef M. RASID: A robust WLAN device-free passive motion detection system. In: 2012 IEEE International Conference on Pervasive Computing and Communications; 2012. p. 180-9.

[15] Li X, He Y, Jing X. A Survey of Deep Learning-Based Human Activity Recognition in Radar. Remote Sens. 2019;11:1068.

[16] Gurbuz SZ, Amin MG. Radar-Based Human-Motion Recognition With Deep Learning: Promising applications for indoor monitoring. IEEE Signal Processing Magazine. 2019;36:16-28.

[17] Sakai M, Aoki Y. Human and Object Detection in Smoke-filled Space using Millimeter-wave radar based Measurement System. In: 18th International Conference on Pattern Recognition (ICPR'06). vol. 3; 2006. p. 750-0.

[18] Miller E, Banerjee N, Zhu T. Smart homes that detect sneeze, cough, and face touching. Smart Health. 2021;19:100170. Available from: https://www.sciencedirect.com/science/article/pii/S2352648320300623.

[19] Kim Y, Moon T. Human Detection and Activity Classification Based on Micro-Doppler Signatures Using Deep Convolutional Neural Networks. IEEE Geoscience and Remote Sensing Letters. 2016;13:8-12.

[20] Trommel RP, Harmanny R, Cifola L, Driessen JN. Multi-target human gait classification using deep convolutional neural networks on micro-doppler spectrograms. 2016 European Radar Conference (EuRAD). 2016:81-4.

[21] Erol B, Amin MG, Boashash B. Range-Doppler radar sensor fusion for fall detection. In: 2017 IEEE Radar Conference (RadarConf). IEEE; 2017. p. 0819-24.

[22] Shao Y, Guo S, Sun L, Chen W. Human Motion Classification Based on Range Information with Deep Convolutional Neural Network. 2017 4th International Conference on Information Science and Control Engineering (ICISCE). 2017:1519-23.

[23] Lien J, Gillian NE, Karagozler ME, Amihood P, Schwesig C, Olson E, et al. Soli: ubiquitous gesture sensing with millimeter wave radar. ACM Trans Graph. 2016;35:142:1-142:19.

[24] Wang S, Song J, Lien J, Poupyrev I, Hilliges O. Interacting with Soli: Exploring Fine-Grained Dynamic Gesture Recognition in the Radio-Frequency Spectrum. In: Proceedings of the 29th Annual Symposium on User Interface Software and Technology. UIST '16. New York, NY, USA; 2016. p. 851-60. Available from: https://doi.org/10.1145/2984511.2984565.

[25] Erol B, Amin MG. Radar Data Cube Analysis for Fall Detection. In: 2018 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP); 2018. p. 2446-50.

[26] Erol B, Amin M. Radar Data Cube Processing for Human Activity Recognition Using Multi Subspace Learning. IEEE Transactions on Aerospace and Electronic Systems. 2019 04;PP:1-1.

[27] Jokanović B, Amin M. Fall Detection Using Deep Learning in Range-Doppler Radars. IEEE Transactions on Aerospace and Electronic Systems. 2018;54(1):180-9.

[28] Jokanović B, Amin MG, Erol B. Multiple joint-variable domains recognition of human motion. 2017 IEEE Radar Conference (RadarConf). 2017:0948-52.

[29] Liu J, Liu H, Chen Y, Wang Y, Wang C. Wireless Sensing for Human Activity: A Survey. IEEE Communications Surveys & Tutorials. 2020;22(3):1629-45.

[30] Halperin D, Hu W, Sheth A, Wetherall D. Tool Release: Gathering 802.11n Traces with Channel State Information. Computer Communication Review. 2011 01;41:53.

[31] Zafari F, Gkelias A, Leung KK. A Survey of Indoor Localization Systems and Technologies. IEEE Communications Surveys and Tutorials. 2019;21:2568-99.

[32] Wang W, Liu AX, Shahzad M, Ling K, Lu S. Device-Free Human Activity Recognition Using Commercial WiFi Devices. IEEE Journal on Selected Areas in Communications. 2017;35(5):1118-31.

[33] Youssef M, Mah M, Agrawala A. Challenges: device-free passive localization for wireless environments. In: Proceedings of the 13th annual ACM international conference on Mobile computing and networking; 2007. p. 222-9.

[34] Sigg S, Shi S, Büsching F, Ji Y, Wolf L. Leveraging RF-channel fluctuation for activity recognition: Active and passive systems, continuous and RSSI-based signal features. ACM International Conference Proceeding Series. 2013 12.

[35] Sigg S, Scholz M, Shi S, Ji Y, Beigl M. RF-Sensing of Activities from Non-Cooperative Subjects in Device-Free Recognition Systems Using Ambient and Local Signals. IEEE Transactions on Mobile Computing. 2014;13(4):907-20.

[36] Parameswaran AT, Husain MI, Upadhyaya S, et al. Is rssi a reliable parameter in sensor localization algorithms: An experimental study. In: Field failure data analysis workshop (F2DA09). vol. 5. IEEE

Niagara Falls, NY, USA; 2009. .
[37] Wang Y, Liu J, Chen Y, Gruteser M, Yang J, Liu H. E-eyes: Device-free location-oriented activity identification using fine-grained WiFi signatures. Proceedings of the Annual International Conference on Mobile Computing and Networking, MOBICOM. 2014 09.
[38] Wang W, Liu AX, Shahzad M, Ling K, Lu S. Understanding and Modeling of WiFi Signal Based Human Activity Recognition. In: Proceedings of the 21st Annual International Conference on Mobile Computing and Networking. MobiCom '15. New York, NY, USA; 2015. p. 65-76. Available from: https://doi.org/10.1145/2789168.2790093.
[39] Wang Y, Wu K, Ni LM. WiFall: Device-Free Fall Detection by Wireless Networks. IEEE Transactions on Mobile Computing. 2017;16(2):581-94.
[40] Palipana S, Rojas D, Agrawal P, Pesch D. FallDeFi: Ubiquitous Fall Detection using Commodity Wi-Fi Devices. PACM on Interactive, Mobile, Wearable and Ubiquitous Technologies (IMWUT). 2018 01;1.
[41] Wang H, Zhang D, Wang Y, Ma J, Wang Y, Li S. RT-Fall: A Real-Time and Contactless Fall Detection System with Commodity WiFi Devices. IEEE Transactions on Mobile Computing. 2017;16:511-26.
[42] Alwan M, Rajendran PJ, Kell S, Mack D, Dalal S, Wolfe M, et al. A Smart and Passive Floor-Vibration Based Fall Detector for Elderly. In: 2006 2nd International Conference on Information and Communication Technologies. vol. 1; 2006. p. 1003-7.
[43] Shao Y, Wang X, Song W, Ilyas S, Guo H, Chang WS. Feasibility of Using Floor Vibration to Detect Human Falls. International Journal of Environmental Research and Public Health. 2020 12;18:200.
[44] Huang Y, Chen W, Chen H, Wang L, Wu K. G-Fall: Device-free and Training-free Fall Detection with Geophones. 2019 16th Annual IEEE International Conference on Sensing, Communication, and Networking (SECON). 2019:1-9.
[45] Valero M, Li F, Zhao L, Zhang C, Garrido JM, Han Z. Vibration sensing-based human and infrastructure safety/health monitoring: A survey. Digit Signal Process. 2021;114:103037.
[46] Demiris G, Oliver D, Giger J, Skubic M, Rantz M. Older adults' privacy considerations for vision based recognition methods of eldercare applications. Technology and health care : official journal of the European Society for Engineering and Medicine. 2009 02;17:41-8.
[47] Bian C, Ye B, Hoonakker A, Mihailidis A. Attitudes and perspectives of older adults on technologies for assessing frailty in home settings: a focus group study. BMC Geriatrics. 2021 05;21.
[48] Laput G, Harrison C. Exploring the Efficacy of Sparse, General-Purpose Sensor Constellations for Wide-Area Activity Sensing. Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies. 2019 06;3:1-19.
[49] Clemente J, Li F, Valero M, Song W. Smart Seismic Sensing for Indoor Fall Detection, Location, and Notification. IEEE Journal of Biomedical and Health Informatics. 2020;24(2):524-32.
[50] Tsukiyama T. In-home Health Monitoring System for Solitary Elderly. Procedia Computer Science. 2015;63:229-35. Available from: https://www.sciencedirect.com/science/article/pii/S1877050915024734.
[51] Fagert J, Mirshekari M, Pan S, Zhang P, Noh HY. Monitoring hand-washing practices using structural vibrations. Structural Health Monitoring. 2017;1(01).
[52] Pan S, Berges M, Rodakowski J, Zhang P, Noh HY. Fine-Grained Recognition of Activities of Daily Living through Structural Vibration and Electrical Sensing. In: Proceedings of the 6th ACM International Conference on Systems for Energy-Efficient Buildings, Cities, and Transportation. BuildSys '19. New York, NY, USA; 2019. p. 149-58. Available from: https://doi.org/10.1145/3360322.3360851.
[53] Shi L, Mirshekari M, Fagert J, Chi Y, Noh HY, Zhang P, et al. Device-free Multiple People Localization through Floor Vibration. Proceedings of the 1st ACM International Workshop on Device-Free Human Sensing. 2019.
[54] Fagert J, Mirshekari M, Zhang P, Noh HY. Recursive Sparse Representation for Identifying Multiple Concurrent Occupants Using Floor Vibration Sensing. Proc ACM Interact Mob Wearable Ubiquitous Technol. 2022 mar;6(1). Available from: https://doi.org/10.1145/3517229.
[55] Javaid M, Haleem A, Rab S, Pratap Singh R, Suman R. Sensors for daily life: A review. Sensors International. 2021;2:100-21. Available from: https://www.sciencedirect.com/science/article/pii/S2666351121000425.
[56] Bouchabou D, Nguyen SM, Lohr C, LeDuc B, Kanellos I. A Survey of Human Activity Recognition in Smart Homes Based on IoT Sensors Algorithms: Taxonomies, Challenges, and Opportunities with Deep Learning. Sensors. 2021;21(18). Available from: https://www.mdpi.com/1424-8220/21/18/6037.

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Understanding User Needs, Persona Scenarios for Privacy-Preserving Visual System Development

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Abstract. As the world's population ages, the demand for active and assisted living technologies that can support older adults maintain their independence, health, and quality of life is increasing. Video monitoring cameras can provide a sense of safety and peace of mind for both older adults and their caregivers. However, these visual sensing systems come with major privacy concerns. Researchers have developed various visual privacy preservation filters that can be used for video-based monitoring technology, such as blurring, pixelation, silhouette, or avatar. To understand the user's needs and fine-tune the system to their preferences, the persona scenario method was employed in this study. The goal-directed approach to persona design was followed. This scenario-based technique involves creating fictitious persona archetypes that represent the unique characteristics, needs, and goals of the target user group and other stakeholders involved in the process of care provision. A set of eight personas were created based on the qualitative data collected through interviews and focus groups in Spain. Data from 62 participants were analyzed, which represented different contributor groups such as older adults, direct caregivers, healthcare experts, and other stakeholders. The final personas are accessible to the public on a Blueprint persona repository.

Keywords. Persona method, Active and Assisted Living, video-based technology, visual sensing systems, privacy, older adults, user-centered design, user needs.

1. Introduction

The world's population is aging, and this demographic shift is creating a growing demand for active and assisted living (AAL) technologies that can support older adults maintain their independence, health, and quality of life [1]. One such technology is video monitoring cameras, which can provide a sense of safety and peace of mind for both older adults and their caregivers [2]. However, privacy concerns are a significant barrier to the widespread adoption of video monitoring cameras in the context of AAL [3,4].

To address this matter, our research group has developed various visual privacy preservation filters which can be used for video-based monitoring technology [5]. The

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privacy-protective visualization models include blurring, pixelation, silhouette, skeleton, or avatar. Our team is working on refining a video-based AAL technology prototype that addresses privacy concerns by using the above-mentioned privacy filters that can be adjusted according to the user's preferences. At the first stage of this process, in order to better understand the user needs and fine-tune the system to their preferences we decided to employ a persona scenario approach, which then is followed by the prototype probing in a living lab setting. The use of persona scenarios is an increasing trend in the tech field aimed toward designing socially impactful products or systems [6]. The main goal of persona design is to understand the needs, preferences, and behaviors of the target audience and use this information to develop better products or services.

From several approaches to persona design we chose the goal-directed approach, originally offered by Cooper [7] and further refined in human-computer interaction settings [8,9]. It involves creating fictitious persona archetypes that represent the characteristics, needs, and goals of the target user group which makes the technology creator understand the user. The goal-directed persona creation method is a scenario-based approach to design, at the heart of which lies an archetype that is not portrayed as an average individual, but rather as a persona with unique characteristics [10]. Even if personas are user models that have fictional elements, they are based on studies of real or possible users. This approach has emerged with the aim of preventing the development of products that are influenced by stereotypes or biased models that exist in the minds of project teams. Such biased approaches can result in solutions that do not align with the actual needs of users, ultimately leading to a failure [11]. This approach can help the development of a technology that is tailored to the needs of the users and takes into account their specific preferences and concerns [10] and hence specifically fitted our goal of developing video-based AAL technology prototype suited to user needs.

The aim of this article is to present the use of the goal-directed persona scenario approach as a way to understand user needs in the process of developing a video-based monitoring system for older adults' care purposes.

2. Methods

Designing personas is a complex task that demands a profound comprehension of the intended audience. We were guided by the goal-directed design research manual in this process [12]. Alan Cooper advocates integrating various qualitative methods, such as literature review, interviews, focus groups, and ethnographic studies of the end users as well as possible stakeholders. This approach recognizes that personas must be based on real-world data, ensuring their authenticity and credibility.

After executing a scoping review on the acceptance and privacy perceptions toward video-based active and assisted living technologies [13], field research was carried out, which consisted of formal interviews, focus groups, and informal interviews.

2.1. Data Collection

Qualitative data collection in the forms of interviews and focus groups was conducted with different stakeholders involved in the process of care provision. All study procedures were approved by the Ethics Committee of the University of Alicante (Ethical Approval N UA-2022-10-16-1).

2.1.1. Participants

Participants in the study were drawn from a convenience sample in a way that fitted different sociodemographic profiles of a diversity of stakeholders suited for the study. The recruitment was executed with the help of the case manager from a healthcare center in Alicante, Spain. The total number of participants in the study was 65 out of which three participants were excluded: one older adult did not wish to sign the consent form, however, they were happy to attend the focus group discussion; two healthcare expert participant data were excluded because of incompleteness. The remaining 62 participants represent different stakeholder groups: older adults or direct care receivers (N=17), direct caregivers (N=18), healthcare experts (N=17), and other stakeholders (N=10). Figure 1 summarizes the data collection carried out for the persona design, where different stakeholder group compositions are displayed in greater detail.

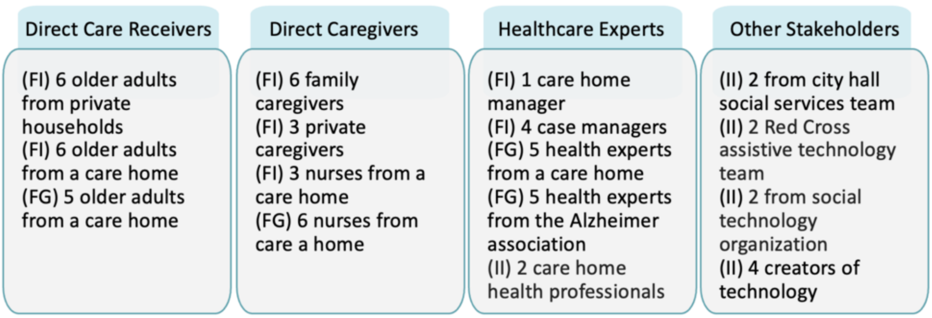

Figure 1. Qualitative data collection for the persona design. Four stakeholder category compositions are given together with the data collection tool used for each composite group: Formal Interview (FI), Focus Group (FG), Informal Interview (II).

2.1.2. Procedure

The data collection procedure was directed by Cooper's goal-directed design research [12], which gives a step by step guidance on how to conduct interviews and focus groups for persona design.

Participants were visited in their natural environments, which was their living space in the case of the older adults - researchers visited them in their private households and care homes, and work environment in the case of the caregivers, healthcare experts, and other stakeholders. All data collection was executed face-to-face, except for the interview with the two participants from a social technology organization, which was held online.

Semi-structured interviews, semi-structured focus groups and informal interviews were the main methods of the data collection. The employed method for each participant group is displayed in Figure 1. Formal interviews and focus groups started off by introducing the goal of the research to the participants and filling out the consent forms, which were followed by the main body of questions and ended with sociodemographic questionnaires. These sessions were audio recorded. Informal interviews followed a different protocol which did not include sociodemographic questionnaires and neither were audio recorded. Hence, the sociodemographic characteristics of the participants who provided data through formal interviews and focus groups are displayed in Figure 2.

	Direct Care Receivers N=17	Direct Caregivers N=18	Healthcare Experts N=15
Age Median [Min; Max]	80 [66; 87]	54 [29; 73]	53 [34; 63]
Sex	12 Females, 5 Males	13 Females, 5 Males	11 Females, 4 Males
Education	6 Primary 5 Secondary 5 Professional 1 University	9 Secondary 6 Professional 3 University	15 University
TechPH Median [Min; Max]	2.4 [2.1; 3.1]	NA	NA
CDS score Median [Min; Max]	64 [50; 70]	NA	NA
ATI Median [Min; Max]	NA	3.9 [2.2; 5.4]	5.4 [3.7; 5.7]
Experience in healthcare, Years Median [Min; Max]	NA	8 [3; 23]	17 [7; 35]

Figure 2. The sociodemographic characteristics of the participants who provided data through formal interviews and focus groups. TechPH - Older People's Attitudes Toward Technology Score from 1 to 5, from lowest to highest technophilia. CDS - Care Dependency Scale, $CDSsumscore \leq 68$ were classified as care-dependent, all others as independent. ATI - Affinity for Technology Interaction Score from 1 to 6, from lowest to highest affinity.

2.1.3. Data collection instrument

The data collection instrument was inspired by the Technology Acceptance (TAC) Toolkit [14,15] and Blueprint Persona framework [16]. The Technology Acceptance (TAC) Toolkit [15] is a research-based approach that helps design health technologies by looking at the user journey as a unique evolving trajectory. This work seeks to facilitate the application of Technology Acceptance Theory [17] in design practice through the toolkit comprising 16 cards, 3 personas, and 3 scenarios. It also allows a generation of one´s own temporal scenarios with user personas. The Blueprint on Digital Transformation of Health and Care for the Ageing Society [16] is an initiative that guides the efforts on how innovation can transform health and care provision in our aging society. As part of the Blueprint, a set of personas was created by a team of experts with varied backgrounds to identify the health and care needs of the population. They also created a venue for continuing their work by further persona construction and dissemination. Hence the interview/focus group guide was created according to the TAC research foundations and Blueprint Persona framework. The guide consisted of three main thematic parts: care provision, technological solutions for care, and privacy-associated risks of technology. Questions of each thematic part were tailored according to respondent profile: older adults or direct care receivers, direct caregivers, healthcare experts, and other stakeholders. Apart from the main body of questions the interview guide also included a sociodemographic questionnaire.

2.2. Persona creation

The manual Approach to the Qualitative Persona Clustering Method was used for the persona creation [18]. This involves techniques such as affinity diagrams, card sorting exercises, empathy mapping, and thematic analysis to develop thematic clusters based on goals, a combination of behaviors and attitudes [19,20,14,21]. Researchers advocate the manual approach to clustering when it comes to the rich qualitative data from interviews

[18]. This method creates a deeper understanding of user profiles, however, it is also criticized for difficulty in making objective judgments [22]. Even so, taking into account the goal-directed approach to the persona design, at the heart of which lies an archetype that is not portrayed as an average individual, but rather as a persona with unique characteristics, the manual approach to clustering emerges as the most suitable option [12]. As a result, a framework analysis [23] in combination with affinity mapping and empathy mapping was used for persona creation using Dovetail software[24]. Framework analysis takes a deductive approach to thematic analysis, the coding process is guided by existing theory or a set of preconceived themes [25,26], which in our case was a framework offered by the Blueprint personas [16]. The same framework guided us for data clustering in empathy maps and affinity diagrams to create a visual representation of the target audience's needs, goals, emotions, and behaviors.

3. Results

A total of eight persona scenarios were developed based on the collected data using the Blueprint persona framework. Three of them represent the care receiver group: an older adult living alone, an older adult living with a spouse, and an older adult from a care home. Two personas portray direct caretaker groups: a family caregiver and a care home nurse. And lastly, three of the personas depict other stakeholders involved in the care provision: a healthcare expert - case manager, a care home manager, and a technology creator. In accordance with the goal-oriented design rationale, our personas were developed by incorporating actual data and specific attributes of the target stakeholder group, including factors like age, health condition, and lifestyle. These personas shall not be taken as an average representation of the target group, but rather as a persona with unique characteristics. Example variables for defining persona clusters are given in Figure 3.

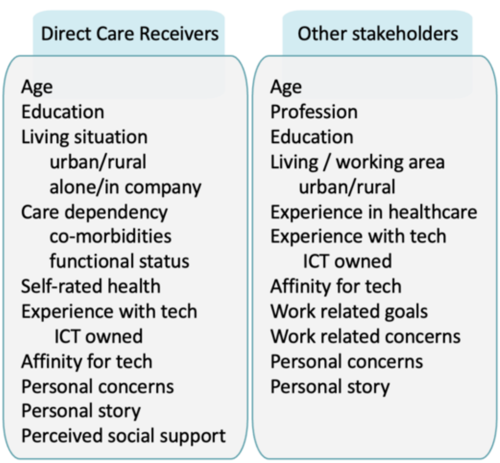

Figure 3. Example variables for defining persona clusters.

An example persona, Sergio is displayed in Figure 4, followed by a Customized Empathy Map for him in Figure 5. All eight personas can be accessed on the Blueprint persona repository: Spin-off Personas and are available for public use, https://blueprint-personas.eu/. The Blueprint website also offers sorting tools for easier filtering of desired persona profiles.

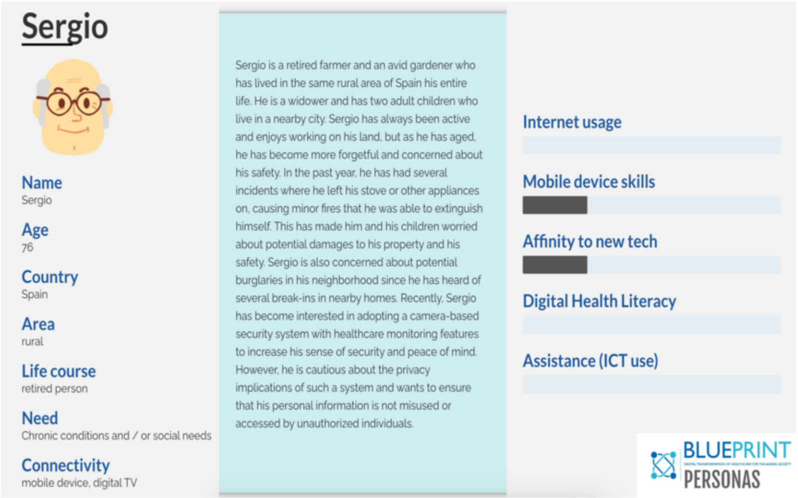

Figure 4. An example persona, Sergio

The set of personas draws a picture of different stakeholder perspectives in order to better understand the user needs in the process of the development of privacy-preserving visual systems. They serve as an empathy tool that facilitates communication between the healthcare sector, technology design teams, and older adults as the main target users. We specifically tried to spot challenges and potential conflicts of interest between the needs and aims of different stakeholders, which arise in the process of the implementation of the monitoring system, and convey them through the persona scenarios.

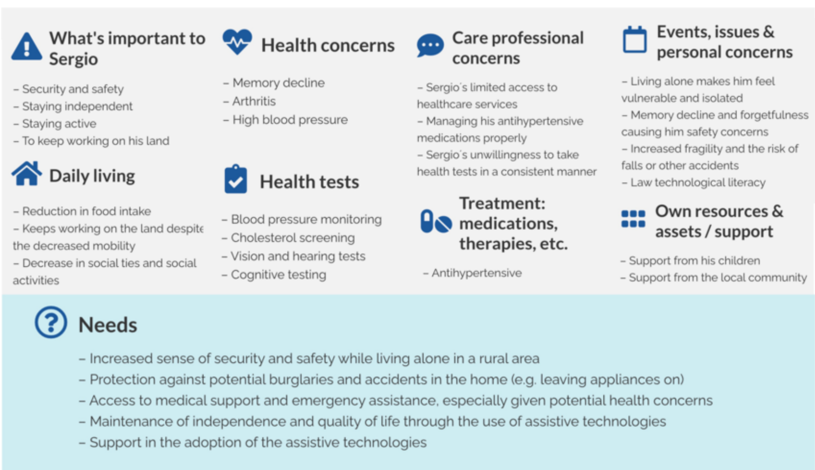

Figure 5. Customized Empathy Map for the example persona - Sergio

4. Discussion

We have presented how the goal-directed persona scenario approach can be utilized to comprehend user requirements for an AAL system development, specifically a video-based monitoring system intended for the care of older adults in this case. This approach to persona design emphasizes that interaction is driven by users' motives and goals and acts as an empathy tool in the system development process. It's worth noting that personas should not be a substitute for direct involvement and engagement with end users. Instead, they serve as a structured and targeted approach to comprehending and conveying user requirements during the product development process. For that reason, the current stage of the design involves user testing of the prototype in a realistic environment of a living lab setting. Different stakeholders represented in the eight personas are part of the user testing. This experience has demonstrated to us that, while personas contain the fundamental information required for designing the proposed system for older adults, they may not encompass all the diverse elements that become evident during user testing. New details and even new core personas are emerging in the process of the prototype probing with diverse stakeholders.

It is also important to note that personas as a design tool are a rather costly and time-consuming approach, which is also often criticized for its transient nature. The majority of personas that are created are tailored to a particular project and design problem, and cannot be applied to different contexts, making it unique in its application [11]. Likewise, the proposed personas represent a very specific context of the proposed system application - older adults living in Spain, which makes it very difficult to generalize the setting and reuse the personas. On the other hand, this approach is beneficial when targeting a very specific audience where, instead, generalization could be counter-effective. Indeed the developed personas serve our goal of advancing an AAL system for the specific Spanish context. We also consider that research teams working on visual sensing AAL technology can be inspired by the use of this tool, and the Blueprint persona repository, which is open to the public, can serve this aim.

In conclusion, video-based active and assisted living technology has the potential to improve the quality of life of older adults, however, privacy considerations need to be taken into account. The use of persona scenarios has helped us in the design process to address privacy concerns and ensure that the technology meets the needs of the target user group. The study findings inform the development of the video-based AAL technological system that is tailored to the needs of the intended audience and can enhance the quality of life for older adults while taking into account their privacy considerations.

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References

[1] AAL Programme [Internet]; 2020. [cited 2023 Jun 17]. Available from: http://www.aal-europe.eu.

[2] Climent-Pérez P, Spinsante S, Mihailidis A, Florez-Revuelta F. A review on video-based active and assisted living technologies for automated lifelogging. Expert Systems with Applications. 2020;139:112847.
[3] Peek ST, Wouters EJ, Van Hoof J, Luijkx KG, Boeije HR, Vrijhoef HJ. Factors influencing acceptance of technology for aging in place: a systematic review. International journal of medical informatics. 2014;83(4):235-48.
[4] Yusif S, Soar J, Hafeez-Baig A. Older people, assistive technologies, and the barriers to adoption: A systematic review. International journal of medical informatics. 2016;94:112-6.
[5] Climent-Pérez P, Florez-Revuelta F. Protection of visual privacy in videos acquired with RGB cameras for active and assisted living applications. Multimedia Tools and Applications. 2021;80(15):23649-64.
[6] Salminen J, Wenyun Guan K, Jung SG, Jansen B. Use cases for design personas: A systematic review and new frontiers. In: Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems; 2022. p. 1-21.
[7] Cooper A. The inmates are running the asylum. Springer; 1999.
[8] Shyba L, Tam J. Developing character personas and scenarios: vital steps in theatrical performance and HCI goal-directed design. In: Proc. of the 5th Conference on Creativity & Cognition; 2005. p. 187-94.
[9] Blomkvist S. The user as a personality-using personas as a tool for design. KTH-Royal Institute of Technology, Stockholm Www Nada Kth Se/tessy/Blomkvist Pdf. 2002;980.
[10] Löwgren J, al, editors. The Encyclopedia of Human-Computer Interaction, 2nd. Aarhus, Denmark: The Interaction Design Foundation; 2014.
[11] Wöckl B, Yildizoglu U, Buber I, Aparicio Diaz B, Kruijff E, Tscheligi M. Basic senior personas: a representative design tool covering the spectrum of European older adults. In: Proceedings of the 14th international ACM SIGACCESS conference on Computers and accessibility; 2012. p. 25-32.
[12] Cooper A, Reimann R, Cronin D, Noessel C. About face: the essentials of interaction design. John Wiley & Sons; 2014.
[13] Mujirishvili T, Maidhof C, Florez-Revuelta F, Ziefle M, Richart-Martinez M, Cabrero-García J. Acceptance and Privacy Perceptions Toward Video-based Active and Assisted Living Technologies: Scoping Review. Journal of Medical Internet Research. 2023;25:e45297.
[14] Nadal C, McCully S, Doherty K, Sas C, Doherty G. The TAC Toolkit: Supporting Design for User Acceptance of Health Technologies from a Macro-Temporal Perspective. In: Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems; 2022. p. 1-18.
[15] TAC Toolkit [Internet]; 2022. [cited 2023 Jun 17]. Available from: http://ehealthacceptancedesign.com.
[16] Blueprint Personas;.
[17] Davis FD. A technology acceptance model for empirically testing new end-user information systems: Theory and results. Massachusetts Institute of Technology; 1985.
[18] Brickey J, Walczak S, Burgess T. A comparative analysis of persona clustering methods. In: AMCIS 2010 Proceedings. 217; 2010. .
[19] Broschinsky D, Baker L. Using persona with XP at LANDesk software, an avocent company. In: Agile 2008 Conference. IEEE; 2008. p. 543-8.
[20] Turner AM, Reeder B, Ramey J. Scenarios, personas and user stories: User-centered evidence-based design representations of communicable disease investigations. Journal of biomedical informatics. 2013;46(4):575-84.
[21] Ferreira B, Silva W, Oliveira E, Conte T. Designing Personas with Empathy Map. In: SEKE. vol. 152; 2015. .
[22] Pruitt J, Adlin T. The persona lifecycle: keeping people in mind throughout product design. Elsevier; 2010.
[23] Gale NK, Heath G, Cameron E, Rashid S, Redwood S. Using the framework method for the analysis of qualitative data in multi-disciplinary health research. BMC medical research methodology. 2013;13(1):1-8.
[24] Dovetail [Internet];. [cited 2023 Jun 17]. Available from: https://www.dovetail.com.
[25] Fereday J, Muir-Cochrane E. Demonstrating rigor using thematic analysis: A hybrid approach of inductive and deductive coding and theme development. International journal of qualitative methods. 2006;5(1):80-92.
[26] Nowell LS, Norris JM, White DE, Moules NJ. Thematic analysis: Striving to meet the trustworthiness criteria. International journal of qualitative methods. 2017;16(1):1609406917733847.

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Video-Based AAL and Intimate Pictures – Criminal Liability in European, Irish, and Polish Law

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Abstract. Active and Assisted Living (AAL) technologies offer solutions for addressing healthcare challenges associated with ageing societies and a shortage of care personnel. At the same time, these technologies raise significant privacy issues, which may constitute a barrier to the sustainable adoption and acceptance of AAL. In particular, concerns arise from the presence of cameras in intimate situations, including nudity, and the potential production and dissemination of intimate pictures, which constitutes a risk for AAL users. The paper compares the regimes of criminal liability for making and disseminating intimate pictures under EU, Irish, and Polish law. The study aims to help AAL users understand their legal protection, and give providers and developers more insight into their legal responsibilities. The paper first presents different understandings of an intimate picture in each jurisdiction, followed by a discussion of what the crime entails and who may be liable for it. The conclusion includes a checklist of rules concerning criminal liability, which may be useful for AAL users and providers, and conclusions *de lege ferenda*.

Keywords. Active and Assisted Living, intimate pictures, criminal law.

1. Introduction

Active and Assisted Living (AAL) technologies have emerged as a promising solution to the healthcare challenges faced by ageing societies and a shortage of care personnel [1]. These technologies aim to provide support and assistance to elderly individuals in their daily lives, with the ultimate goal of enabling them to live independently and comfortably in their own homes. Among the various technological components used in AAL, visual components such as video or depth cameras are particularly promising as they provide a natural and direct way to record situations and movements and supply rich information – for example, about accidents like falls [2]. However, the use of cameras in private spaces raises significant privacy concerns that may hinder the sustainable adoption and acceptance of AAL [3, 4]. One of the biggest concerns is the presence of cameras in intimate situations, including nudity, which may lead to a potential production and dissemination of intimate pictures and constitute a risk for AAL users [3, 5, 6]. These issues are being addressed not only from a technical perspective [7, 8], but also by the law.

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This contribution aims to compare the regimes of criminal liability for the production and dissemination of intimate pictures under EU, Irish, and Polish law, and to identify potential gaps and shortcomings in the existing legal regimes. The study provides a comprehensive overview of the legal protections available to users of AAL systems, and offers insights into the legal responsibilities of providers and developers in these jurisdictions. Firstly, the concept of an intimate picture is examined in each jurisdiction. Secondly, the paper analyses the elements of a crime in the respective legislations. Thirdly, the potential criminal liability of natural and legal persons, including AAL providers, is investigated. This paper focuses on Ireland and Poland with the aim of analysing countries with different legal traditions (common law and civil law) and distinct socio-economic contexts. The two countries' EU member status also provokes questions concerning the level of legal harmonisation, and coherence with the Union's law.

2. Understanding of an intimate picture

The first step in investigating criminal liability in the context of intimate pictures is to identify the material scope of the research, i.e. what legal acts regulate that issue and how an intimate image may be defined. Currently, there is no EU legislation concerning intimate pictures. However, in March 2022, the European Commission proposed a new Directive on combating violence against women and domestic violence (Directive) [9], which includes measures on the "non-consensual distribution of intimate and manipulated" images (Article 7). In Ireland, the Harassment, Harmful Communications and Related Offences Act 2020 (Act) was passed [10]. The Act contains two offences related to intimate pictures: recording or distributing (section 3), and distributing, publishing, or threatening to do so (section 2). In Polish law, unconsented depicting or disseminating a "representation of a naked person" or "a person engaged in sexual activity" constitute a criminal offence under Article 191a §1 of the Penal Code (Polish: Kodeks Karny, KK) since 2010 [11]. This paper discusses the notion of intimate pictures in the identified regulations in chronological order, i.e., from the Polish one, through the Irish Act, to the proposed Directive, which allows tracking changes in the legislative approach to intimate pictures.

The location of Article 191a §1 KK is not without relevance for its interpretation. That article is located in the part of the Code concerning offences against freedom, and the value protected by Article 191a §1 KK is a person's freedom of deciding upon depicting and disseminating one's representation [12]. Polish law does not employ the term "intimate pictures" but instead uses the phrase "representation of a naked person or a person engaged in sexual activity". However, these two situations may be considered jointly as intimate ones. The sexual activity shall be interpreted broadly, taking into account cultural and social context [13, 14]. Nudity is not legally defined in Poland. In a case like that, the literal interpretation, based on dictionaries and common understanding, should be pursued, following the principles of strict interpretation and *in dubio pro reo* ("[when] in doubt, rule for the accused") (Article 1§1 KK, Article 5§2 Code of Criminal Proceedings) [11, 15, 16, 17]. Consequently, a naked person would mean a person not wearing any piece of clothing or being covered. That interpretation is considered by many scholars as irrational and against *ratio legis* [18]. Instead, some propose considering a person naked when "a considerable part" of the body is uncovered" [19, 20], or when some particular parts of the body are revealed, i.e., genitals and, in the case of a female, her breasts [21, 22]. To reconcile various approaches and limit legal uncertainty, Filek [16] proposes defining a naked person as a person whose at least one intimate part of the body is recognizable. That definition, not contested in the discourse, may be seen as a consensual one [23].

In Irish law, the term "intimate picture" is legally defined in section 1 of the Act. Under that section, intimate image "means any visual representation made by any means, including any photographic, film, video or digital representation." The law defines also the content of the intimate image, providing a closed list of representations:

a) "of what is, or purports to be the person's genitals, buttocks or anal region and, in the case of a female, her breasts;

b) of the underwear covering the person's genitals, buttocks or anal region and, in the case of a female, her breasts;

c) in which the person is nude, or

d) in which the person is engaged in sexual activity."

The definition of an intimate image provided in Irish law has several significant implications. Firstly, it distinguishes four types of intimate images. This differentiation suggests that these conditions are viewed as distinct by the law, even though they can occur simultaneously. Secondly, while nudity is listed as one constitutive criterion of an intimate picture, it is not defined by the law. The fact that the law distinguishes between images of intimate areas or underwear covering them and images of nude persons may imply that being lightly covered does not constitute nudity. However, this distinction may not be rational as a person can be nude, but their intimate parts may be covered. In such a scenario, the image would be protected under section 1 (c). This interpretation is supported by Bowie [24], who notes that the Act was intended to prevent situations like the tragic case of a person detained in 2017 after walking naked on a Dublin's street and whose arrest was recorded by CCTV cameras, and who subsequently took her own life. Thirdly, it is worth noticing that the Irish definition covers also "what purports to be" a person's intimate parts, a definition that encompasses Photoshopped images and deepfakes [24, 25, 26].

The proposed EU Directive aims to "effectively combat violence against women and domestic violence throughout the EU" by laying down minimum rules on the definition of relevant criminal offences, including "non-consensual sharing of intimate or manipulated material" (Article 7). Despite its name, the Directive understands the victim as "any person, regardless of sex or gender" (Article 4(c)). The Directive makes a distinction between intimate and manipulated images, videos, and "other material." According to Article 7(b), manipulation refers to "making it appear as though another person is engaged in sexual activities." Consequently, the provisions governing manipulated material would not extend to a deepfake that depicts a person naked. Article 7(a) pertains to the dissemination of "intimate images, or videos or other material depicting sexual activities, of another person" through ICTs. However, the extent of this norm is ambiguous, and it may only apply to representations of sexual activities. Rigotti and McGlynn [27] suggest a broader interpretation that includes "images which are deemed sexual and/or intimate". The absence of a clear definition of an intimate image is a notable drawback of the Directive. It would be advantageous to establish a comprehensive description of what constitutes an intimate image, drawing on the legal frameworks of Member States and academic research.

3. Matter of a crime

To comprehensively explore the criminal liability surrounding intimate pictures, it is essential to examine the elements that constitute a crime. Across the three jurisdictions discussed, the common condition of a crime is the absence of consent from the depicted person. There are no specific requirements regarding the form in which consent must be given, which can lead to various difficulties in cases of dispute. In the context of AAL, providers can potentially mitigate the illegality of intimate pictures by obtaining the user's acceptance that such pictures may be taken in specific situations, such as assisting in toileting.

In the investigated jurisdictions two actions constitute a crime: production and dissemination of intimate pictures (Article 191a §1 KK, Section 2 and 3 Act, Article 7(a) and 7(b) Directive). Committing either of these actions separately is sufficient to constitute a crime. Consequently, disseminating legally obtained nude images is sufficient to commit a crime. It is important to note that consent for dissemination may be restricted [20, 28, 29]. For example, an individual using AAL technologies may agree to allow their images to be viewed only by AAL provider's employees, care facility staff, or family members. Disseminating such images to anyone beyond this group would constitute a criminal offence.

The third element that may be required for an action to be illegal is harm. In Irish law, section 3 of the Act requires harm to occur as an element of the crime, while section 2 requires the offence to be committed "with intent to cause harm or being reckless as to whether harm is caused." Both sections define harm as "serious interference with that other person's peace and privacy, causing alarm, distress or harm to that other person," including psychological harm (section 1). As noticed by Bowie [24], these provisions "could potentially limit prosecutorial possibilities, especially in relation to the intent of the perpetrator." The law mandates that the harm and its connection with the action or intention of the perpetrator be proven beyond a reasonable doubt. There are two potential challenges resulting from this requirement, as identified by McGlynn and Rackley [25]. Firstly, there is a risk that these provisions "reify an 'ideal victim' by predetermining what is seen to be the 'appropriate' response from victims." This may result in a situation where prosecution is unlikely if the victim does not react as expected. Secondly, if there are multiple victims or a potential victim is unaware that they have been victimized, prosecution may not be feasible. However, from the perspective of an AAL provider, the requirement of harm excludes criminality of an action if the provider acts diligently and with good intentions. Contrary to Irish regulations, there is no reference to harm in the proposed Directive or the Polish law. Because Article 191a §1 KK safeguards personal freedom, and non-consensual depiction of a person in an intimate situation is considered implicitly harmful [12, 19].

Reference to harm brings the discussion to the fourth element of a crime, which is the purposefulness of an action. Section 2(1) Act conditions the criminal nature of the act on the intention of the perpetrator to cause harm or their recklessness as to whether harm is caused, to the extent predictable to a "reasonable person" (Section 2(2)). Similarly, Polish law defines intent as a will to commit a prohibited act or "foreseeing the possibility of perpetrating it, and accepting it" (Article 9 §1 KK). Additionally, a crime may be committed by omission if a person who had borne a legal, special duty to prevent such a consequence, failed to do so (Article 2 KK). Arguably, this provision can be applied to providers of AAL systems. On one hand, the main function of AAL technology is to support the quality of life and independence of users. On the other hand, the protection of privacy, including intimate situations, is a crucial requirement of users [5]. Moreover, as AAL providers deliver care and assistance products, they are in a relation of trust with users. For these reasons, there is a high probability that they have a special duty of care. Consequently, providers may commit the crime by omission in Polish law. However, there is a lack of relevant case law to verify that hypothesis.

Finally, it is important to note that Polish legislation incorporates provisions that address the methods employed to make an intimate picture. According to Article 191a §1 KK, the act of capturing an intimate image is deemed unlawful only if it involves deception, coercion, or threat against the victim. Therefore, using a hidden camera would constitute a criminal offence, whereas capturing the same image with a visible camera would be permissible. In the context of video-based AAL a potential act of deception may occur if the camera is operational, but the user has reasonable grounds to believe otherwise (for instance, if the control device incorrectly indicates that the system is turned off). However, it should be emphasized that the offence is only committed if such deception is intentional or results from negligence.

To conclude, in all discussed jurisdictions, an intended production or dissemination of an intimate image without the consent of the depicted person is a prohibited act. In Ireland harm is an additional condition for an act to be considered criminal. Under Polish law, the crime in question may be committed also by omission, on the basis of AAL providers' duty of care. Moreover, in Polish jurisdiction capturing an intimate image is deemed unlawful only if it involves deception, coercion, or threat against the victim.

4. Criminal liability of natural and legal persons

In the context of producing and disseminating intimate images, the question arises as to who may be held accountable for the offence. The crucial point is whether only individuals (such as employees or managers of the AAL provider) or legal entities, (the AAL provider as a company) may be subject to prosecution. Notably, the proposed EU Directive does not include specific provisions regarding the criminal liability of legal entities. It does not preclude criminal liability of organisations or companies but rather leaves those issues to Member States' laws.

Both Irish and Polish laws contain provisions about the criminal liability of people other than just the direct perpetrators. Section 6(1) Act states that in some circumstances the managers of a company are liable for acts of the body corporate. To apply that provision, an offence must be committed by a body corporate, and it must be proven that the offence can be attributed to "any wilful neglect" or was committed with the consent or connivance of a manager. In the context of section 6(1) Act, "managers" refers to the directors, managers, secretaries, or other officers of the body corporate or of a person purporting to act in such a capacity. Similarly, in Polish law every person that was both in a position to and legally obliged to prevent the crime but did not do so is criminally liable as an associate (Article 18 §3 KK). Additionally, whenever a special duty of care exists, a person may be held liable on the ground of negligence (Article 2 KK). In the context of a company providing AAL, these rules may be applied to managers on various levels of management, but also to employees working on the development of technology.

Additionally, in some cases legal persons may also be held criminally liable. According to Section 6(1) Act, if the conditions discussed in the relations to managers are satisfied, the corporate body itself is guilty of an offence and subject to prosecution and punishment. Thus, the AAL provider as a company, not just its employees, may be held criminally liable. Similarly, Polish law allows for the criminal prosecution of a legal person if three requirements are met. The first condition requires the identification and conviction of the natural person who committed the prohibited act under Article 4 of the Act of 28 October 2002 on the Liability of Collective Entities for Prohibited Acts [30]. The second condition is that the convicted natural person acted in the name or interest of the legal entity, and the act itself must have potentially benefited the legal person in any way under Article 3. Finally, the legal entity must have failed to exercise due diligence in selecting or supervising employees or other agents who committed the prohibited act, under Article 5. All three conditions must be met simultaneously for a natural person to be criminally liable. This high bar for criminal liability means that, in most cases, the AAL provider would not be criminally liable under Polish law. Conversely, Irish regulations make it easier to hold the company responsible for the crime of producing or disseminating intimate images.

5. Conclusions

Two kinds of conclusions can be drawn from the current paper. First, rules concerning criminal liability in Ireland and Poland may be presented in the form of a checklist with questions. This checklist may be useful both for AAL users and providers for getting informed about their rights and obligations. The Directive is not included in that summary due to a lack of detailed norms.

Table 1. Checklist of conditions of criminal liability in the context of intimate pictures in Ireland and Poland.

Ireland	Poland
1. Is a picture an intimate one?	
1.1. Does it depict a person engaged in sexual activity?	1.1. Is depicted person identifiable?
1.2. Is it a picture a) of what is, or purports to be, the person's genitals, buttocks or anal region and, in the case of a female, her breasts; b) of the underwear covering the person's genitals, buttocks or anal region and, in the case of a female, her breasts; c) in which the person is nude, or d) in which the person is engaged in sexual activity?	1.2. Does it depict a person engaged in sexual activity? 1.3. Is at least one intimate part of the body recognisable?
If the answer to 1.1. or 1.2. a, b, c, or d is "yes", then a picture is an intimate one.	If the answers to 1.1. and to 1.2. or 1.3. are "yes", the picture is an intimate one.
2. Was there a criminal offence?	
2.1. Did you depict an intimate picture?	2.1. Did you depict an intimate picture?
2.2. Did you disseminate an intimate picture?	2.2. Did you disseminate an intimate picture?
2.3. Did you do that without the consent of the depicted person?	2.3. Did you do that without the consent of the depicted person?
2.4. Did your action cause or intended to cause harm?	2.4. Did you do that intentionally? 2.5. Did you make an intimate picture using deception, coercion, or threat? 2.6. Did you have a special duty of care and failed to comply with it?
If the answers to 2.1. or 2.2., and both 2.3. and 2.4. are "yes", the prohibited act has been committed.	If the answers to 2.1. and 2.3. and 2.4., and 2.5., or to 2.2. and 2.3. and 2.4. or 2.6. are "yes", the prohibited act has been committed.
3. Criminal liability of manager or organisation	

3.1. Did the prohibited action result from the operation of the body corporate? 3.2. Was the offence committed with the consent or connivance of a manager, or can it be attributed to any wilful neglect?	3.1. Did a person have a special obligation to prevent the crime? 3.2. Did a person have a special duty of care
If the answers to 3.1. and 3.2. are "yes", the managers can be criminally liable.	If the answer to 3.1. or 3.2. is "yes", the managers can be criminally liable.
	3.3. Was the offender of the crime convicted? 3.4. Did the offender act in the name or the interest of an organisation? 3.5. Did the legal entity fail to exercise due diligence in selecting or supervising employees or agents that committed a crime?
If the answers to 3.1. and 3.2. are "yes", the company may be criminally liable.	If the answers to 3.3., 3.4., and 3.5. are "yes", the organisation may be criminally liable.

Second, a critical comparison of three legal systems yields important insights for potential legal reforms. Firstly, Irish law stands out for its comprehensive and precise definition of an intimate picture, encompassing various types and enhancing legal certainty. This could serve as a valuable reference point for other legislations. Secondly, the requirement of proven harm in Irish law may inadvertently limit the protection afforded to individuals. To better safeguard individuals' rights, it is crucial to recognise the inherent harm of unconsented intimate pictures, as in the Polish approach. Thirdly, there is a pressing need to clarify and harmonize rules on the criminal liability of legal entities within the EU. The significant disparities observed among the examined Member States necessitate a cohesive and uniform approach. These three conclusions should guide EU legislators in future efforts to refine the Directive, ensuring harmonization that benefits both users and providers of AAL technologies by clearly defining their respective responsibilities and rights.

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References

[1] Jaschinski C, Ben Allouch S. An extended view on benefits and barriers of ambient assisted living solutions. Int J Adv Life Sci. 2015;7(2).
[2] Climent-Pérez P, Spinsante S, Mihailidis A, Florez-Revuelta F. A review on video-based active and assisted living technologies for automated lifelogging. Expert Systems with Applications. 2020;139:112847. doi:10.1016/j.eswa.2019.112847.
[3] Arning K, Ziefle M. "Get that camera out of my house!" conjoint measurement of preferences for video-based healthcare monitoring systems in private and public places. Inclusive Smart Cities and e-Health. 2015;152–64. doi:10.1007/978-3-319-19312-0_13
[4] Yusif S, Soar J, Hafeez-Baig A. Older people, Assistive Technologies, and the barriers to adoption: A systematic review. International Journal of Medical Informatics. 2016;94:112–6. doi:10.1016/j.ijmedinf.2016.07.004
[5] Maidhof C, Hashemifard K, Offermann J, Ziefle M, Florez-Revuelta F. Underneath your clothes: A social and technological perspective on nudity in the context of Aal Technology. Proceedings of the 15th

International Conference on PErvasive Technologies Related to Assistive Environments. 2022; doi:10.1145/3529190.3534733
[6] Ehrari H, Ulrich F, Andersen HB. Concerns and trade-offs in information technology acceptance: The balance between the requirement for privacy and the desire for safety. Communications of the Association for Information Systems. 2020;47(1):227–47. doi:10.17705/1cais.04711
[7] Cámara-Chávez G, Araújo A de. Harris-sift descriptor for video event detection based on a machine learning approach. 2009 11th IEEE International Symposium on Multimedia. 2009; doi:10.1109/ism.2009.116
[8] Sui L, Zhang J, Zhuo L, Yang YC. Research on pornographic images recognition method based on visual words in a compressed domain. IET Image Processing. 2012;6(1):87. doi:10.1049/iet-ipr.2011.0005
[9] European Commission. Proposal for a Directive of the European Parliament and of the Council on combating violence against women and domestic violence. COM/2022/105 final.
[10] Harassment, Harmful Communications and Related Offences Act 2020. Available from: https://www.oireachtas.ie/en/bills/bill/2017/63/.
[11] Act of 6 June 1997 - Penal Code, Journal of Laws 1997, no. 88, item 553. Available from: https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=wdu19970880553..
[12] Hypś S. Przestępstwa przeciwko wolności. In: Grześkowiak A, Wiak K, Ciepły F, editors. Kodeks Karny: Komentarz. Warszawa: Wydawnictwo C.H. Beck; 2021.
[13] Bielski M. Wykładnia znamion "obcowanie płciowe" i "inna czynność seksualna" w doktrynie i orzecznictwie sądowym. Czasopismo prawa karnego i nauk penalnych. 2008;1:211-228.
[14] Supreme Court of Poland. Resolution of the Supreme Court dated 19 May 1999, I KZP 17/99, OSNKW 1999, no. 7/8, item 37.
[15] Act of 6 June 1997 - Code of Criminal Procedure, Journal of Laws 1997, no. 89, item 555, https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=wdu19970890555.
[16] Filek B. Wizerunek nagiej osoby jako znamię przestępstwa z art. 191a § 1 kk. Prokuratura i Prawo. 2012;7:61-77.
[17] Królikowski M, Zawłocki R, Budyn-Kulik M, Długosz J, Dróżdż D, Hryniewicz-Lach E, et al. Kodeks Karny - część Szczególna. Warszawa: Wydawnictwo C. H. Beck; 2017.
[18] Lech Morawski. 2002. *Wykładnia W Orzecznictwie SĄDÓW: Komentarz*, Toruń: Towarzystwo Naukowe Organizacji i Kierownictwa "Dom Organizatora".
[19] Polińska A. Nudity. A legal study with a special perspective of Polish criminal law [dissertation]. Olsztyn, Poland: University of Warmia and Mazury in Olsztyn; 2020.
[20] Królikowski M. Przestępstwa przeciwko wolności . In: Wąsek A, Flemming M, Zawłocki R, editors. Kodeks Karny: Część Szczególna. Warszawa: C. H. Beck; 2010.
[21] Filar M. Przestępstwa przeciwko wolności. In: Filar M, editor. Kodeks karny. Komentarz. Warszawa; 2014.
[22] Kłączyńska N. Przestępstwa przeciwko wolności. In: Giezek J, Gruszecka D, Lipiński K, Łabuda G, Muszyńska A, Razowski T, editors. Kodeks Karny: Część Szczególna: Komentarz. Warszawa: Wolters Kluwer; 2021.
[23] Księżak P, Pyziak-Szafnicka M. Kodeks cywilny. Cześć ogólna. Warszawa: Wolters Kluwer; 2009.
[24] Bowie E. Image-Based Sexual Offences and Irish Law: Does the Harassment, Harmful Communications and Related Offences Bill 2017 Provide Adequate Legal Protection for Victims? Trinity Women's Review. 2021;4(1):140-155. DOI: http://dx.doi.org/https://www.esr.ie/index.php/TrinityWomensReview/article/view/2054/621
[25] McGlynn C, Rackley E. More than 'Revenge Porn': Image-Based Sexual Abuse and the Reform of Irish Law. Irish probation journal. 2017;14:38-51. DOI: http://dx.doi.org/http://www.probation.ie/EN/PB/0/12D6F4D1961C4695802581D0003D92D9/$File/ClareMcGlynn_ErikaRackley_IPJ.pdf
[26] Gladston B, Laws C. Why One mom's investigation might actually stop revenge porn: On the media. (December 2013). Retrieved January 26, 2023 from https://www.wnyc.org/story/why-one-moms-investigation-might-actually-stop-revenge-porn/#transcript
[27] Rigotti C, McGlynn C. Towards an EU criminal law on violence against women: The ambitions and limitations of the Commission's proposal to criminalise image-based sexual abuse. New Journal of European Criminal Law. 2022;13(4):452-477. DOI: http://dx.doi.org/10.1177/20322844221140713
[28] Supreme Court of Poland. Judgment of 15 October 2009, case no. I CSK 72/09. Case Law of the Supreme Court in Civil Cases 2010; Nr A: 29.
[29] Kosonoga J. Karnoprawna ochrona intymnego wizerunku osoby. In: Studia i Analizy Sądu Najwyższego. Warsaw: Wolters Kluwer; 2011. p. 220-224.
[30] Act of 28 October 2002 on the Liability of Legal Entities for Prohibited Acts Under Penalty]. Dziennik Ustaw [Journal of Laws] 2002, Nr 197, poz. 1661.

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Privacy by Design Solution for Robust Fall Detection

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Abstract. The majority of falls leading to death occur among the elderly population. The use of fall detection technology can help to ensure quick help for fall victims by automatically informing caretakers. Our fall detection method is based on depth data and has a high level of reliability in detecting falls while maintaining a low false alarm rate. The technology has been deployed in over 1,200 installations, indicating user acceptance and technological maturity. We follow a privacy by design approach by using range maps for the analysis instead of RGB images and process all the data in the sensor. The literature review shows that real-world fall detection evaluation is scarce, and if available, is conducted with a limited amount of participants. To our knowledge, our depth image based fall detection method has achieved the largest field evaluation up to date, with more than 100,000 events manually annotated and an evaluation on a dataset with 2.2 million events. We additionally present an 8-months study with more than 120,000 alarms analysed, provoked by 214 sensors located in 16 care facilities in Austria. We learned that on average 2.3 times more falls happen than are documented. Consequently, the system helps to detect falls that are otherwise overseen. The presented solution has the potential to make a significant impact in reducing the risk of accidental falls.

Keywords. fall detection, depth data, evaluation, practice

1. Introduction

Falls are a major public health issue that can lead to physical and psychological consequences [1]. Every year, one in three people aged 65 and over experience a fall [2], increasing to one in two people for those over 80 [3]. The majority of injury-related hospitalizations, including falls leading to death, occur among the elderly population [4]. Assisting people when getting out of bed and fast reactions to falls can help to reduce costs [5] and the risk of injury [6]. Fall detection technology can provide quick help for fall victims through automated alerts to caretakers. Detecting sitting-up positions can even play a preventive role in reducing falls, as care personnel can be alerted to offer timely support. Our method, based on depth data, has high reliability in detecting falls while maintaining a low false alarm rate.

The system has been implemented in more than 1,200 locations, indicating user acceptance and technological maturity. We follow a privacy by design approach by using

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range maps instead of RGB images, and all data is processed in the sensor. Consequently, the need for data transmission is eliminated. We provide an extensive evaluation of our method on 2.2 million events, with more than 100,000 events manually annotated. The aim of this paper is to report our fall detection system's maturity and reliability.

2. State of the Art

Vision-based approaches provide advantages of easy installation and flexibility without having to wear a sensor, but also privacy issues need to be considered carefully. Since cameras being placed in public places is widely discussed in our society [7], the use of vision-based systems within private homes of elderly people needs to be addressed and privacy as well as dignity of persons using the system must be ensured.

Chaaraoui et al. [8] discuss privacy issues of vision-based systems within private homes. The authors propose to modify or remove different areas from an image to protect the privacy. This can either be performed by applying image filters (blurring, pixelating), modification of the face, or replacement of subjects by abstract visualizations. Moreover, the authors note that a trade-off between privacy and usefulness need to be obtained. Within the context of Active Assisted Living (AAL), especially the identity, appearance, location and activity of the subject need to be protected. Other methods to ensure privacy in vision-based approaches range from using skeleton data derived from RGBD data (Kong et al. [9]) to the use of thermal (Kido et al. [10]) and depth data (Planinc and Kampel [11]). RGB sensors provide true-color images of a person, while thermal images represent the temperature distribution of the visualized scene, and depth images deliver information based on the distances between objects.

In depth and thermal images, the privacy is preserved technically [12], however organizational aspects allow to identify the person even within these data. If the location of the sensor is mapped together with the name of the person living in the flat, people can be identified (assuming that only one person lives in the flat). In depth images, although the person is identified, the appearance of the person is fully protected. Only the silhouette is detected and thus no conclusions whether the person is wearing clothes or the emotional state can be obtained. Thermal images on the contrary allow to see the clothes of a person.

Elderly people are skeptical using new technology and fear, that they are monitored 24/7 [13]. Although from a technical point of view the privacy is preserved, risks cannot be eliminated, but minimized. The use of technology in AAL always comprise risks, but on the other hand provides benefits for the elderly. Hence, elderly people need to balance reasons if the benefits or the risks for a specific system predominate, thus resulting in the decision whether or not to use a system.

When examining the maturity of existing fall detection systems, to the best of our knowledge, no other system has undergone a field evaluation of comparable scope to ours. Wang et al. [14] present a systematic review on fall detection, highlighting the limited time and funding for most research projects to collect data continuously for a longer period. In most cases, young adults are performing falls for the dataset [15,16,17], or stunt actors are hired [18]. It is questionable if models trained on younger adults are applicable for real-life scenarios with elderly people. This is because older people typically have decreased reaction time and less control over speed of their body movements [19].

For systems evaluated in real-world scenarios, gathered data is limited. Liu et al. [20] use nine real falls along with 445 simulated ones, while Demiris et al. [21] install a multi-modal system to detect falls in 16 apartments of elderly people. Ozcan et al. [22] use wearable cameras attached to the waist and carry out experiments with 10 different people, resulting in 30 falls. Although Adhikari et al. [23] collect 15,800 images of fall scenarios, they are based on only five healthy participants. In their systematic review, Wang et al. [14] also present fall detection systems that have turned into commercial products, but solely focus on wearable devices. They state that vision-based systems have the potential to turn into commercial products in the future. Even the biggest known real-world fall dataset recorded with inertial sensors by Klenk et al. [24] solely comprise about 300 falls.

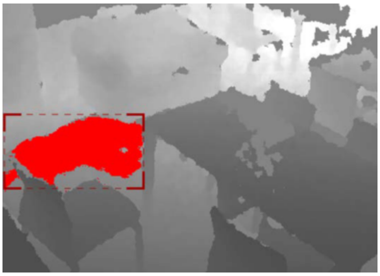
The literature review shows that real-world fall detection evaluation is scarce, and if available, is conducted with a limited amount of participants. To our knowledge, our depth image based fall detection method has achieved the largest field evaluation up to date, with more than 100,000 events manually annotated and more than 1,200 installations in care facilities.

3. Materials & Methodology

We use depth sensors for our fall detection model, since depth information preserves privacy by its design inherently. The flat of a person cannot be identified [25]. It is possible to identify e.g. chairs and tables, but not their appearance as shown in Figure 1a.

The main advantages of choosing a depth sensor, especially within the context of AAL, can be summarized as follows:

1. No additional light source needed: due to the use of infrared light for the pattern projection, depth sensors also work during the night
2. Robustness to changing lighting conditions: switching the lights on and off does not affect the results. However, direct sunlight interferes with the projected infrared pattern. This restricts the use of our sensor to indoor environments only.
3. No calibration needed: in contrast to the use of a calibrated multiple camera setup in order to calculate a 3D reconstruction, no calibration is needed.
4. Privacy protection: in contrast to many other 3D sensors like the Microsoft Kinect (version 1 and 2), our device only obtains depth data and does not provide a camera.



(a) Range image

(b) Privacy by design depth Sensor

Figure 1. Depth sensor and corresponding range image.

An important privacy and legal aspect is the streaming or storage of data on a server or cloud system. As a privacy by design feature and in order to minimize the hardware costs for the users, our method was designed to be efficient enough to run on inexpensive edge devices. Our setup uses the Raspberry Pi 4 single-board computer for near-sensor execution of deep neural networks integrated in our depth sensor, see Figure 1b, combining an Orbbec Astra depth sensor with the processing unit. The advantage of this approach is that potentially sensitive data never leaves the device at any point.

Our fall detection pipeline can be divided into two components: object detection and tracking. A 2D Convolutional Neural Network (CNN) is used for feature extraction. To gain depth information, a transformation step from image space to space is performed. A transformer-based tracker architecture allows to associate the detected individuals across different frames. The generated output consists of trajectory oriented bounding boxes. The detailed technical insight into our commercial vision-based sensor has been previously described in [26].

During the whole development process, actions were taken to involve end-users in the design process, train and inform them about the system, and address ethical concerns. These actions included webinars, co-creation activities, discussion groups, and surveys of primary, secondary, and tertiary users. To better understand the secondary end-users' needs and preferences, we gathered information from a questionnaire, presenting the results in [27].

4. Results from the Field

Up to date, the system has been deployed to a number of care institutions with more than 1,200 sensors in daily use, of which 214 sensors and participants were part of a large evaluation study.

4.1. Field Evaluation Study

The duration of the study was 8 months with more than 120,000 alarms analysed, provoked by 214 sensors located in 16 care facilities (belonging to 4 care and 3 hospital organisations) in Austria. Table 1 shows the demographic information of the study. The level of dementia differs between participants, with 31 participants diagnosed with light, 37 with medium, 38 with strong and 21 with very strong dementia.

Table 1. Number and age of participants in the study.

		Age			
	total	**mean**	**std**	**max**	**min**
all	214	85,62	8,74	102	57
female	104	86,98	7,69	102	61
male	41	82,17	10,29	99	57

The false alarm rate per sensor was 1 every 10 days and it is estimated that less than one fall out of hundred was overseen. Part of the deployment was the validation of the core functionalities fall detection and fall prevention. A visual representation of three mobilization stages (raiseup, situp and getup together with a virtual bed rail) as part of the fall prevention module is shown in Figure 2. A virtual, invisible bed rail triggers an alarm when a resident crosses the line.

As a major outcome it was shown that the early detection of falls can significantly reduce additional work and costs. We learned that on average 2.3 times more falls happen than are documented. The dark figure varies strongly in between the facilities. It ranges from 50% to 275% undetected falls on top of documented ones. Consequently, the system helps to detect falls that are otherwise overseen and not communicated to the caregivers. This way, a quick treatment of injuries can take place.

On average, one false alarm every three days is produced either by personnel or the system. All false alarms have been categorized either as *object induced false alarms* or *personnel-induced*. Sometimes, moving objects are mistaken for human body parts. In contrast to laboratory conditions, moving objects like wheelchairs or walkers are a main source of false alarms. Caregivers or visitors can cause false alarms by taking postures that resemble critical situations.

Alarms without apparent reason could be reduced to 1 every 10 days which represents an exceptional value and helps to not put additional workload on caregivers.

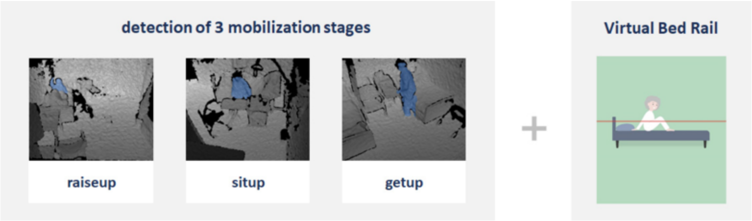


Figure 2. Detection of mobility: raiseup, situp, getup and virtual bed rail

4.2. Long-term Results from Daily Business

As of today, we have collected 2.2 million events from daily use, that can be separated in approximately 7.5% fall, 35% bed exit, 2.5% absence and 55% prevention (raiseup, situp and getup) alarms. All sensors together sum up to 1 million operation days (24h). In order to detect these events, the training database consists of 100,000 annotated events from 1,000 different sensors.

5. Discussion & Conclusion

In this paper, we described our depth sensor based fall detection system and focused on its large-scale field evaluation.

The presented system has the potential to replace existing fall detection systems like fall mats, bed security systems, and mattress sensors, thus saving acquisition and maintenance costs. By using a depth sensor, night shifts can be staffed more easily again because caregivers feel more secure when they are looking after several wards or assisted living units at the same time and have less of a feeling of missing out on something. Despite of the system already achieving a high accuracy, we are still looking to improve it by eliminating object and personnel induced false alarms.

In conclusion, the development of fall detection methods is crucial for ensuring the safety and well-being of elderly individuals in care facilities. The presented fall detection method, based on depth-data and using a privacy by design approach, has shown promising results with over 1,200 installations in care facilities, demonstrating its maturity and acceptance by users. Additionally, the evaluation of the method on a large dataset with manually annotated events has shown the reliability and accuracy of the method. The presented solution has the potential to make a significant impact in reducing the risk of accidental falls and ensuring quick help for fall victims by implementing a privacy by design approach for increasing user trust as well as meeting legal requirements.

Acknowledgements

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References

[1] Sadigh S, Reimers A, Andersson R, Laflamme L. Falls and Fall-Related Injuries Among the Elderly: A Survey of Residential-Care Facilities in a Swedish Municipality. Journal of Community Health. 2004 05;29:129-40. doi: https://doi.org/10.1023/B:JOHE.0000016717.22032.03.

[2] Blake A, Morgan K, Bendall MJ, Dallosso H, Ebrahim SB, Arie TH, et al. Falls by elderly people at home: prevalence and associated factors. Age and Ageing. 1988;17(6):365-72. doi: https://doi.org/10.1093/ageing/17.6.365.

[3] Tinetti ME, Speechley M, Ginter SF. Risk factors for falls among elderly persons living in the community. New England Journal of Medicine. 1988;319(26):1701-7. doi: https://doi.org/10.1056/NEJM198812293192604.

[4] World Health Organization. WHO Global Report on Falls Prevention in Older Age.; 2007.

[5] Atoyebi OA, Stewart A, Sampson J. Use of information technology for falls detection and prevention in the elderly. Ageing international. 2015;40:277-99. doi: https://doi.org/10.1007/s12126-014-9204-0.

[6] Gurley RJ, Lum N, Sande M, Lo B, Katz MH. Persons found in their homes helpless or dead. New England Journal of Medicine. 1996;334(26):1710-6. doi: https://doi.org/10.1056/NEJM199606273342606.

[7] Arning K, Ziefle M. "Get that Camera Out of My House!" Conjoint Measurement of Preferences for Video-Based Healthcare Monitoring Systems in Private and Public Places. In: Geissbühler A, Demongeot J, Mokhtari M, Abdulrazak B, Aloulou H, editors. Inclusive Smart Cities and e-Health. Cham: Springer International Publishing; 2015. p. 152-64. doi: https://doi.org/10.1007/978-3-319-19312-0_13.

[8] Chaaraoui AA, Climent-Pérez P, Flórez-Revuelta F. A review on vision techniques applied to Human Behaviour Analysis for Ambient-Assisted Living. Expert Systems with Applications. 2012 Sep;39(12):10873-88. doi: https://doi.org/10.1016/j.eswa.2012.03.005.

[9] Kong X, Meng Z, Meng L, Tomiyama H. A privacy protected fall detection IoT system for elderly persons using depth camera. In: 2018 International Conference on Advanced Mechatronic Systems (ICAMechS). IEEE; 2018. p. 31-5. doi: https://doi.org/10.1109/ICAMechS.2018.8506987.

[10] Kido S, Miyasaka T, Tanaka T, Shimizu T, Saga T. Fall detection in toilet rooms using thermal imaging sensors. In: 2009 IEEE/SICE International Symposium on System Integration (SII). IEEE; 2009. p. 83-8. doi: https://doi.org/10.1109/SI.2009.5384550.

[11] Planinc R, Kampel M. Introducing the use of depth data for fall detection. Personal and ubiquitous computing. 2013;17:1063-72. doi: https://doi.org/10.1007/s00779-012-0552-z.

[12] Bian C, Ye B, Hoonakker A, Mihailidis A. Attitudes and perspectives of older adults on technologies for assessing frailty in home settings: a focus group study. BMC Geriatrics. 2021;21. doi: https://doi.org/10.1186/s12877-021-02252-4.

[13] Kavčič M, Petrovčič A, Dolničar V. Model of acceptance and use of market-ready home-based e-care services: A qualitative study with care receivers and informal caregivers. International Journal of Human–Computer Interaction. 2023;39(5):988-1002. doi: https://doi.org/10.1080/10447318.2022.2041898.

[14] Wang X, Ellul J, Azzopardi G. Elderly fall detection systems: A literature survey. Frontiers in Robotics and AI. 2020;7:71. doi: https://doi.org/10.3389/frobt.2020.00071.

[15] Zhao F, Cao Z, Xiao Y, Mao J, Yuan J. Real-time detection of fall from bed using a single depth camera. IEEE Transactions on Automation Science and Engineering. 2018;16(3):1018-32. doi: https://doi.org/10.1109/TASE.2018.2861382.

[16] Li M, Xu G, He B, Ma X, Xie J. Pre-impact fall detection based on a modified zero moment point criterion using data from Kinect sensors. IEEE Sensors Journal. 2018;18(13):5522-31. doi: https://doi.org/10.1109/JSEN.2018.2833451.

[17] Ma C, Shimada A, Uchiyama H, Nagahara H, Taniguchi Ri. Fall detection using optical level anonymous image sensing system. Optics & Laser Technology. 2019;110:44-61. doi: https://doi.org/10.1016/j.optlastec.2018.07.013.

[18] Li Y, Banerjee T, Popescu M, Skubic M. Improvement of acoustic fall detection using Kinect depth sensing. In: 2013 35th annual international conference of the IEEE Engineering in medicine and biology society (EMBC). IEEE; 2013. p. 6736-9. doi: https://doi.org/10.1109/EMBC.2013.6611102.

[19] Bourke AK, O'Brien J, Lyons GM. Evaluation of a threshold-based tri-axial accelerometer fall detection algorithm. J Gait & Posture. 2007;26(2):194-9. doi: https://doi.org/10.1016/j.gaitpost.2006.09.012.

[20] Liu L, Popescu M, Skubic M, Rantz M. An automatic fall detection framework using data fusion of Doppler radar and motion sensor network. In: 2014 36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE; 2014. p. 5940-3. doi: https://doi.org/10.1109/EMBC.2014.6944981.

[21] Demiris G, Hensel BK, Skubic M, Rantz M. Senior residents' perceived need of and preferences for "smart home" sensor technologies. International journal of technology assessment in health care. 2008;24(1):120-4. doi: https://doi.org/10.1017/S0266462307080154.

[22] Ozcan K, Velipasalar S, Varshney PK. Autonomous fall detection with wearable cameras by using relative entropy distance measure. IEEE Transactions on Human-Machine Systems. 2016;47(1):31-9. doi: https://doi.org/10.1109/THMS.2016.2620904.

[23] Adhikari K, Bouchachia H, Nait-Charif H. Activity recognition for indoor fall detection using convolutional neural network. In: 2017 Fifteenth IAPR International Conference on Machine Vision Applications (MVA). IEEE; 2017. p. 81-4. doi: https://doi.org/10.23919/MVA.2017.7986795.

[24] Klenk J, Schwickert L, Palmerini L, Mellone S, Bourke A, Ihlen E, et al. FARSEEING consortium The FARSEEING real-world fall repository: A large-scale collaborative database to collect and share sensor signals from real-world falls. Eur Rev Aging Phys Act. 2016;13(8). doi: https://doi.org/10.1186/s11556-016-0168-9.

[25] Mucha W, Kampel M. Addressing Privacy Concerns in Depth Sensors. In: Miesenberger K, Kouroupetroglou G, Mavrou K, Manduchi R, Covarrubias Rodriguez M, Penáz P, editors. Computers Helping People with Special Needs. Cham: Springer International Publishing; 2022. p. 526-33. doi: https://doi.org/10.1007/978-3-031-08645-8_62.

[26] Pramerdorfer C, Planinc R, Kampel M. Effective Deep-Learning-Based Depth Data Analysis on Low-Power Hardware for Supporting Elderly Care. In: 2020 IEEE/CVF Conference on Computer Vision and Pattern Recognition Workshops (CVPRW); 2020. p. 1584-90. doi: https://doi.org/10.1109/CVPRW50498.2020.00205.

[27] Machado N, Dantas C, Leandro AF, Guardado D, Münzer T, Helfenberger N, et al. What Do Nurses and Careers in Portugal Wish and Need from a Digital Intelligent Assistant for Nursing Applications. In: Pires IM, Spinsante S, Zdravevski E, Lameski P, editors. Smart Objects and Technologies for Social Good. Cham: Springer International Publishing; 2021. p. 293-9. doi: https://doi.org/10.1007/978-3-030-91421-9_22.

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Audio-Conversion of Biomedical Signals - A Possible Approach to Improve Remote Monitoring of Elderly and Visually Impaired People

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Abstract. Long-term remote patients monitoring implies minimal discomfort and reliability throughout the study period. These requirements are fulfilled by portable (wearable) patient devices, with low consumption, which transmit data wirelessly, at a short distance, to a mobile communication device (GSM) and through it, to a remote end recipient - doctor, medical center or a hospital server. The data transfer technology requires the monitored person to perform a sequence of actions, such as: selecting the appropriate application on the mobile phone, establishing a connection between the patient module and the phone, recording the data in the phone's memory, starting the data transfer from the phone to the final receiver. Practice shows that often this sequence of activities is difficult for elderly people and especially for visually impaired people, which as a result compromises the remote monitoring process. In this paper are presented an approach and conceptual implementation of a system for remote monitoring of cardiac activity, using the most popular way of remote connectivity - voice (sound) communication. In addition to the ease of use, this type of communication does not require special data protection, due to the lack of RF interfaces for short-distance data transmission. The presented results of laboratory studies, as well as conducted tests under medical supervision of patients in a cardiology clinic, confirm the workability of the proposed approach for remote monitoring of patients by audio conversion of the ECG signal.

Keywords. Remote patient monitoring, patients telemetry, ECG monitoring, ECG sonification

1. Introduction

A basic approach in diagnostic medical practice is the recording of electrical potentials on the surface of the body (biopotentials), characterizing the functional state of a specific organ or system in the human body. The graphical visualization of biopotentials allows reliable interpretation of life processes in the body. Typical examples are electrocardiographic signal (ECG), electroencephalographic signal (EEG),

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electromyographic signal (EMG), electrogastrographic signal (EGG), etc. There are also some exceptions where the diagnosis is based on audio interpretation of processes in the human body, as for example:

- Ultrasound Doppler echography makes it possible to sound (other terms – sonify, auscultate) the flow of blood in blood vessels and to localize narrowings, aneurysms, blockages, as well as to measure blood flow velocities;
- Auscultatory blood pressure measurement uses a widely applied non-invasive method to record sound signals ("Korotkoff sounds") generated by the passage of blood through a section of a blood vessel subjected to external pressure;
- Phonocardiography is a specialized audio-method for studying cardiac activity, in which the tones generated by the mechanical activity of the heart are registered and analyzed;
- Stethoscope registration and interpretation of sound signals is used in the diagnosis of the respiratory system;
- Voice analysis (hoarseness in voice) is one of the methods for early diagnosis of some oncological diseases.

At a certain level of the technological development of communication technologies, the alternative audio representation of biosignals has allowed their transmission at a distance using analog telephones and in practice has played an essential role in the development of telemedicine and remote patient monitoring (RPM). Naturally, the transmission quality, speed and volume of data at this initial stage are unmatched by up-to-date devices for digital communication. However, a number of studies [1], [2], [3], [4], [5] related to the implementation of new ICT technologies in assistive systems for the elderly and disabled show that not a small number of these people may have difficulties in accepting and using the new technologies, mainly due to:

- Lack of previous exposure or experience with technology;
- Difficulty in adapting to changes;
- Resistance to learning new skills;
- Difficulty in using small screens, buttons and navigating digital interfaces;
- Remote monitoring devices can be expensive, making access and use difficult for individuals with limited financial resources;
- Inaccessibility or lack of awareness of available resources and support.

Similar problems are observed in the blind, as well as in the people with impaired vision. Blind people may face difficulties in accessing and using the remote monitoring device due to a lack of visual information and tactile cues [6], [7]. Often the technology used in remote monitoring devices can be complex, requiring special training and technical know-how. This can be an obstacle for blind people to independently carry out a seemingly elementary sequence of actions necessary for remote monitoring of vital parameters. Many of these problems can be solved by designing user-friendly interfaces that are easy to operate. For example, incorporating familiar elements, such as physical buttons or analog interfaces, can make new technologies more acceptable for them [8].

A recent study [9] concluded that the sonification as a new method has great potential for presenting health data, but has not yet been sufficiently explored as a practical tool. In light of the fact that cardiovascular diseases are a significant factor to mortality rates globally, it's crucial to prioritize early detection of cardiac activity abnormalities by remote patient monitoring. The aim of the present work is to present a conceptual solution of a system allowing self-registration of heart activity and transmission via GSM of the electrocardiogram, converted into a sound signal, to a remote receiver.

2. Method and Results

The audio-conversion (sonification) of the electrocardiographic signal can be realized directly with an analog frequency modulation scheme (VCO - voltage-controlled oscillator) or with a digital procedure after analog-to-digital conversion of the signal. The sonified ECG is reproduced with a loudspeaker and received by the microphone of the GSM (fig. 1). The modulating procedure must be matched on the one hand with the frequency band of the ECG signal (0.1 – 100 Hz) and on the other hand with the frequency band of the audio channel of the GSM devices (typically 0.3 – 3.8 kHz). After transmission of the sonified ECG signal, digital demodulation is applied at the receiving part, whereby the ECG signal is restored and visualized in its original form.

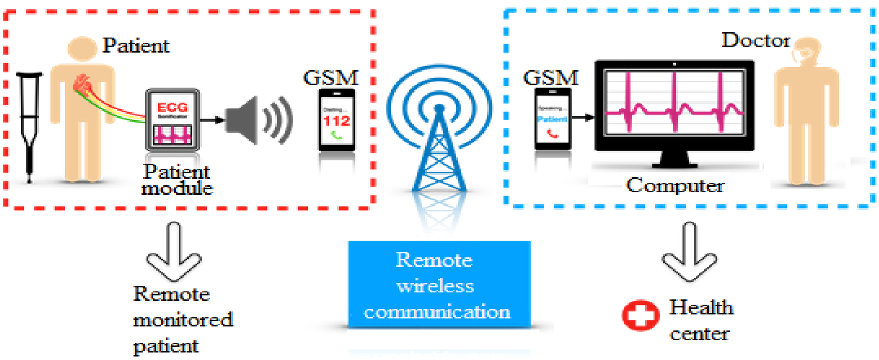


Figure 1. The audio-conversion and transmission of the sonified ECG signal.

The proposed approach was initially tested with a signal from the AHA database [10] using built-in software functions for digital modulation and demodulation in MATLAB. The audio-converted signal is played from a speaker connected to the personal computer and transmitted between two GSMs located in distant buildings. The receiving GSM is connected to the audio card of another computer, which performed demodulation and visualization of the received signal. The result of this experiment is presented in fig.2.

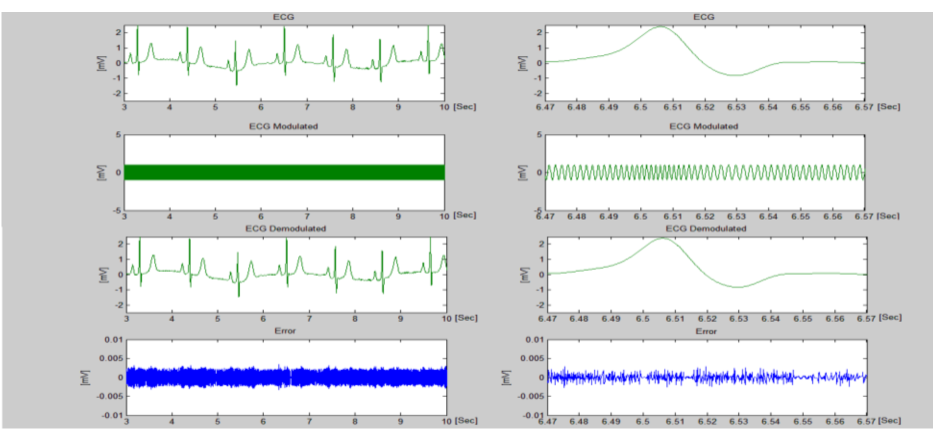
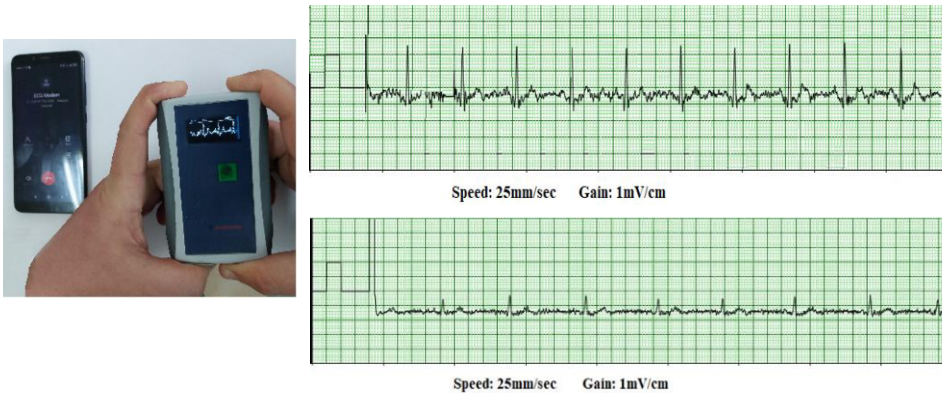


Figure 2. Results of proposed sonification procedure applied on an ECG signal from AHA database.

In the left group of graphs, in sequence from top to bottom, are presented the original signal, the modulated signal, the demodulated signal, and the error (difference) between the original and the recovered signal after modulation and demodulation. In the same sequence, the signals are presented in the right group, which shows a time-scaled 10 ms fragment, for a clearer visualization of the signal after digital modulation/demodulation. As can be seen, the error is negligibly small (below 0.5%) of the signal amplitude.

For verification of the proposed approach, a portable patient module was developed for recording 1-channel ECG from the chest or fingers (Fig. 3a). After switching on, it waits a few seconds for the electrocardiogram to be visualized on the display and its sound reproduction (playing) begins. The user (patient) dials the number of a remote GSM modem connected to a doctor's computer, server or other receiving device.



a/ b/

Figure 3. ECG self-registration: a/ - portable patient module; b/ - visualized after demodulation sonified ECG signals registered from the fingers of two volunteers.

During the transmission of the sonified ECG, the user's GSM should be at a distance of 10-15 cm from the patient module. The receiving GSM modem is connected to the computer through the analog input of the audio card, and the data is recorded in a file (in *wav* format). The laboratory tests for registering the ECGs from the fingers were conducted with volunteers. The received sonified signals were demodulated and visualized using specially developed software application in VisualBasic (Fig. 3b). It is worth noting that the presence of EMG noises superimposed on the ECG recordings is typical in cases of finger-type ECG registration.

Validation tests were conducted under doctor’s supervision to assess the applicability of ECG sonification. Nine patients at the Cardiology Clinic of the Medical University - Sofia were trained to record and send a sonified electrocardiogram by themselves via GSM. These self-made ECG recordings were compared with the patients' control recordings made with a standard electrocardiograph (12-channel ECG - MAC 3500 "General Electric"). ECG records of a patient with mitral valve stenosis and visual impairment (cataract) are presented in fig. 4. The upper ECG is a record made by MAC 3500. The lower electrocardiogram is a self-made record with the portable module, six hours after admission for treatment. The conclusion of the supervising cardiologist was that the self-made ECG record correctly reflects the current state of this patient. In the analogous tests with the other patients, the correlation between the recordings of the two devices was also confirmed.

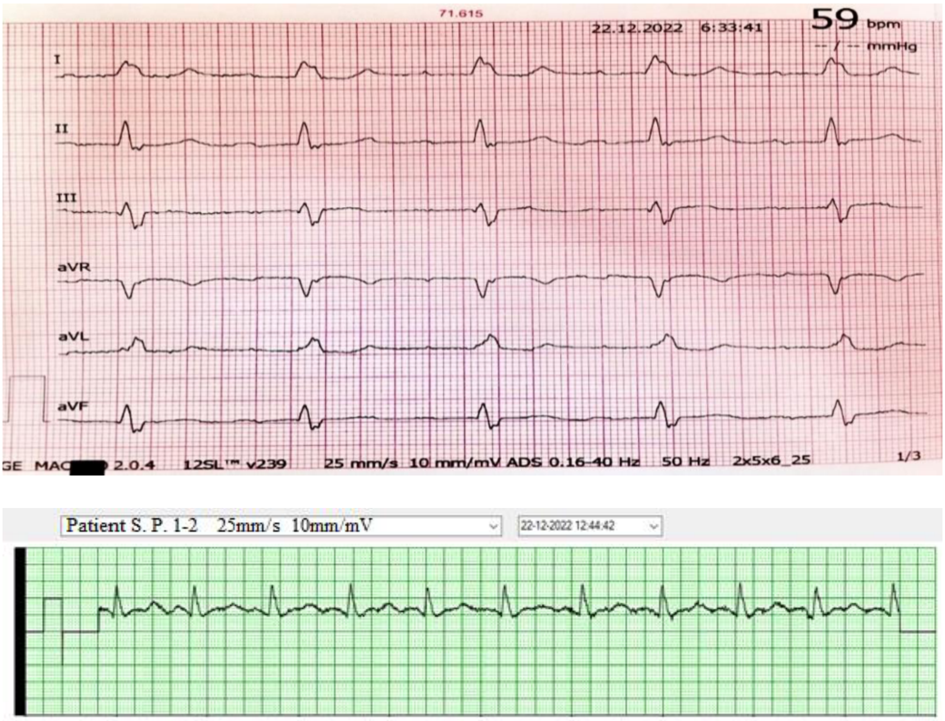


Figure 4. Upper trace – electrocardiogram made with 12-channel ECG - MAC 3500. Lower trace – electrocardiogram made with portable patient module.

3. Discussion

Remote patient monitoring improves patient outcomes, increases patient engagement in their own care, and reduces healthcare costs. Patients can benefit from improved access to care, reduced travel time and expenses, and increased convenience. Healthcare providers can benefit from the ability to track patient data in real-time, detect potential health problems earlier, and provide more personalized care. In addition, RPM is becoming increasingly important in the context of the COVID-19 pandemic, as it allows people in quarantine to be monitored remotely, and can help reduce the risk of exposure of healthcare workers to the virus.

One of the limiting factors for the wide application of RPM is related to the need for a series of technological operations for reliable and qualitative registration and transmission of vital parameters. To the greatest extent, this is valid for the elderly, especially to those with visual impairments. The solutions and results of the experimental tests presented in this article are aimed at a maximally simplified way of self-registration of an important vital indicator - heart activity and translation of this information to the remote specialist (cardiologist). The proposed approach, based on sonification of the electrocardiographic signal, allows easy use of a GSM device to transmit an ECG signal, analogous to carrying out a standard telephone talk, by pressing only one button (or symbol on touch screen) for quick dialing and start of the data transfer.

The experimental laboratory tests with volunteers confirmed the applicability of ECG sonification as a reliable approach for remote patient monitoring. The comparative analysis between electrocardiograms obtained by a professional electrocardiograph and the developed patient module for recording and transmitting of sonified ECG signals confirmed the identity of the records which is a prerequisite for correct medical diagnostics.

4. Conclusion

It is important to note that ECG sonification is still a developing field and more research is needed to fully understand its potential applications and limitations in clinical practice. An additional advantage of sonification would be the unified sound representation of the electrocardiographic signal. This opens a new field for scientific research aimed at: creating algorithms for the automatic analysis and processing of the sound electrocardiographic signal; transforming existing electrocardiographic databases into audio databases; targeted training to achieve a high degree of reliability in recognizing cardiac arrhythmias (short-term or life-threatening events), including the detection of specific noises; finding new diagnostically useful features of the acoustic electrocardiographic signal in time and/or frequency intervals, and also evaluating the complete information contained in the acoustic electrocardiographic signal. Selection of only a few of the most diagnostically relevant electrocardiographic audio parameters would be important in systems for remote transmission of compressed data records.

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References

[1] Free C, Phillips G, Watson L, Galli L; Felix L, Edwards P, Patel V, Haines A. The Effectiveness of Mobile-Health Technologies to Improve Health Care Service Delivery Processes: A Systematic Review and Meta-Analysis. Plos Med 2013, 10, e1001363, doi:10.1371/journal.pmed.1001363.

[2] Deng RZ, Mo X, Liu S. Comparison of the Middle-Aged and Older Users' Adoption of Mobile Health Services in China. Int J Med Inform 2014, 83, 210–224, doi:10.1016/j.ijmedinf.2013.12.

[3] Vaportzis E, Clausen MG, Gow AJ. Older Adults Perceptions of Technology and Barriers to Interacting with Tablet Computers: A Focus Group Study, Front. Psychol. 8:1687. doi: 10.3389/fpsyg.2017.01687.

[4] Venkatesh T, Thong X. Consumer Acceptance and Use of Information Technology: Extending the Unified Theory of Acceptance and Use of Technology. Mis Quart 2012, 36, 157, doi:10.2307/41410412.

[5] Yusif S, Soar J, Hafeez-Baig A. Older people, assistive technologies, and the barriers to adoption: A systematic review, nt J Med Inform, 2016 Oct; 94:112-6. doi: 10.1016/j.ijmedinf.2016.07.004.

[6] Elmannai W, Elleithy K. Sensor-Based Assistive Devices for Visually-Impaired People: Current Status, Challenges, and Future Directions. Sensors (Basel), 2017 Mar 10;17 (3):565. doi: 10.3390/s17030565.

[7] Page T. Touchscreen mobile devices and older adults: A usability study, January 2014 International Journal of Human Factors and Ergonomics 3(1):65 – 85.

[8] Kiriakose B. Tools and Technologies for Blind and Visually Impaired Navigation Support: A Review, IETE Technical Review, Volume 39, 2022 – Issue 1.
[9] Mihalaş GI, Andor M, Tudor A, Paralescu S. Sonification: Principle, Methods and Medical Applications, Applied Medical Informatics; Cluj-Napoca Vol. 43, (2021): 13.
[10] American Heart Association (AHA) ventricular arrhythmia ECG database. Emergency care Research Institute 5200 Butler Pike, Plymouth Meeting, PA 19462 USA.

Acces to STEM Content

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Extracting Contextual Semantic from a Concordance Containing Mathematical Definition

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Abstract. With the increased penetration of screen reading software, effective audio rendering of equations can significantly assist in making many electronic mathematics documents accessible. However, linear syntactic rendering of equations not only creates a considerable cognitive load, even for relatively simple equations, but also becomes crucial in more advanced mathematical subjects where the precise and correct interpretation of symbols is essential. To overcome this challenge, we are working on a procedure to extract contextual semantics for mathematical expressions from the surrounding text. In this paper, we will present one of its modules: the Semantic Extractor. This module aids in extracting semantics from the concordance that contains valid mathematical definitions. This approach enables contextually aware audio rendering of complex mathematical expressions, rather than relying solely on syntactic rendering.

Keywords. Syntactic Rendering, Equation, Audio Rendering, Cognitive load, Visually Impaired, Contextual Semantic

1. Introduction

Despite significant advances in assistive technologies, a large section of visually impaired students, especially in developing countries like India, are not able to pursue STEM subjects in senior school years and college. Inaccessible STEM content including textbooks contribute in a major way to this challenge. Clearly when significant employment opportunities depend upon STEM education, this has a huge impact on their employability and integration into society. Access to equations is a critical requirement for STEM. Audio rendering and tactile Braille are the two main modalities used by persons with visual impairment for accessing equations. Audio is the preferred modality due to ease and cost of production, possibility of digital dissemination as well as having no need for specially trained instructors to teach Braille/Tactile Graphics.

MathJax [1], Access8Math [2], MathCAT [3], MathPlayer [4], ChattyInfty [5], etc. are some of the common tools used for accessing equations using audio. All these solutions provide syntactical audio rendering with optimized use of lexical and prosodic cues. None of these solutions have the capability of adapting the rendering on the basis of the

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contextual semantics. E.g., A^T can be "the transpose of the matrix A" or "A to the power T" depending on the context whether A is a matrix or a variable, respectively. Similarly, A' can be "A transpose" or "First derivative of A" or "Label to a specific point on a line". Current systems will always read them as "A superscript T" and "A prime", respectively, which is a syntactical rendering. Table 1 contain a list of semantic ambiguity examples and corresponding syntactic rendering.

Lack of contextual rendering adds cognitive load and leads to the steepness in the learning curve for users using audio rendering. The true meaning of mathematical symbols can only rarely be deduced by their occurrence in a single formula alone. And although many commonly used mathematical symbols often have widely understood semantics, their meaning in context of a particular mathematical text might differ considerably. E.g., while in non-associative algebra structures like rings, when they use addition and multiplication symbols, their meaning must not be confused with their counter-parts in traditional arithmetic.

Table 1. Examples of semantic ambiguity across various mathematical expressions and corresponding syntactic rendering speech string.

Expression	Various Possibilities	Syntactic Rendering
$A \times B$	multiplication, cartesian product of A and B, cross product of A and B, A by B (In case of matrix dimension)	A times B
$\|A\|$	Absolute value of A, Modulus of the complex number A, order of A, determinant of the matrix A, cardinality of A	Vertical line A vertical line
(a,b)	cartesian point, open set, ordered pair, cycle, GCD of a and b	left paran a comma b right paran
$< A >$	cyclic sub-group, ensemble average	less A greater
$\bar{Z}$	complex conjugate, mean, topological closure, algebraic closure	Z bar

In the past, there have been few attempts in this area. It has been shown previously [6,7,8,9,10,11,12] that the consideration of surrounding text can relatively improve the performance of semantic disambiguation in comparison with a mere expression analysis [13,14,15]. The various techniques proposed requires a knowledge base which covers all the topics related to mathematics. It's clearly not possible to develop such a knowledge base manually. Hence, a self-learning system is required which can harvest the definitions from the document itself and learn with time.

In recent developments, the MathML4 specifications [16] have introduced the attributes "intent" and "arg", theoretically enabling authors to specify the intended meaning of mathematical symbols during content creation. However, in practice, mathematicians author their work in LaTeX, where there is little support for specifying additional intent, even if authors were willing to do so. Consequently it's even more important to develop a system capable of inferring contextual semantics from the surrounding text, to effectively utilize these attributes to establish the intent of different mathematical symbols.

In particular we are extending the work from [11], following a methodology that is outlined in Fig. 1. The first two modules; Concordance extractor and Classifier are discussed in [17,18]. In this paper, we have discussed semantic extractor module, which extracts contextual semantic from a concordance containing valid mathematical definition.

2. Concordance and Mathematical Definition

Our machine learning approach is based on a concordance analysis - that is on a enumeration of all expressions in question together with the context in which they occur. In our case, we are working with mathematical expressions and as context we consider five words or expressions before and after the principal expression. This whole part, five words in the prefix and five words in the postfix including the central mathematical entity is referred to as a concordance in this paper.

Mathematical definitions are those phrases that assign mathematical properties to symbols used in subsequent text. E.g., “Let $F : R^n \to R^n$ be a C^1-vector field” defines F to be a C^1-vector field. Similarly, “Suppose that f and g are differentiable functions” defines that f and g are differentiable functions. Unfortunately, definitions are only rarely given in such obvious manner and meaning is often assigned to symbols in a much more implicit way. E.g., some of the concordances containing valid mathematical definitions are listed below –

- an element of the set CENTERMATH, we write MATH
- set of even integers and CENTERMATH is the set of odd integers
- for a set containing elements CENTERMATH or

Here, “CENTERMATH” refers to the principle mathematical expression for which the definition is available in the surrounding text. However, “MATH” refers to the mathematical entity/expression present in the surrounding text.

To further add complexity, multiple scenarios exist in the definitions. The definitions can be classified into the following categories based on the availability of semantics in a definition:

1. **Concordance with Incomplete Definition**: As we are only considering window size of five words for the context, it is possible that the semantics get trimmed in the concordance. E.g., in the concordance, “set of even integers and CENTERMATH is the set of odd”, the semantic is ‘set of odd’ corresponding to the CENTERMATH. The next word, which is most likely integers, got trimmed here. All such concordances are classified as Concordance with Incomplete definition.
2. **Concordance with Complete Definition**: This is in contrast to the previous scenario. The semantics present in the concordance is complete, not trimmed. E.g., in the concordance, “for a set containing elements CENTERMATH or” , the semantic is ‘set containing elements’.
3. **Concordance Containing Multiple Definitions**: Although efforts were made to keep the window size small to avoid multiple semantics within the same concordance, it is still possible to encounter concordances with multiple semantics corresponding to CENTERMATH. E.g., In the concordance, “MATH to MATH. The relation CENTERMATH is a mapping, but MATH”, ‘relation’ and ‘mapping’ are the semantic corresponding to the CENTERMATH.
4. **Concordance Containing Negative Definition**: Let us understand this scenario with an example. In the concordance, “and MATH itself. An integer CENTERMATH that is not prime is”, we can infer that CENTERMATH is ‘not prime’. In this case, we are also able to infer that CENTERMATH is ‘integer’, but this may not be true for all such concordances. We have clasified such concordances containing negative definition.

Figure 1. Architecture to extract contextual semantic from the document.

5. **Concordance with Tricky Scenario**: In certain concordances, it is not straightforward to extract semantic. E.g., in the concordance, “logarithm and the exponential functions, CENTERMATH and MATH, are inverses of”, the semantic corresponding to the CENTERMATH is ‘logarithm function’, which is not straightforward to extract.

By considering these categories, we can gain a better understanding of the diverse nature of definitions and the challenges they pose for semantic extraction.

3. Contextual Semantic Analysis

The proposed architecture for the analysis is shown in Fig. 1, whose each module is described as 1. **Concordance Extractor** – Extracts the concordances from the document. 2. **Classifier** – Classify concordances based on whether the incoming concordance contains a valid definition or not. 3. **Semantic Extractor** – Extracts the semantic from the concordance containing valid mathematical definition. 4. **Scope Finder** – Finds the scope of the extracted semantic. Certain variables may be defined multiple times within the same document and may have local scope, whereas, others may be valid for the entire document. 5. **Speech Rule Engine** – Generates the speech string by utilizing the extracted semantic information.

In [17,18], we have discussed techniques for extracting concordances given a document and classifying them into the one containing valid mathematical definition and not containing valid mathematical definition. Once we have the concordance containing valid mathematical definition, the next step is to extract the semantic information from it. Here, for extracting semantic from the concordance, we have experimented with a pattern matching based algorithm, described in section 5.

4. Ground Truth

For the current analysis, we have annotated a part of the book titled ‘Abstract Algebra: Theory and Applications’ [19] using a self-developed annotation tool. The total number of concordances annotated were 1025. Out of this, 288 contains the valid definition, whereas, 737 does not contains a valid definition.

4.1. Analysis of the Patterns in the Semantic

Let us now first try to analyze what kind of patterns exists in the semantic definition. For this, we computed the frequency spectrum of Part-of-Speech (POS) tags corresponding to each semantic example (some examples shown in Table 2). Table 3 shows the different variations with their respective frequencies. Here, if we assume that the various combinations of adjective (ADJ) and noun (NOUN) can be considered as Noun Phrase (NP). Then, we can notice that all the semantics contain at least one NP and also ending with NP, this is something which one would also expect intuitively.

Table 2. Examples of POS tags corresponding to the semantic defined in the concordance.

Concordance	Semantic	POS Tag(s)
an element of the set CENTERMATH, we write MATH.	set	NOUN
property MATH. E.g., if CENTERMATH is the set of even	set of even	NOUN,ADP,ADJ
a subset of MATH, written CENTERMATH or MATH, if every element	subset of MATH	NOUN,ADP,NOUN

Table 3. Frequency spectrum of the semantic.

Semantic Pattern	Frequency
NOUN	169
NOUN,ADP,ADJ	4
NOUN,ADP,NOUN	8
ADJ,NOUN	64
NOUN,ADP,DET,NOUN	2
NOUN,CCONJ,NOUN	2
ADJ	20
ADJ,CCONJ,PART,NOUN	1
NOUN,CCONJ,ADJ,NOUN	2
ADJ,ADP,NOUN	2
ADJ,CCONJ,ADJ	2
ADJ,NOUN,ADP,NOUN	2
NOUN,NOUN	14
NOUN,NOUN,ADP,NOUN	1
NOUN,ADJ,NOUN	1
ADJ,ADP,NOUN,NOUN	1
ADJ,NOUN,NOUN	2
NOUN,NOUN,NOUN	1
NOUN,ADJ	1
ADJ,ADJ	1
ADJ,ADP,DET,NOUN	3
NOUN,ADP,DET,ADJ	1
ADJ,ADJ,NOUN	4
PART,ADJ	1

The description of various POS tags used is ADJ (Adjective), ADP (Adposition), ADV (Adverb), CCONJ (Coordinating conjunction), DET (Determiner), NOUN (Noun), NUM (Numeral), and PART (Particle) [20].

5. Algorithm of Semantic Extractor

For semantic extraction, we have developed a pattern matching algorithm. The algorithms utilizes rules and heuristics based on the patterns found in the concordance string and their corresponding parts of speech (POS) tagged forms. In this paper, we refer to the concordance string as ”phrase” and its POS tagged form as ”posForm”. To perform POS tagging, we have employed the wink-nlp library [21]. We chose this library primarily because of its compatibility with the browser environment, as we have integrated this workflow with MathJax. The rules are defined as a set of regular expressions. Each rule consists of two parts: the precondition and the action. The precondition specifies the condition that needs to be satisfied for the rule to be applied, and if the precondition is met, the corresponding action specified in the rule will be executed. We have developed around thirty such rules, some of them with examples are listed below –

- If CENTERMATH followed by “,/is/are” followed by “called/said” then the NP present post the specified pattern is a potential definition. E.g.,
    - ∗ can define a new set CENTERMATH, called the **Cartesian product** of
    - ∗ The set CENTERMATH is called the **domain** of
    - ∗ is MATH, i.e., MATH, then CENTERMATH is said to be **onto**
- If punctuation is present in the postfix, then ignore everything post punctuation. E.g.,
    - ∗ an element of the set CENTERMATH, **we write MATH.**
    - ∗ a subset of MATH, written CENTERMATH, **if every element**
    - ∗ complement of MATH, denoted by CENTERMATH, **to be the set**

All of these rules get applied in a particular order. The NP which survives till the end is the semantic corresponding to the CENTERMATH.

While working on the algorithm, we also came to the realization that the standard POS tagging models available for the English language would not be sufficient to meet our requirements. It became evident that a separate model needed to be trained specifically for mathematical content. As an interim solution, we implemented a workaround by hard-coding POS tags for certain words. The list of these words and their corresponding POS tags can be found in Table 4.

Table 4. The list of hard-coded POS tags for certain tokens.

POS Tag	Tokens
NOUN	set, sets, map, maps, integer, integers
VERB	forms, form
ADJ	ordered, fixed, equivalence, equivalent, identity, onto, reflexive, even
PRON	such, case
ELEMENT	CENTERMATH

6. Results and Conclusion

The developed algorithm is able to accurately extract 307 out of 309 definitions, resulting in an accuracy of 99.35%. The total number of definitions is 309, taking into account that 21 concordances contain multiple definitions. The two definitions that the algorithm fails to extract correctly are mentioned in Table 5.

Table 5. Concordances for which extracted definition is not correct.

Concordance	Correct Definition	Extracted Definition
logarithm and the exponential functions, CENTERMATH and MATH, are inverses of	logarithm function	logarithm
Let MATH and CENTERMATH be integers and MATH be	integers	integers and MATH

It's very important to classify concordances and make sure that the incoming concordance has a valid mathematical definition. Otherwise, there will be lot of noise as well as many of these patterns can be observed in the concordances which do not have any valid mathematical definition. To validate the same, we also ran this algorithm on the concordances which does not contain valid definition. Its purpose was to check whether the algorithm has the capability to reject the concordances which does not contain valid mathematical definition. We found that it is able to reject 62% concordances. This way, it also improves the classification accuracy by rejecting 62% false positive passed by the classifier.

As our dataset was not very large and constructed from a part of a book, we need to validate how much of these rules hold valid across various domains and writing styles used by various authors. Hence, we may also need to add more rules in the future. The proposed algorithm sounds promising for extracting semantic definition from the concordance. This will enhance the audio rendering of equations and will reduce the cognitive load experienced by the users. We believe that this work has set the foundation for learning semantic definitions from the surrounding text.

References

[1] Cervone D, Krautzberger P, Sorge V. Towards universal rendering in MathJax. In: Proceedings of the 13th Web for All Conference. ACM; 2016. p. 4.

[2] Tseng W. Access8Math NVDA Adon; 2021. https://addons.nvda-project.org/addons/access8math.en.html.

[3] Soiffer N. MathCAT – Math Capable Assistive Technology; 2022. https://nsoiffer.github.io/MathCAT/.

[4] Frankel L, Brownstein B, Soiffer N. Navigable, customizable TTS for Algebra. In: 28th Annual International Technology and Persons with Disabilities Conference Scientific/Research Proceedings. California State University, Northridge; 2014. .

[5] Yamaguchi K, Komada T, Kawane F, Suzuki M. New features in math accessibility with infty software. In: International Conference on Computers for Handicapped Persons. Springer; 2008. p. 892-9.

[6] Wolska M, Grigore M. Symbol declarations in mathematical writing. 2010.

[7] Wolska M, Grigore M, Kohlhase M. Using discourse context to interpret object-denoting mathematical expressions. 2011.

[8] Yokoi K, Nghiem MQ, Matsubayashi Y, Aizawa A. Contextual analysis of mathematical expressions for advanced mathematical search. Polibits. 2011;(43):81-6.

[9] Nghiem MQ, Kristianto GY, Topić G, Aizawa A. A hybrid approach for semantic enrichment of MathML mathematical expressions. In: International Conference on Intelligent Computer Mathematics. Springer; 2013. p. 278-87.

[10] Stathopoulos Y, Teufel S. Mathematical information retrieval based on type embeddings and query expansion. In: Proceedings of COLING 2016, the 26th International Conference on Computational Linguistics: Technical Papers; 2016. p. 2344-55.

[11] Almomen R. Context classification for improved semantic understanding of mathematical formulae. University of Birmingham; 2018.

[12] Grigore M, Wolska M, Kohlhase M. Towards context-based disambiguation of mathematical expressions. In: The joint conference of ASCM; 2009. p. 262-71.

[13] Stuber J, Van den Brand M. Extracting Mathematical Semantics from +LaTeX Documents. In: International Workshop on Principles and Practice of Semantic Web Reasoning. Springer; 2003. p. 160-73.

[14] Doush IA, Alkhateeb F, Al Maghayreh E. Towards meaningful mathematical expressions in e-learning. In: Proceedings of the 1st International Conference on Intelligent Semantic Web-Services and Applications; 2010. p. 1-5.

[15] Nghiem MQ, Yoko G, Matsubayashi Y, Aizawa A. Towards Mathematical Expression Understanding. 2014. Available from: inftyreader.org.

[16] (W3C) WWWC. MathML4 specifications – The intent attribute; 2022. https://www.w3.org/TR/mathml4/#mixing_intent.

[17] Bansal A, Sorge V, Balakrishnan M, Aggarwal A. Towards Semantically Enhanced Audio Rendering of Equations. In: Computers Helping People with Special Needs: 18th International Conference, ICCHP-AAATE 2022, Lecco, Italy, July 11–15, 2022, Proceedings, Part I. Springer; 2022. p. 30-7.

[18] Bansal A, Kumar P, Sorge V, Balakrishnan M. Locating Mathematical Definitions in a Document. In: 4th Int Workshop on Digitization and E-Inclusion in Mathematics and Science; 2021. .

[19] Judson T. Abstract Algebra: Theory and Applications. PreTeXt; 2022.

[20] Part-of-Speech Tags reference – wink-nlp – npm; 2022. https://winkjs.org/wink-nlp/part-of-speech.html.

[21] wink-nlp - npm; 2022. https://www.npmjs.com/package/wink-nlp.

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On Support for Dyslexic Students in Senior-High School and Higher Education

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Abstract. It is very difficult to provide dyslexic students in senior-high school or higher education with all necessary textbooks in ordinary accessible format such as multimedia DAISY. Here, a new approach to provide them with a new type of accessible textbooks named "Fixed-Layout DAISY" is shown. In it, the whole page is treated as a multi-layer picture, the front layer of which has the same form as the original PDF. A DAISY (EPUB3) player can read out any texts together with highlighting them. It does not have the reflow function. The page layout is always kept as same as the original. It does not have information either in which order texts on the page should be read out, and readers need to click a text block on a page where they want to read. Dyslexic people can see and click a place where they want to read, and obviously, Fixed-Layout DAISY should work for them. Fixed-Layout DAISY can be produced almost automatically from an original "e-born PDF" by making use of our OCR system, and it should be very helpful for the dyslexic students to get accessible version of their textbooks.

Keywords. EPUB3, Fixed-Layout DAISY, e-born PDF, dyslexia

1. Introduction

As is well known, "DAISY (Digital Accessible Information System)" (or accessible EPUB3 that is essentially DAISY4) has already held the position of the international standard for accessible e-books [1]. In Japan, "the Japanese Society for Rehabilitation of Persons with Disabilities (JSRPD)" has been providing print-disabled students with e-textbooks in multimedia DAISY or accessible EPUB3 (audio-embedded DAISY/EPUB3 as media overlay) since 2008 [2]. It now organized 23 volunteer groups/organizations and produced around 300 titles of accessible textbooks for elementary and junior-high school (the ages of compulsory attendance at school in Japan). Now, more-than-15,000 print-disabled students (mostly ones with developmental reading disorder, namely, dyslexia) use those textbooks. Certainly, Braille and large-print versions are also provided to blind and low-vision students, respectively.

Concerning textbooks in senior-high school and higher education, however, it is very hard for dyslexic students in Japan to obtain accessible textbooks. A number of textbook titles in elementary and junior-high school is limited, but extremely many titles (more than 1,000) are used even in senior-high school. As you know, recently, very complicated

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layout is usually used in a textbook, and conversion process into multimedia DAISY requires a lot of manual works to get a DAISY player to read out them properly. It is almost impossible to convert all necessary titles into multimedia DAISY just for senior-high-school students. Furthermore, in higher education, the titles of textbooks reach astronomical numbers. Thus, no official organizations including JSRPD do not provide the dyslexic students with accessible textbooks. Several small volunteer groups help them individually with converting a limited number of textbooks into multimedia DAISY, but obviously, it is not good enough. Unfortunately, in Japan, many students who do need accessible textbooks due to the severe dyslexia decide to give up the idea of going to senior-high school or college.

Here, we show our new approach to provide dyslexic students in senior-high school or higher education with a new type of accessible textbooks which can be produced almost automatically from an original "e-born PDF" by making use of our OCR (optical character recognition) system.

2. Some Background

2.1. PDF Accessibility

One of the most serious problems in digitized STEM (science, technology, engineering and mathematics) contents, which are provided in PDF in most cases, is their poor accessibility. So-called "PDF/UA" is supposed to be accessible in a certain level; however, making PDF/UA contents requires a lot of extra works [3], and print-disabled people hardly expect to obtain such accessible PDF. Thus, they usually use OCR software to read PDF contents. In terms of STEM contents, however, the ordinary OCR software cannot recognize technical parts such as mathematical formulas properly, and it is hard for them to read PDF STEM contents. To solve this problem, we have been working on the development of OCR software for STEM contents, "InftyReader" [4].

There are essentially two different types in PDF. The first one, "e-born PDF" is PDF produced directly from a digital file such as a document in Microsoft Word, LaTeX, Adobe InDesign, etc. We refer to the other type as "image PDF," which is usually made by scanning or copying.

We have released InftyReader for almost twenty years. Through user supports for the software, we have realized that in recent years, most of the (individual) end users use InftyReader to read STEM contents in e-born PDF, and the importance of e-born PDF accessibility is definitely increasing.

From the viewpoint of computerized processing to convert e-born PDF into accessible form, its most significant advantage is that the accurate information on each character/symbol such as the character code, the font name, the coordinate on a page is embedded in it. Actually, in ICCHP2016, we reported the new method of mathematical OCR to improve recognition accuracy for e-born PDF, by combining analysis technologies in our mathematical OCR with character/symbol information extracted from the PDF by a PDF parser [5]. At that time, however, the ambiguity of the character information in mathematical formulas obtained by the PDF parser was our remaining problem.

As well as our first approach reported in ICCHP2016, Sorge, et al. have also studied a method to recognize e-born PDF for STEM by making use of embedded character information and image-based OCR [6, 7]. However, as far as a mathematical part is concerned, a font bounding box (a rectangular area being circumscribed on the font) extracted from e-born PDF by the PDF parser often differs significantly from the graphical (real) bounding box of the original character image. Consequently, in the previous works, it was impossible to realize mathematical recognition based only on character information extracted from PDF. To solve this problem, we as well as Sorge et al. estimated the correct graphical bounding box of characters/symbols in a mathematical part, by combining the extracted data with image-based OCR.

In the DEIMS2021 conference, Fujiyoshi, et al. reported a completely new approach to extract character information from PDF [8]. They developed an application named “PDFContentExtracter” that makes the vector information of drawing each character/symbol in scalable vector graphics (SVG) by trapping a function for printing PDF. This application allows us to get a correct graphical bounding box even in a mathematical part. By making use of their application, we have actually improved InftyReader so that its structure analysis of mathematical formulas is less dependent on the image-based OCR result for characters/symbols [9, 10]. This approach has improved remarkably recognition accuracy for e-born PDF STEM contents represented in Latin characters. Furthermore, even if a Unicode-based local language is used in its text part, without a special OCR engine for that language, InftyReader can convert the PDF into various accessible e-formats: LaTeX, human-readable (HR) TeX, Microsoft Word, xHTML with MathML, accessible EPUB3, Multimedia Daisy, “ChattyBook (it will be discussed later).”

2.2. *Difficulty in Automatic Conversion*

If page layout were not complicated, InftyReader could recognize and convert it into accessible formats automatically. As was pointed out, however, the textbook layout recently tends to be very complicated. Its page consists of not only Body texts but also many sub-texts such as foot notes or other marginal notes, balloons, figure captions, etc.

Figure 1. A page sample of a Japanese textbook.

Fig. 1 is a page sample of a textbook in Japan (To avoid breach of copyright, it is slightly shaded off). As you see, there are many separated text blocks. OCR software probably can recognize the blocks themselves, but unfortunately, it cannot judge their order in which they should be read out. Without reading-order annotation, a DAISY player would read out them from the left to the right, from the top to the bottom in disregard of word connection. To get the player to read out the content properly, you do need to consider the order and give appropriate annotation to the recognition result manually. In addition, DAISY contents should be displayed properly through so-called "reflow." An authoring process to optimize those things requires you a lot of extra time and efforts in addition to ordinary editing works such as error correction.

2.3. Some extension in DAISY/EPUB3

A remarkable feature of recent textbooks in Japan is to use a lot of pictures to tell important points. They are often conveyed only by those pictures. To understand the content of the textbooks thoroughly, you do need to read texts included in the pictures. Certainly, many pictures are also used in textbooks especially ones for young students in other countries, but they are usually so-called illustrations to help a reader with understanding a story. In most cases, you should find word descriptions corresponding to them in the main article, and you could understand the content even if you could not read texts in the pictures. Thus, most popular DAISY/EPUB3 players in the world do not have a function to read out text in a picture. Instead, they would read out an alternative text for the picture if it were available. In Japan, however, many pictures in a textbook often play a role to tell a certain part of its main article, which is not explained sufficiently in words. Certainly, you could give them alternative text, but in many cases, a long passage should be necessary to tell. Thus, the alternative-text approach does not work enough in Japan. Furthermore, here, we would like to point out that the picture representation would rather be good for dyslexic students. They can see, and the picture representation should be easier for them to understand if texts in the pictures were read out. They should prefer that to the alternative text.

To mee this demand, we have introduced a layer structure in multimedia DAISY/ accessible EPUB3. A picture is represented in multiple layers, the front layer of which is an image that appears in the completely same layout as the original PDF. On the underlying layers, text-related information such as fonts, their coordinate on the page and bounding box, etc. (the recognition result) is stored, and by making use of it, a DAISY (EPUB3) player could read out texts in the picture with a TTS (text-to-speech) voice together with highlighting them. This multi-layer EPUB3 (DAISY) is authenticated by an EPUB3 validator [11], and it should be regarded as a kind of accessible EPUB3. Actually, some EPUB3 (DAISY) players in Japan can read out texts in a multi-layer picture. JSRPD has already adopted this- type DAISY/EPUB3 textbooks and provided print-disabled students.

To make DAISY/accessible EPUB3 contents more useful, we have also developed a Windows application named "ChattyBooks" that converts STEM contents in DAISY/accessible EPUB3 into audio-embedded HTML5 with JavaScript ("ChattyBook") [9, 12]. It consists of two component modules: a converter and a file manager. If a DAISY/accessible EPUB3 content is dropped on the ChattyBooks icon or in its main window, the content is converted automatically into HTML5 with JavaScript (a ChattyBook content). A popular browser such as Microsoft Edge, Google Chrome, Safari can display the content which has the almost-same functionality and operability of high-quality as the original DAISY/accessible EPUB3. A special DAISY/EPUB3 player is no longer needed to read out the content. JSRPD has also adopted ChattyBooks as one of standard players for their accessible textbooks that include multi-layer pictures.

3. Fixed-Layout DAISY

The layer structure allows us to develop a new-type accessible e-book named "Fixed-Layout DAISY." In it, the whole page is treated as a multi-layer picture, the front layer of which has the same form as the original (outline) PDF. A DAISY (EPUB3) player can read out any texts together with highlighting them as same as a multi-layer picture located locally on a page.

A main difference of Fixed-Layout DAISY from ordinary DAISY is that it does not have the reflow function. The page layout is always kept as same as the original. It does not have information either in which order texts on the page should be read out. These features look disadvantage for print-disabled students to read the content.

As is well known, DAISY was originally designed for visually disabled people, and subsequently, dyslexic people have become to use. Thus, DAISY is designed so that various-types of print-disabled people can read the same contents. However, as far as dyslexic people are concerned, some features of DAISY such as reflow, "automatic" aloud reading are not absolutely necessary requirements. In Fixed-Layout DAISY, its content cannot be read out automatically. You need to click a position on a page where you want to start reading; then, the text is read out up to the end of the text block. Certainly, this mechanism may not work for visually disabled people; however, dyslexic people can see and click a place where they want to read. Fixed-Layout DAISY should work for dyslexic people, we believe. In addition, Fixed-Layout DAISY would rather be appropriate to produce the accessible version of a book other than textbooks such as comics, picture books, (Pictorial) maps, etc.

In Fixed-Layout DAISY, you do not need to author it either so that a DAISY/EPUB3 player can read out its texts in a proper order. Thus, it becomes possible to realize almost automatic conversion from e-born PDF into Fixed-Layout DAISY. Actually, we have implemented this function in InftyReader. Using it, dyslexic people can convert PDF into Fixed-Layout DAISY for themselves. It should be very helpful for dyslexic students in senior-high school or higher education to get the accessible version of their textbooks.

4. Preliminary Evaluation

At some meetings in Japan, we have recently introduced Fixed-Layout DAISY and demonstrated how it worked. In the online lecture on 26 February 2023, more-than-200 people (teachers, volunteer-group members, parents and publishers who are associated with education for dyslexic students) participated, and we listened to their opinions. We realized that majority of them gave it strong support. In addition, some teachers pointed out that Fixed-Layout DAISY should be more appropriate for an exam paper. In it, keeping the original layout is often more important than a textbook. Someone said that Fixed-

Layout DAISY should be very useful for students with slight dyslexia who were in a transition process to a reader of ordinary print books.

There also were some participants who pointed out the shortcoming of Fixed-Layout DAISY. They said, "Some dyslexic students do need to modify contents such as adding Ruby (kana added alongside Chinese characters to show their pronunciation) or inserting word breaks. Such modifications look difficult in Fixed-Layout DAISY." We agree that multimedia DAISY/accessible EPUB3 contents should be produced in the ordinary style if necessary. However, we would like to point out that such shortcomings are all peculiar to Japanese, and Fixed-Layout DAISY should work more enormously in many countries other than Japan.

5. Conclusion and Future Task

We show our new accessible e-books for dyslexic people, Fixed-Layout DAISY which can be produced almost automatically from an original e-born PDF by making use of our OCR system. It should be very helpful for dyslexic students in senior-high school or higher education to get the accessible version of their textbooks. Based on this technology, we now proceed to a new project to provide dyslexic people with an online service so that uploaded PDF is automatically converted into Fixed-Layout DAISY. We expect that we will be able to demonstrate the prototype of this online service at the AAATE2023 Conference.

References

[1] DAISY Consortium [Internet]. [cited 2023 May 10]. Available from: http://www.daisy.org/
[2] Japanese Society for Rehabilitation of Persons with Disabilities [Internet]. [cited 2023 May 10]. Available from (Japanese only): http://www.dinf.ne.jp/doc/daisy/book/daisytext.html
[3] sAccessNet [Internet]. [cited 2023 May 10]. Available from: http://www.sciaccess.net/en/
[4] Soiffer N. Accessible PDF: $2 \not> 1$. Proc. the 4th International Workshop on "Digitization and E-Inclusion in Mathematics and Science 2021" (DEIMS2021) online; Nihon University. 2021; 1-8.
[5] Suzuki M, Yamaguchi K. Recognition of E-Born PDF Including Mathematical Formulas. Proc. the 15th International Conference on Computers Helping People with Special Needs (ICCHP 2016); Linz: Springer; 2016; LNCS 9758: 35-42. DOI: https://doi.org/10.1007/978-3-319-41264-1_5.
[6] Baker J, Sexton A, Sorge V. Extracting Precise Data from PDF Documents for Mathematical Formula Recognition. Proc. 8th IAPR International Workshop on Document Analysis Systems; 2008 [cited 2023 May 10]. Available from: https://research.birmingham.ac.uk/en/publications/extracting-precise-data- from-pdf-documents-for-mathematical-formu
[7] Baker J, Sexton A, Sorge V. A Linear Grammar Approach to Mathematical Formula Recognition from PDF. Proc. GREC-05: Springer; 2006; LNCS3926: 227-238.
[8] Nakamura S, Kohase K, Fujiyoshi A. Extracting Precise Coordinate Information of Components from E-Born PDF Files. Proc. the 4th International Workshop on "Digitization and E-Inclusion in Mathematics and Science 2021" (DEIMS2021) online; Nihon University. 2021; 15-18.
[9] Suzuki M, Yamaguchi K. On Automatic Conversion from e-Born PDF into Accessible EPUB3 and Audio-Embedded HTML5. Proc. the 17th International Conference on Computers Helping People with Special Needs (ICCHP 2020), online: Springer; 2020; LNCS12376: 410-416. DOI: https://doi.org/10.1007/978-3-030-58796-3_48.
[10] Suzuki M, Yamaguchi, K. Conversion of Multi-Lingual STEM Documents in E-Born PDF into Various Accessible E-Formats. Proc. the 18th International Conference on Computers Helping People with Special Needs (ICCHP-AAATE 2022); Lecco: Springer; 2022; LNCS13341: 7-14. DOI: https://doi.org/10.1007/978-3-031-08648-9_2.

[11] pagina EPUB-Checker [Internet]. [cited 2023 May 10].
Available from: https://pagina.gmbh/startseite/leistungen/publishing-softwareloesungen/epub- checker/

[12] Yamaguchi K, Kanahori T, Suzuki M. ChattyBook: Making Math Accessible for Online Education. Presentation at the 36th CSUN Assistive Technology Conference, online: 2021 March 09.

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Multilingual Support for Accessibility in PowerPoint STEM Contents

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Abstract. Many online educational materials for sighted students such as presentation slides, PDF materials, MP4 videos, etc. are produced with Microsoft PowerPoint (PPT). In terms of non-technical contents, accessible PPT contents can be produced in a certain level; however, as far as STEM contents are concerned, there is still a serious difficulty. Our new add-on for PPT allows users to make efficiently/easily PPT STEM contents accessible. By making use of it, alt text/aloud reading by a TTS voice can be added to any technical part such as mathematical expressions included in PPT slides. An accessible MP4 video for STEM education also can be produced efficiently. By making use of multilingual support in Infty software, this add-on has been recently improved so that users can use it for PPT contents in various local languages other than Japanese or English.

Keywords. Online education, PowerPoint; add-on, STEM, multilingual contents

1. Background

Many online educational materials for sighted students are produced with Microsoft PowerPoint (PPT). They are provided as lecture videos in MP4 and/or PDF. Otherwise, the PPT slides are displayed directly on a computer screen in remote lectures. In an inclusive class, if the lecture were face-to-face, a teacher could explain directly any part of the PPT or PPT-originated educational materials as necessary even if they were not necessarily accessible. On the other hand, in case of distance education, print-disabled students should access the entire content for themselves at home.

Currently, various method to make PPT presentations accessible are suggested by Microsoft or other organizations [1]. Certainly, in terms of non-technical contents, we actually can produce accessible PPT contents in a certain level, based on those methods. However, as far as STEM (science, technology, engineering and mathematics) contents are concerned, there is still a serious difficulty. In many cases, print-disabled students hardly access important technical elements such as mathematical formulas, diagrams and tables included in STEM educational materials created with PPT. Embedding an alternative text (alt text) is usually suggested as effective countermeasures to make them accessible. Otherwise, you might add audio (aloud reading) information to them as audio

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objects. You could add the explanation in a recorded voice to each slide and export the result to a MP4 video. However, all of those processes should require you a lot of extra manual works.

In many of the early approaches to STEM accessibility such as Raman's work [2], LaTeX played an important role in STEM accessibility. While it is important even now, recently, MathML has become a key technology in assistive tools for print-disabled people to access STEM. For instance, DAISY (Digital Accessible Information System; it is one of international standards for accessible e-books) has adopted MathML to represent mathematical formulas [3], and some DAISY/accessible EPUB3 players could read out such mathematical formulas with a TTS (text-to-speech) voice even if alternative texts for them were not available. In terms of web accessibility, recently, "MathJax" is widely used to represent MathML formulas on the web. The current version of JAWS, the most popular screen reader in Windows OS, can read out such mathematical contents to a certain extent [4, 5]. In Microsoft Word, its new feature named "Immersive Reader" allows a screen reader to read out a mathematical formula in Microsoft math object.

Unfortunately, however, as was mentioned, those technologies cannot be applied to make PPT STEM contents accessible, such as images, diagrams, and tables containing mathematical formulas. To solve this problem, we have developed an efficient method to make PPT or PPT-originated STEM educational content be accessible by making use of Infty software (an accessible math-document editor, "ChattyInfty" and math-OCR (optical character recognition) software, "InftyReader") [6]. Using its functions, our new add-on for PowerPoint allows you to embed easily an alt text or/and aloud reading by a TTS voice to any technical part such as mathematical expressions included in PPT slides. An accessible MP4 video for STEM education also can be produced efficiently. In addition, by making use of the localization scheme in Infty software, we have been recently improved this assistive tool so that end users can customize the add-on for their local language. It can be used for PPT slides in their own language.

2. Method

We have recently developed a PowerPoint add-on with VBA (Visual Basic for Application) to realize a systematic/efficient-processing mechanism for embedding alt texts or/and aloud reading in PPT contents [7, 8]. This new add-on requires that computer OS is Microsoft Windows 10 or later and that PowerPoint, ChattyInfty and InftyReader are all installed and work properly.

The add-on provides you with three ways to embed the alt text or/and the MP3 audio file (aloud reading) for each mathematical part in PPT slides.

(1) Converting a mathematical part in an existing PPT slide into the alt text and the MP3 audio file and embedding.
By copying a selected mathematical part in the PPT slide, it is stored on the Windows clipboard as an image. The add-on uses VBA shell functions to recognize the image automatically with InftyReader, its command-line application, "infty.exe" and to paste the result into ChattyInfty in an editable form. If necessary, the result can be corrected in an intuitive manner, and then, it can be converted manually into its word description (alt text) or/and MP3 audio file (aloud reading) with a TTS voice.

In the next step, the add-on converts the generated audio file into a PPT audio object and embeds it at the background of the original mathematical part in the slide. The generated text is treated as an alt text for this audio object and also embedded.

(2) Converting a mathematical part in PDF into the alt text or/and the MP3 audio file.
If a PDF or other printed source of a PPT slide is available, you may copy a selected mathematical part from it with a Snapshot function in Acrobat Reader. The add-on also can generate the alt text or/and the MP3 audio file in the same manner as is described in (1).

(3) Newly creating a mathematical formula together with its alt text or/and MP3 audio file.
When editing a PPT slide, the add-on allows you to start up ChattyInfty to create newly a mathematical formula. You can insert it into the slide together with its alt text or/and MP3 audio file.

In addition, by making use of "ChattyPad" function of ChattyInfty, the add-on also allows you to revise/correct easily the alt text or the MP3 audio file that is already inserted in the slide. By clicking the mathematical part, at the background of which the audio object is embedded, ChattyPad window opens automatically to display its ChattyInfty form, and you can revise/correct it as you like. The previous audio object will be replaced automatically with the revised one.

From the viewpoint of software GUI (graphic user interface), by installing the add-on, three new items appear in the PowerPoint ribbon menu: "Add New Alt Text from Selected Object", "Add New Aloud Reading from Selected Object" and "Add New Aloud Reading ". Using " Add New Alt Text from Selected Object"/"Add New Aloud Reading from Selected Object", you can select a mathematical part in a PPT slide and paste it into ChattyInfty. As was mentioned, its snapshot is automatically recognized by InftyReader, and the result is pasted into ChattyInfty in an editable form. After correcting recognition errors (if necessary), the mathematical formula is converted into its word description (alt text) or/and aloud reading with a TTS engine. You can add that alt text and/or aloud reading at the indicated position in the original Slide.

"Add New Aloud Reading" starts up ChattyInfty automatically. As was also mentioned, if a mathematical formula is not written yet in the PPT slide, you may create the necessary formula directly in ChattyInfty (which is easily done in an intuitive manner) and insert it into the PPT slide together with aloud reading.

By making use of this method, teachers can easily/efficiently make mathematical parts in PPT slides be accessible. Furthermore, ChattyInfty can read out entire STEM contents and convert that into a MP3 audio file. If a lecture script for PPT slides were prepared in ChattyInfty, you could add the speech presentation generated by ChattyInfty to each slide and convert PPT into a MP4 video, in which all the content including technical parts would be read out properly with a TTS voice.

3. Multilingual Support

The add-on has been developed for Japanese in first stage. It is implemented by making use of ChattyInfty/InftyReader as PowerPoint VBA. For the past several years, we have been working on developing Infty software so that it can treat more various local languages.

3.1. Multilingual Support in ChattyInfty

In 2016, a research group at Indian Institute of Technology, Delhi inquired of us if a Hindi version of ChattyInfty could be developed. They said, "Millions of children with visual disabilities exist even now in India or other developing countries due to inadequate medical treatment. Accessible books should be exactly necessary for those countries." It strongly impressed us, and they thoroughly examined its possibility. Through this process, it was concluded that a much better localization scheme for ChattyInfty should be given.

As the first step to realize that, the following new features have been implemented in ChattyInfty.

(1) Unicode can be used on its main Window so that users can input a text in their local language other than Japanese if characters are included in Unicode.
(2) The definition file for reading aloud mathematical symbols and formulas, "ReadSetting.txt," is also represented in Unicode so that users can prepare its local-language version.
(3) STEM terminology in menu items can be also replaced with local names. Ordinary menu items such as "File" might be OK even if they were represented in English. In developing countries, users are usually familiar with the menu items in English; however, names of technical symbols and mathematical formulas such as "Regular Triangle" and "Square Root," which also appear as the menu items, should be represented in their local manner.
(4) Any SAPI5 voices can be selected for speech output.

After that, a new localization scheme has been compiled for end-users to incorporate ReadSetting.txt and the other necessary definition files efficiently/systematically into ChattyInfty without software-developer's help [9]. It allows users to customize the software simply by putting the definition files in a specified folder and changing some software settings. In addition, the software has been improved for the following points.

(1) Its latest version can be customized for languages that are represented in Unicode using Grapheme Cluster such as Hindi and Tamil, in which a single character is often represented with multiple codes. In addition, extended Latin characters that are input with multiple keystrokes (characters with an accent mark) can be also used. (However, unfortunately, languages written from right to left such as Arabic are still out of scope.)
(2) Unfortunately, a SAPI5 voice is often not available or of low quality in a local language. To correspond to such cases, a new application named "SpeechFiveMagic" was developed to allow people to use voices of "Windows OneCore" as SAPI5 [10].

Based on the above, the current version of ChattyInfty can read out properly STEM contents in several other local languages such as English, Vietnamese, Czech, Italian, etc.

3.2. Multilingual Support in InftyReader

There are essentially two different types in PDF. The first one, "e-born PDF" is PDF produced from a digital file such as a document in Microsoft Word, LaTeX, Adobe InDesign, etc. We refer to the other type as "image PDF," which is usually made by scanning or copying.

From the viewpoint of computerized processing to convert e-born PDF into accessible form, its most significant advantage is that the accurate information on each character/symbol such as the character code, the font name, the coordinate on a page is embedded in it. In ICCHP2016, we reported the new method of mathematical OCR to improve recognition accuracy for e-born PDF, by combining analysis technologies in InftyReader with character/symbol information extracted from the PDF by a PDF parser [11].

If a character set for a local language is included in Unicode, character information in e-born PDF is usually represented in Unicode. As is well known, to recognize a local language correctly, image-based OCR software does need a special OCR engine well-customized for that language. However, our new method for e-born PDF no longer uses image-based OCR in the recognition of local-language texts. Thus, without a special OCR engine, it is possible to develop a system to convert e-born STEM contents in other local languages into accessible format. We have improved InftyReader so that it can treat e-born PDF in any Unicode-based language. Those e-born STEM contents can be converted automatically into various accessible e-formats: LaTeX, human-readable (HR) TeX, Microsoft Word, xHTML with MathML, accessible EPUB3, Multimedia Daisy, "ChattyBook" (audio-embedded HTML5 with JAVA script) [12, 13].

3.3. Multilingual Support in Add-on for PowerPoint

We have been recently improved the add-on so that it can treat PPT STEM contents in various a local language available in ChattyInfty/InftyReader. Using a localization scheme in ChattyInfty [9], you could customize the add-on so that it could treat PPT contents in your own local language. If a certain local language is chosen in ChattyInfty, the add-on generates automatically an alt text or an audio file in that language. Thus, you can add easily the alt text or the aloud reading (audio file) in your language to PPT slides.

4. Preliminary Evaluation

We actually produce accessible MP4 videos for online education in this manner at Nihon University. In 2021 and 2022, by making use of the new method, Komada produced a MP4 video in the following steps.

(1) Convert the PPT slides prepared in 2020 into ChattyInfty; in addition, create/input directly new STEM contents in ChattyInfty or convert existing PDF STEM contents including mathematical formulas into ChattyInfty (also with InftyReader).
(2) Prepare a lecture script for the PPT slides by editing the ChattyInfty content.
(3) Generate aloud reading of the lecture script in MP3 with ChattyInfty and embed the MP3 files into the slides.
(4) Convert the PPT slides into a MP4 video.

We realized that this way is certainly more efficient than the previous. In addition, if necessary, you can modify the accessible MP4 video quite easily.

To compare this video with other accessible format, we also prepared a ChattyBook content [13] for the same class. ChattyBook is an accessible web content: audio-embedded HTML5 with JAVA script which has the same operability and functionality as multimedia DAISY.

We issued a questionnaire to the students to ask their impressions on those two-type accessible contents. The rate of the students who judged the content "easy to understand" or "rather easy to understand" are 84% for the MP4 video and 91% for the ChattyBook content in total, respectively.

5. Conclusion and Future Task

Here, we show a new efficient method to make PPT or PPT-originated STEM educational content be accessible by making use of Infty software. Using its functions, our new add-on for PowerPoint allows you to embed easily an alt text and aloud reading by a TTS voice to any technical part such as mathematical expressions included in PPT slides. An accessible MP4 video for STEM education also can be produced efficiently. This function can be also used PPT STEM contents in various local languages.

For the present, there are some manual steps such as selecting each mathematical part in our workflow of adding alt text or/and aloud-reading. It requires you a certain skill to carry out. It should be improved so that the process is done automatically as well as possible.

We intend to realize more-direct transformation from PPT to ChattyInfty and vice versa. If this function were realized, it would be possible to convert a PPT content (via ChattyInfty) into various other accessible formats such as multimedia DAISY, accessible EPUB3 or audio-embedded HTML5 (ChattyBook). A ChattyInfty content could be also converted into accessible PowerPoint directly. It should give a more efficient way to produce accessible materials for inclusive mathematics education.

We intend to conduct more thorough evaluation test to understand remaining tasks in the PPT add-on, which we should work on. We will provide mathematics teachers with its trial version to ask them to test it on their online STEM lectures. Based on its feedback, we intend to polish up it and to release its revised version on demand.

References

[1] CSUN (California State University, Northridge). Accessible PowerPoint [Internet]. [cited 2023 May 13]. Available from: https://www.csun.edu/universal-design-center/PowerPoint

[2] Raman TV. Audio System for Technical Readings [Dissertation]. Cornell University. Berlin: Springer; 1998.

[3] DAISY Consortium [Internet]. [cited 2023 May 13]. Available from: http://www.daisy.org/

[4] MathJax. Accessibility Features – MathJax 3.0 [Internet]. [cited 2023 May 13]. Available from: https://docs.mathjax.org/en/latest/basic/accessibility.html

[5] Freedom Scientific, Inc. JAWS [Internet]. [cited 2023 May 13]. Available from: https://www.freedomscientific.com/

[6] Science Accessibility Net. [cited 2023 May 13]. Available from: http://www.sciaccess.net/en/

[7] Komada T. Realization of Inclusive Environment in Online STEM Lectures Using PowerPoint. Proc. the 4th International Workshop on "Digitization and E-Inclusion in Mathematics and Science 2021" (DEIMS2021) online; Nihon University. 2021; 29-31.

[8] Komada T, Yamaguchi K, Suzuki M. An Efficient Method to Produce Accessible Contents for Online STEM Education. Proc. the 18th International Conference on Computers Helping People with Special Needs (ICCHP-AAATE 2022); Lecco: Springer; 2022; LNCS13341: 15-21. DOI: https://doi.org/10.1007/978-3-031-08648-9_3

[9] Yamaguchi K, Suzuki, M. An accessible STEM editor customizable for various local languages. Journal of Enabling Technologies. Emerald Publishing Ltd. 2019; 13(4): 240-250.

[10] DIGITALNAUTS Co., Ltd. Speech Five Magic [Internet]. [cited 2023 May 13]. Available from: http://www.digitalnauts.co.jp/sfm/?lang=en

[11] Suzuki M, Yamaguchi K. Recognition of E-Born PDF Including Mathematical Formulas. Proc. the 15th International Conference on Computers Helping People with Special Needs (ICCHP 2016); Linz: Springer; 2016; LNCS9758: 35-42. DOI: https://doi.org/10.1007/978-3-319-41264-1_5.

[12] Suzuki M, Yamaguchi K. On Automatic Conversion from e-Born PDF into Accessible EPUB3 and Audio-Embedded HTML5. Proc. the 17th International Conference on Computers Helping People with Special Needs (ICCHP 2020), online: Springer; 2020; LNCS12376: 410-416. DOI: https://doi.org/10.1007/978-3-030-58796-3_48.

[13] Yamaguchi K, Kanahori T, Suzuki M. ChattyBook: Making Math Accessible for Online Education. Presentation at the 36th CSUN Assistive Technology Conference, online: 2021 March 09.

AT Service Delivery

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Process Evaluation of the Optimized Provision of AT for Impaired Upper Extremity Function Within the OMARM Study

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Abstract. A quality standard for the ICF-oriented provision of arm supports and robotic arms was designed. To facilitate this new working method, tools were developed in co-creation with all stakeholders. Professionals received training and were asked to apply the new working method among their clients who participated in the intervention group of the OMARM project. To find out whether the provision had changed following the introduction of the quality standard, and to gain insight into the usage of tools and the perceived added value, a process evaluation was conducted after 3, 6 and 9 months by an online survey. In sum, the new working method was applied to 43 of 137 clients, and tools were used 105 times. Opinions on perceived changes, benefit, and practicability varied widely. Although tools were developed in co-creation with all stakeholders, several professionals' satisfaction with the developed way of working is lower than expected and its adoption lags.

Keywords. Quality standard, AT provision, dynamic arm supports, robotic arms, process evaluation

1. Introduction

Previous research has ascertained the need for optimizing the provision of Assistive Technology (AT) devices for impaired upper extremity function, especially dynamic arm supports and robotic arms [1-3]. All identified bottlenecks are thoroughly described elsewhere [4,5] and were attempted to be solved by an optimized working method for the provision as detailed in the corresponding module "Assistive Technology Care around arm supports and robotic arms". This quality standard was developed as part of the OMARM (OptiMization of the provision process of AT devices for impaired upper extremity (ARM and hand) function) project [4], funded by ZonMw (853001107), in co-creation with all stakeholders. It describes the proceeding steps to be taken by clients and professionals involved to arrive at an ICF-oriented prescription and provision of dynamic arm supports and robotic arms - based on an analysis of clients' current and intended functioning [6]. To perform the provision in the best viable way, tools were developed in co-creation with all stakeholders to underpin the various steps. The main changes to be implemented by the introduction of the quality standard can be summarized as follows:

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- availability of more objective information on the provision process, and devices, including differences between products (e.g., a client version of the quality standard (step-by-step plan), and an orientation aid on dynamic arm supports and robotic arms)
- tools to determine the type of solution and the most suitable device (e.g., a functionality diagnosis form, a form for drawing up the program of requirements, and a form technical specifications)
- more involvement of clients in the selection and possibility to try out products in real life situations for better fitting
- better collaboration between occupational therapists and suppliers' advisors to inform realistic goalsetting and to facilitate a good match between user and device (e.g., more time available, both professionals are present during delivering and instructing)
- more consideration for training (structured by a training schedule form) and evaluation (facilitated by an evaluation tool)

More information on commercially available dynamic arm supports and robotic arms as well as the client version of the quality standard and accompanying tools can be found here: Arm- en Handondersteuning - Vilans Hulpmiddelenwijzer.

In spring 2021, 23 occupational therapists, and one rehabilitation mechanic were trained in applying the quality standard and its tools, during 16 hours of training, including a demonstration of all dynamic arm supports and robotic arms commercially available in the Netherlands. Afterwards, from June 2021 until July 2022, participants were included in the intervention group of the OMARM study. Among these participants, the new working method described in the quality standard was applied. To find out whether the provision of dynamic arm supports and robotic arms had actually changed following the introduction of the quality standard, and to gain insight into the usage of tools and the perceived added value, a process evaluation was conducted after three, six and nine months after inclusion of the first participants of the OMARM study.

2. Methods

The process evaluation was conducted as an online survey by means of a questionnaire distributed via Questback to all professionals collaborating with clients with limited arm-hand function who were involved in the development of the new working method and associated tools and/or attended the corresponding training. The questionnaire comprised 35 questions categorized in three main parts. First, professionals were asked how many clients during the last three months were eligible for dynamic arm supports or robotic arms, how often they applied the new working method and if they experienced it as an optimization compared to the method used before. As the procedure differs for professionals with diverse backgrounds, routing was used to display only applicable questions to the individual respondent. Before publication, the survey was pre-tested to check technical aspects (distribution, routing etc.) and aspects concerning content (e.g., comprehensibility and relevance of all questions).

In total, the questionnaire was sent to 40 professionals; 30 received the invitation to participate directly by e-mail from the researchers; 10, mainly suppliers' advisors, received a link to the questionnaire via the suppliers. The first survey took place in

October and November 2021, the second in January and February 2022, and the third in April and May 2022. The data were exported to an Excel file and analyzed using descriptive statistics. Answers to open-ended questions were analyzed with a directed content analysis [7]. Results are presented for the total group of respondents, and additionally specified by professional background to reveal possible differences.

3. Results

The response rate of the first survey was 42,5%: 17 professionals completed the questionnaire, of whom 10 were occupational therapists (OT), 6 suppliers' advisors (SA) and one a rehabilitation physician (RP). The response rates of the second and third survey were 26%, and 29% respectively, 8 respondents after 6 months (6 OT and 2 SA), and 9 after 9 months (7 OT, 1 SA and 1 RP).

Overall, 103 clients considering a dynamic arm support or robotic arm were guided through the provision process by respondents in the first 3 months subsequent to the implementation of the new working method. Occupational therapists guided 14 clients (average 1.4 per OT), suppliers' advisors 84 (average 14 per SA) and the rehabilitation physician (RP) 5. In 18 of those clients, professionals had applied the new working method; OT 10 clients (mean 1.25), SA 4 (mean 2), and the RP 4.
In months 4 to 6 OT guided 13 clients, SA did not provide any information on this. In months 7 to 9 OT guided 16 clients and the RP 5, OT applied the new working method with 12 clients.

Respondents who actually applied the new working method with their clients (n=10) were then asked to what extent they agreed with the statement, that the new working method was an improvement on care as usual (CAU). This was further specified using the seven steps of the provision process. Response options ranged from 1 (totally disagree) to 5 (totally agree). The average level of agreement was highest about the information available on AT, fitting AT and delivering and instructing AT (average 3.0) and lowest with regard to the evaluation of AT and related services (average 2.67), with some respondents indicating that they had not yet experienced evaluation.

Table 1. Perceived changes of the new working method compared to CAU, after 3, 6 and 9 months

Improvement on CAU	**Mean**											
Steps in the provision	**Total**			**OT**			**SA**			**RP**		
of AT	**3**	**6**	**9**	**3**	**6**	**9**	**3**	**6**	**9**	**3**	**6**	**9**
Available information	3.0 n=10	3.7 n=6	3.6 n=5	3.1	3.8	3.8	1.5	3.0	3.0	5.0	-	-
Indication	2.9 n=10	3.5 n=6	2.8 n=5	3.1	3.6	3.3	1.5	3.0	1.0	4.0	-	-
Selection	2.9 n=10	3.8 n=6	2.6 n=5	3.1	4.0	3.0	1.5	3.0	1.0	4.0	-	-
Fitting	3.0 n=10	3.8 n=6	3.0 n=5	3.4	4.0	3.5	1.5	3.0	1.0	3.0	-	-
Delivering & instructing	3.0 n=8	3.2 n=6	3.2 n=5	3.2	3.2	3.3	2.5	3.0	3.0	3.0	-	-
Training/ using	2.9 n=9	2.8 n=6	3.0 n=5	2.8	2.8	3.0	3.0	3.0	3.0	3.0	-	-
Evaluation	2.7 n=9	3.2 n=6	3.4 n=5	3.0	3.2	3.5	1.5	3.0	3.0	3.0	-	-

CAU = care as usual; AT = Assistive Technology; OT = Occupational Therapists; SA = Suppliers' Advisors; RP = Rehabilitation Physicians

3.1. Explanation of perceived changes from respondents' perspective

One OT indicated that more **information** on assistive devices is **available** via suppliers or due to following the training, whereas another OT complained that the suppliers' websites still do not provide comparable information on different dynamic arm supports. Whilst the **indication** for the assistive devices remained unchanged (OT & SA), the **selection** is clearer through the tools (OT); highly experienced practitioners recognized minor change (OT, SA & RP). **Fitting** takes more time, but, according to one OT does not produce a better result, whereas another OT finds more time positive, allowing for more client involvement and more attention to the pros and cons of a device and relevant environmental factors, but still depending on the SA and whether all persons involved have the same goal and approach in mind. A third OT points out that the SA was not aware of her data. One OT describes her presence during the fitting as a *"safety net"*; another indicates that she was not present during the fitting because, according to the suppliers' advisor, this was not necessary. Both OT felt that their contribution was not appreciated by the SA. OT's presence at **delivery** is especially pleasing for the client/OT (SA): *"The OT can contribute to insights around realistic expectations already mentioned at the fitting but can be repeated, and where the client obtains more direct guidance and support from the OT to stay within the range of those expectations during the initial period of use"*. One SA notes that **training** by the OT is now more consciously included in the plan. Although her client was already coping well with the arm support additionally needed AT (e.g., a specific fork) could be identified (OT). Another OT stated that training sometimes is not realizable due to too long distances. According to one SA the **evaluation** of devices has not changed because the new working method appeared to be the same as their old one (care as usual), the other respondents who commented on the evaluation, indicated, that it has not been addressed yet or that they were not involved (RP).

Table 2. Perceived practicability of the new working method after 3, 6 and 9 months

Rating practicability	**Total**			**OT**			**SA**			**RP**		
(school marks 1-10)	**3**	**6**	**9**	**3**	**6**	**9**	**3**	**6**	**9**	**3**	**6**	**9**
Time required	5.0 n=15	5.4 n=5	4.3 n=6	4.7	5.3	4.5	5.6	5.5	2.0	5.0	-	6.0
Attractiveness	6.2 n=13	6.4 n=5	6.0 n=6	6.4	6.7	5.8	5.0	6.0	5.0	7.0	-	8.0
Clarity of manual and procedure	6.9 n=13	6.2 n=5	6.2 n=6	7.0	6.7	5.8	6.3	5.5	6.0	8.0	-	8.0
Avail- & accessibility tools & materials	6.6 n=14	7.8 n=5	6.3 n=6	7.1	8.7	6.0	5.0	6.5	6.0	9.0	-	8.0
Comprehensibility for the client	6.9 n=12	7.3 n=3	6.2 n=6	7.2	7.5	6.3	6.0	7.0	5.0	-	-	6.0
Burden on the client	6.6 n=13	7.3 n=4	5.8 n=6	6.9	8.5	6.0	5.7	6.0	5.0	7.0	-	6.0
Required expertise professional	6.6 n=13	7.0 n=5	6.2 n=6	6.6	7.0	6.3	6.3	7.0	6.0	8.0	-	6.0
Perceived usefulness	5.3 n=15	7.4 n=5	4.7 n=6	6.3	8.7	4.5	3.0	5.5	3.0	8.0	-	7.0

OT = Occupational Therapists; SA = Suppliers' Advisors; RP = Rehabilitation Physicians

3.2. Explanation of practicability of the new working method from respondents' perspective

Respondents were asked to rate the practicability of the new working method with regard to specific aspects [8] as displayed in Table 2 together with the quantitative results. Respondents indicated that the provision process now takes (much) more **time**, because of filling in forms, a consultation, and a home visit plus extra travel time and one respondent wondered "*whether this time investment yields enough in terms of quality of care"*. One OT confirms higher time investment but notes that she still needs to develop routine. For one SA, no change is noticeable; another finds the new working method rather cumbersome and questions its added value. The RP feels that the whole provision process is time-consuming, which has already been the case before.

Suggestions to improve the **attractiveness** were made related to the layout and accessibility of the developed forms (tools). The training day positively contributed to the **clarity** of the **manual** and **procedure**, but one SA *"experienced problems in conveying the right information"* due to their *"struggle with the documents"*. Respondents regretted that **tools and materials** were not compatible with their own documentation systems, and had to be managed separately, which decreased their **availability** and **accessibility**.

Regarding the **required expertise of professionals**, one SA experienced more insight from the OT involved, however, he felt that steering towards a product prior to fitting was still as difficult as before. Two respondents found the working method "*comprehensive and perhaps a bit pretentious"*, as it demanded a lot from the professional and a lot of knowledge was expected.

Asked about the **perceived usefulness**, one respondent judged it as overly complicated. In general, it is noticeable that for all aspects, some SA had the impression that these were not applicable to them, and therefore did not use the new working method and its tools.

The RP referred all clients who were eligible for a device to support arm/hand function to the (trained) OT with expertise in this field ('Ergo-E') for establishing the functionality diagnosis, as OT with expertise are members of the treatment team on location. No OT and no RP was consulted following physical complaints of the client due to use of the device.

In total, respondents used the **client version of the quality standard** (step-by-step plan) 5 times. Three respondents commented that they had no eligible clients, one respondent forgot to draw clients' attention to it and one SA left it to the OT. One OT looked at the module, finding it clearly described and good that it emphasises talking to an OT. *"This reduces the chances of clients coming to the OT with their desired solution instead of the question"*. They used the **orientation aid** 7 times. In addition to the comments described above, one respondent indicated that she found the first question difficult: *"Often a question is less specific and then it seems like you already have to choose here between what you find more important, being able to comb your hair or being able to eat a sandwich. Even though it says, you can change that, and you can do that very easily on the next page. Could you also select multiple boxes here, for example?"*. They used the **functionality diagnosis** form 33 times. One respondent found it troublesome that it is a separate form to be used alongside the electronic health record and only did part of the process during the training, but this caused steps to be skipped. One respondent indicated that they found the form extremely useful. The form for

drawing up the **program of requirements** was used 31 times. One SA indicated that most clients did not wish to cooperate. One OT used it by walking through with the client and her daughter which requirements the arm support should meet. They then noticed that they started with other items of interest. They would like to change the order of what comes up and is discussed first. Another respondent who only used it during training found it a nice way of identifying the specific problems. The form **technical specifications** of dynamic arm supports and robotic arms was used 18 times. One OT commented: *"Yes, but now I was fiddling with a pile of loose forms, on which it is difficult to get an overview. At one point, I started making piles. Some kind of decision tree would be handy, just like you do with a booking site."* A respondent who only used it during training indicated that the technical requirements were interpreted differently by various suppliers, as a result of which not all requirements and specifications turned out to be comparable. The **training schedule** form was only used during the training day. One respondent thought this was *"a nice addition with regard to the follow-up process"*. The **evaluation tool** was used 5 times.
The **overview of OT with expertise in dynamic arm supports and robotic arms** was used once, and the **OMARM group in Siilo**, a secure messaging app for healthcare professionals, was used 6 times (active and as follower).

4. Discussion

The average level of agreement was highest regarding selection and fitting of AT (3.8 after 6 months) and lowest with regard to selection of AT (2.6 after 9 months). The avail- and accessibility of tools and materials was rated highest (7.8 after 6 months), and the time required was rated lowest (4.3 after 9 months).

Although the tools and materials were developed in co-creation with all stakeholders, the satisfaction with the developed way of working is lower than expected and its adoption lags behind. Since a substantial proportion of suppliers' advisors and occupational therapists already had much expertise in the provision of dynamic arm supports and robotic arms, which they also brought to bear in developing the new way of working, the contrast between the new way of working and care as usual might appear smaller in this study than it probably is in daily practice.

References

[1] Graham CD, Rose MR, Grunfeld EA, Kyle SD, Weinman J. A systematic review of quality of life in adults with muscle disease. J Neurol. 2011; 258(9): 1581-1592. doi:10.1007/s00415-011-6062-5
[2] Van der Heide LA. Dynamic arm supports; matching user needs and preferences with technology. Dissertation. Maastricht: Maastricht University; 2017.
[3] Van der Heide LA, Gelderblom GJ, de Witte LP. Effects and effectiveness of dynamic arm supports: A technical review. Am J Phys Med Rehabil. 2015; 94(1): 44-62. doi:10.1097/PHM.0000000000000107
[4] Roentgen UR, van der Heide LA, Kremer IEH, Creemers H, Brehm MA, Groothuis JT, Hagedoren EAV, Daniëls R, Evers SMAA. Effectiveness and cost-effectiveness of an optimized process of providing assistive technology for impaired upper extremity function: Protocol of a prospective, quasi-experimental non-randomized study (OMARM).Technol Disabil. 2021; 33: 207-20. doi:10.3233/TAD-210335
[5] Van der Heide L, Hagedoren E, Roentgen U, Daniëls R. Challenges in the Provision Process of Dynamic Arm Supports and Robotic Arms as Perceived by End-Users. ICCHP-AAATE 2022 Open Access Compendium "Assistive Technology, Accessibility and (e)Inclusion" Part II.

[6] Heerkens Y, Claus E, Hagedoren E, Jonker H, Bougie T, Muylkens J, van Ravensberg D, Vreeswijk P. Verslag van het Project Opstellen Richtlijnen voor Functiegerichte Aanspraak hulpmiddelen. RiFA. Fase 1 opstellen van een basisrichtlijn. Utrecht: Chronisch Zieken en Gehandicapten Raad; 2010
[7] Hsieh H-F, Shannon SE. Three approaches to qualitative content analysis. Qualitative health research. 2005 15(9):1277–88. doi:10.1177/1049732305276687
[8] Dalemans R, Stevens A. Stap 6: wat is de hanteerbaarheid van meetinstrumenten? In: Beurskens S. Meten in de praktijk: Stappenplan voor het gebruik van meetinstrumenten in de gezondheidszorg. Houten: Bohn Stafleu van Loghum; 2020.

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MS@Work in Flanders: The Development of a MS Toolkit for a Stable Employment

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Abstract. Persons with MS have the highest unemployment rates compared to other chronic diseases. We want to develop a MS Toolkit with several aids for persons with MS to help them gain a sustainable employment with sufficient and permanent attention and guidance for the daily obstacles in the workplace. Therefore, the opportunities and bottlenecks were mapped through a survey with persons with MS and employers, a diary and expert interviews. There were 3 major problems identified: Persons with MS find it difficult to ask for help in time; they have little or no concrete knowledge about who they can turn to for support and healthcare professionals do not always possess the expertise to guide their patients through problems experienced on the work floor. These problems were used as fundaments in a cocreation session to create the content of the MS Toolkit: a screening tool and dashboard. The screening tool ensures an annual reflection of the work situation. The dashboard links each problem to the most appropriate service.

Keywords. Multiple sclerosis, employment, MS toolkit, screening, prediction, dashboard

1. Introduction

Multiple Sclerosis (MS) is a chronic, inflammatory and neurodegenerative disease that affects the central nervous system by forming plaques. In Belgium, more than 12.000 inhabitants suffer from MS and it is one of the most common neurological disorders in working adults with ages between 20 and 50 years old [1-3]. People with MS are a vulnerable group in our society. On the one hand, their condition is chronic. The symptoms, progression and severity of the disease have an unpredictable character and vary per person. On the other hand, people with MS encounter many problems to stay at work. 60-90% of this group effectively has a job at the time of diagnosis or has worked in the period before diagnosis [4-6]. However, 10 years after diagnosis, only 30% are

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still actively working [1,7,8]. MS patients have the highest unemployment rates compared to other chronic diseases [9]. These high rates are a consequence of complex interactions between health status (physical, cognitive and psychological function, type of immunomodulator, ...), work environment (temperature, accessibility, parking, ergonomics, support from colleagues/employer, ...), job requirements (job content, hours, flexibility, ...) and personal factors (education level, health perception, personality, ways of coping with illness, age, ...). However, it is proved that a stable, long-term employment has a positive impact on patients with MS. It is associated with higher quality of life, higher well-being, better disease management, higher self-confidence, higher social participation and fewer problems in the workplace [7,10,11]. In contrast, losing a job or an unstable professional future has a negative impact on health. It is associated with lower quality of life (both physical and psychological) and higher mortality rates [12].

Aside the fact that persons with MS are a very vulnerable group in our society due to their chronic and unpredictable disease character, they are very motivated to (continue to) work. They want to contribute to the society, want to remain useful, still have career goals and have a great perseverance. In addition, to maintain a decent standard of living, they need a decent financial return. Our society currently does not provide enough answers to give vulnerable groups with such a diverse course of illness a stable place in the labour market. There are no simple tools or well-known support channels specific to this group that could help them continuing work. This makes them a population with high labour potential, but with reduced opportunities and higher health costs.

To find a solution for this fundamental problem, it is, in first instance, necessary to precisely identify the opportunities and bottlenecks on the work floor for persons with MS in Flanders. In the second place, based on the results, we want to develop a MS Toolkit including several aiding tools for persons with MS and their network to help them (re)gain a sustainable employment.

2. Methods

2.1 Part 1 "Opportunities and bottlenecks"

To map the opportunities and bottlenecks, 4 methods were used:

1. **an online survey for working persons with MS.**

Prior to the development of this survey, inspiration was sought from (international) literature on relevant questions and themes. This formed the basis for a questionnaire that was thoroughly reviewed and revised by the entire project team in order to arrive at a final version. The final survey consisted of four parts: current and previous work experiences, detailed information about working with MS, disease characteristics and background information. The survey was composed in Qualtrics and the link was distributed via social media channels. In order to achieve the widest possible inclusion, no predetermined selection criteria were imposed on the basis of work status or working age. The themes which were particularly important at a later stage of the investigation were:

- The impact of MS on current or past employment
- The biggest challenges in current or past employment
- Helping factors to stay at work

- The desired vs. the made adjustments
- Level of information on support measures

2. **an online survey for employers of persons with MS.**

The survey was created in the same way as described above. This survey also consisted of four sections: background information, opportunities for adaptations on the work floor, concerns and current knowledge. The dissemination of this survey was a lot more personalised: (1) through the network of MS-Liga Flanders, (2) direct demand for employer contact data in the survey and reflection study of persons with MS and (3) via social media. Here too, the survey was composed in Qualtrics and distributed via a link.

The inclusion criteria included 1 condition: at least one person with MS had to be actively employed. The issues that were taken to the next stage were:

- What disadvantages they experience of employing someone with MS
- What benefits they experience in employing someone with MS
- What impact the company has already experienced
- What adjustments have already been made
- What are the main barriers to keep someone at work for a long time
- Knowledge support measures

3. **a 5-day online reflection diary for working persons with MS.**

To get a deeper insight in persons with MS, an online reflection study was done. 5 days in a row, 5-6 questions were asked within a particular theme. The themes were: illness and impact on daily (work) life, working experience, communication, support, social network/context. Once again, inspiration was drawn from (international) literature to pick the themes, together with the themes of the survey. On the one hand, the search for potential participants took place via social media, on the other hand persons with MS were recruited through the participating rehabilitation centres. Here too, Qualtrics was used as a medium to send out the short diary surveys on a daily basis. The inclusion criteria were working persons with MS, jobseekers, persons on sick leave or retired persons.

4. **semi-structured in-depth interviews with multiple experts.**

As the surrounding network is also very important, the opinion of a wide range of experts in the field was also taken into account. These expert profiles (medical insurance advisor, occupational doctor, job coach, disability case manager, occupational therapist, general practitioner, social assistant, MS nurse, neurologist, psychologist, rehabilitation doctor, care manager, employer) were specifically searched for within the existing network of the project partners. The inspiration for the interview guide also came from (international) literature and was of course closely related to the themes that were already covered by previous methods: their role, bottlenecks, opportunities, important measures, level of communication, knowledge of employment pathways and support measures.

A descriptive analysis was done for the questionnaires and a thematic analysis was applied on the diaries and interviews.

2.2 Part 2 "Co-creation"

The results of part 1 were used to create personas and customer journeys as input for 2 cocreation sessions with multiple experts (Director of MS-Liga Flanders, occupational therapist, care manager, professor, social worker, researcher) in the MS domain. For the personas, the International Classification of Functioning, Disability and Health (ICF) model was used as the basis for objective mapping of each participant. The personas were categorised according to the degree of limitations: no-light-moderate-serious. One of the five personas eventually disappeared, as it included the population who retired early and no longer had any job motivation. Furthermore, the following themes were included in the personas: demographics, goals, type of work, work motivation, communication with employer, acceptance, support, used support measures, contacts with healthcare professionals and participation in the society.

For the creation of the customer journeys, suitable time points were sought (diagnosis, first interview with employer, symptoms at work, etc.) within the results of part 1 and ordered in a realistic timeline. This timeline was expanded with information on positive or negative experiences and current bottlenecks. Subsequently, a process analysis was done during a co-creation session, where each participant had to indicate 5 priorities. The elements that received the most attention were used as fundament to formulate 5 concluding opportunities. These opportunities were the starting point to brainstorm about new ideas (short individual process). After this individual brainstorm phase, each participant indicated the 5 most innovative ideas. The idea with the highest score became the fundament of the group brainstorm to further refine the concept.

Afterwards, this concept idea was then developed, prototyped, investigated and further refined and received the name "MS Toolkit".

3. Results

A total of 118 working persons with MS, 2 job seekers, 16 persons in sick leave, 12 retired persons, 5 students, 4 work volunteers and 19 employers finished the questionnaire, 24 persons with MS participated in the diary study and 23 experts cooperated in the in-depth interviews. This data was used to create 5 personas and 4 customer journeys to support the co-creation process and idea generation.

The generated idea from the co-creation session is eventually a solution for 3 major problems (identified from the customer journeys): (1) Persons with MS find it very difficult to ring the alarm bells in time and ask for help; (2) they have little or no concrete knowledge about who they can turn to for support or advice and (3) healthcare professionals do not always possess the expertise to guide their patients through questions or problems experienced on the work floor. This means that potential problems often drag on and usually result in a relapse, attack or flare-up, forcing the person with MS to quit his/her job for a while (or permanently) to recuperate.

In the cocreation session, these 3 elements were used as the fundaments to brainstorm about the MS Toolkit content. Two online aiding tools were the result:

A **screening tool** ensuring an annual reflection of the work situation and motivates a faster detection (**Figure 1**). The content was based on an extensive literature search, where an overview was created about all the existing screening tools to discover work problems. Based on certain criteria (availability, validation, scoring system, collection time, purpose, language, etc.) this list was screened. The current screening tool became

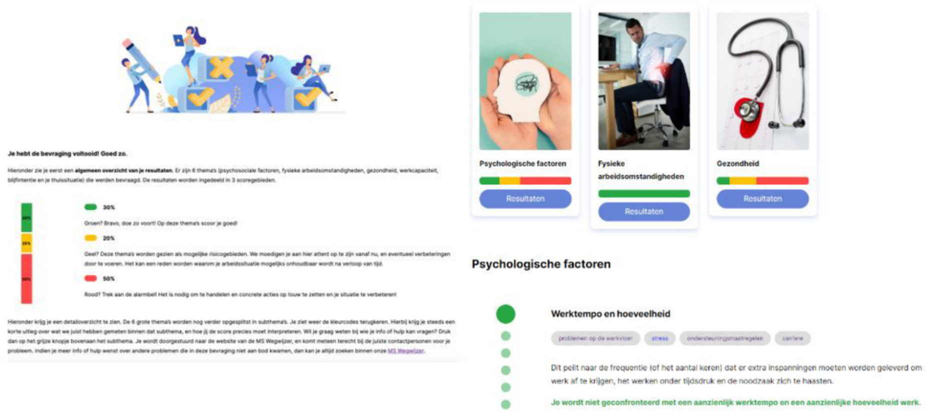

Figure 1. Print screen from screening tool (in Dutch)

a combination of 2 validated dutch workability questionnaires (Vragenlijst over Werkbaarheid (VOW) [13] and Vragenlijst Arbeidsreintegratie (VAR) [14]), which assesses how the employee experiences the balance between his own characteristics and the demands he is confronted with in the workplace. Results are calculated in diverse levels: psychosocial factors, physical working conditions, health condition, work capacity, the intention to stay and stressful home situations. All these levels are subdivided into different subdimensions. The choice of VOW and VAR was decided by a small test group (n=14) of persons with MS and experts (Director of MS-Liga Flanders, occupational therapist, care manager, professor, social worker, researcher). To start the screening, each patient receives an unique weblink. Only the persons who have this link, can enter the screening or the results (for GDPR reasons). Each test is automatically saved, so that current or previous results rest available.

In addition, a **dashboard,** functioning as a user-friendly supporting online platform, which is either accessible from the screening results, or by surfing to www.werkenmetms.be (**Figure 2**). It can be consulted by the person with MS itself or a healthcare professional. This dashboard is a website which guides a person with MS immediate to the desired source of information in a quick and easy way, if they encounter problems in their work situation. The development was done in 2 phases: 1) based on literature research and a questionnaire for persons with MS (n=36) and experts (n=13), all possible work problems were gathered. This was followed by 2) desk research and 19 in-depth interviews with diverse experts (social worker, job coach, MS nurse, occupational physician, disability case manager, occupational therapist, HR, labour union, career coach, psychologist, return to work coach) were done to find out which service(s) exist in Flanders per reported problem. This information became the blueprint of the dashboard. Each link was double checked afterwards with the concerning instance. Eventually, the dashboard provides 10 main themes ("most common problems"): Communication, Problems on the work floor, Energy, Reintegration, Career, Psychological factors, reorienting, mobility, education, laws & duties. Under each main theme, there are multiple subthemes. Each subtheme is subdivided into 4 categories: aids on the work floor, external aids, trajectories, tips & tools. Under each category, a summary is found of the existing (Flemish) solutions (e.g. service, professional, organisation, …). The goal of the dashboard is to provide a simple and straightforward guidance for each problem or question concerning work towards the right solution.

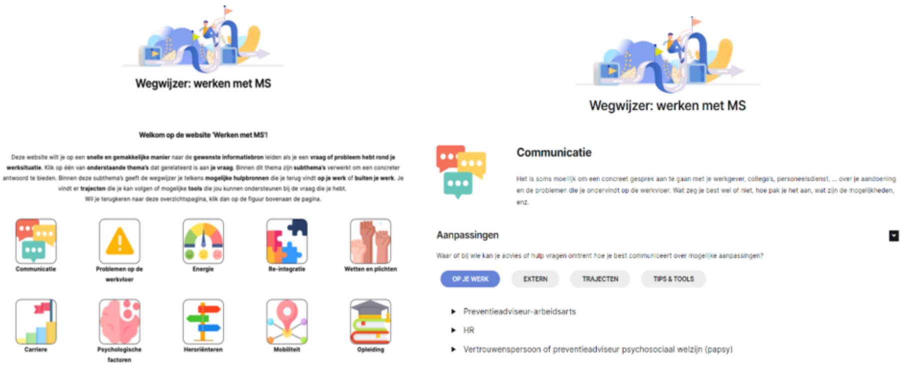

Figure 2. Print screen of dashboard, available at www.werkenmetms.be (in Dutch)

Through this medium, we want to create instant lines to an immediate and correct referral per problem/question, so that interventions could be initiated faster and the person with MS is immediately advised or helped by the right person. In Flanders many solutions exists, but healthcare professionals and patients do not know where to find them.

The screening tool and dashboard were developed as online tools. Both tools are stepwise prototyped in a small group of persons with MS (n=3 to 4) with attention to lay-out, guiding texts, figures, fonts, size, user friendliness, etc.

4. Discussion

This study reaches 2 easy and applicable aiding tools for persons with MS and their surrounding network to help them with a sustainable place in the labour market with sufficient and permanent attention and guidance for the daily obstacles in the workplace. With 430 new cases per year in Belgium, without intervention, the problem of unemployment and sickness will only increase, with an ever-lasting negative impact on the economy, patient well-being and businesses.

Our ultimate goal is to implement this MS toolkit in each Flemish hospital and in services who work with persons with MS (e.g. patient associations like MS-Liga Flanders) in order to reach annually and automatically as many as possible working persons with MS. A stable employment will not cure MS, but seen it is associated with a better disease management, higher quality of life, higher wellbeing, etc. this toolkit might be seen as an indirect, non-invasive assistance in the treatment of MS.

In the long term, this project will have a positive impact on society, for the well-being of the individual MS patient and for society through the growth towards a more inclusive society, but also economically, for government through cost savings, for employers and businesses by maintaining their experienced workforce and associated expertise and for the person with MS through a better financial condition. For the policy areas, it is initially very relevant for the Flemish labour market: the more people with MS that are actively working, the higher the contribution to the efficacy rate of the Flemish population. This also has an advantage to preserve the knowledge-based economy, which is based on the presence of sufficient human resources: Almost half of the Flemish population between 25 and 44 years old are highly educated [15], but also a large number of people with MS are included in this group. If they continue to participate, they can help maintain the high level of knowledge in Flanders. But a lasting expertise of the technically skilled is also an added value for the knowledge economy. They are the bridge between innovation and practice.

Between May-July 2023, the MS Toolkit will have its first try-out in Flanders. We aim to evaluate, improve and validate the MS Toolkit. In addition, we will check which steps are necessary to be able to implement it easily in the current health care sector, so we can prepare the MS Toolkit for further distribution and validation. This will be done by organizing a focus group with different profiles inside the healthcare sector (managers, therapists, etc.). The NASSS (non-adoption, abandonment, scale-up, spread, sustainability) framework will be used in this focus group to help predict and evaluate the possible success of this MS Toolkit [16].

In the future, the MS Toolkit also need to be complemented with a flyer, given at the moment of diagnosis, which informs persons with MS about the possibilities to stay at work with MS. Also different kinds of aiding materials to facilitate communication about MS to avoid misunderstandings are welcome to support this population. These were 2 other aiding tools that were discussed in the co-creation session but are not developed yet. The MS Toolkit is the first step towards a better support for patients with MS, but certainly not the last.

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References

[1] Han AR, Park SA, Ahn BE. Reduced stress and improved physical functional ability in elderly with mental health problems following a horticultural therapy program. Complement Ther Med 2018;38:19-23.

[2] Ng KST, Sia A, Ng MKW, Tan CTY, Chan HY, Tan CH, Rawtaer I, Feng L, Mahendran R, Larbi A, Kua EH, Ho RCM. Effects of Horticultural Therapy on Asian Older Adults: A Randomized Controlled Trial. Int J Environ Res Public Health 2018;15.

[3] Gezondheid en Wetenschap. 2019. At https://www.gezondheidenwetenschap.be/richtlijnen/multiple-sclerose-ms.)

[4] Kobelt G, Thompson A, Berg J, Gannedahl M, Eriksson J. New insights into the burden and costs of multiple sclerosis in Europe. Mult Scler 2017;23:1123-1136.

[5] Pompeii LA, Moon SD, Mccrory DC. Measures of physical and cognitive function and work status among individuals with multiple sclerosis: a review of the literature. J Occup Rehabil 2005;15:69-84.

[6] Shahrbanian S, Auais M, Duquette P, Andersen K, Mayo NE. Does pain in individuals with multiple sclerosis affect employment? A systematic review and meta-analysis. Pain Res Manag 2013;18:e94-e100.

[7] Federation. Multiple Sclerosis International. Global MS Employment Report 2016.

[8] Deluca J, Nocentini U. Neuropsychological, medical and rehabilitative management of persons with multiple sclerosis. NeuroRehabilitation 2011;29:197-219.
[9] Medicine. British Society of Rehabilitation. Undergraduate medical education in rehabilitation medicine. London: BSRM; 2006.
[10] Vijayasingham L, Mairami FF. Employment of patients with multiple sclerosis: the influence of psychosocial-structural coping and context. Degener Neurol Neuromuscul Dis 2018;8:15-24.
[11] Sweetland J, Howse E, Playford ED. A systematic review of research undertaken in vocational rehabilitation for people with multiple sclerosis. Disabil Rehabil 2012;34:2031-2038.
[12] Clougherty JE, Souza K, Cullen MR. Work and its role in shaping the social gradient in health. Ann N Y Acad Sci 2010;1186:102-124.
[13] Federale Overheidsdienst Werkgelegenheid, Arbeid en Sociaal Overleg. https://werk.belgie.be/nl/de-vow-qft-meetinstrument-over-werkbaarheid
[14] Vragenlijst Arbeidsreintegratie. https://www.var-2.nl
[15] Population to level of education(education level). 2018. At https://vlaamsestatistieken.login.kanooh.be/bevolking-naar-onderwijsniveau-scholingsgraad.
[16] Greenhalgh T, Wherton J, Papoutsi C, Lynch J, Hughes G, A'Court C, Hinder S, Fahy N, Procter R, Shaw S. Beyond Adoption: A new framework for theorizing and evaluating nonadoption, abandonment, and challenges to the scale-up, spread, and sustainability of health and care technologies. J Med Internet Res 2017;19(11):e367, doi: doi:10.2196/jmir.8775

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Global AT Service Delivery Challenges

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Digital Enabling Assistive Technology Through the Provision Lens – A Global Perspective in a Nordic Context

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Abstract. The Nordic healthcare system is well-established, taxation-based, and locally administered, featuring person-centered care as a social welfare pillar. Public provision of assistive technology and welfare technology within healthcare systems means every citizen has equal access to services. But how well are policies and procedures keeping pace with demographic changes and technology developments?. This study critically analyses qualitative data from 24 stakeholders involved in municipal-level procurement and allocation of assistive and welfare technology in Sweden with a specific focus on emerging digital technology. An extant analysis framework was used: the World Health Organization-GATE 5P framework for strengthening access to AT. Recommendations are made for agile procurement and an outcome-based decision frame. The voice of the AT user may be a valuable addition to inform policy.

Keywords. Assistive technology, welfare technology, Eco-system, provision, ICF, ISO 9999

1. Introduction

Societies endeavor to collect and distribute resources for the benefit of citizens. This straightforward proposition is, in reality, a super complex problem. In Nordic countries, the Nordic Welfare Model provides health care to everyone, regardless of gender, age, financial situation, or social status (1). The Nordic healthcare system is well established, especially within primary and preventive healthcare; the system is taxation based and locally administrated, with every citizen having equal access to services. A fundamental assumption in the welfare system is that everyone has a right to full participation in society (2). The right to participate in care, rehabilitation, and the process of assistive technology (AT) is also regulated in the law (3) (SFS 2014:821).

However, those administering public services face challenges delivering on sets of overarching principles and rights and balancing multiple competing priorities. One rapidly changing factor to be managed is increasing life expectancy leading to an aging population. Rapidly diversifying technologies represent another dynamic factor.

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Evidence suggests that a substantial proportion of people who depend on welfare services are also at risk of exclusion in different ways (1). In Sweden, for example, while the welfare system promotes universal rights and social equality, the provision of services such as assistive technology (AT) and welfare technology (WT) (defined below) is believed to be a further step in the digital transformation to sustain equality and universal rights for Swedish citizens, increased demand, and limited resources for welfare services (4,5).

2. Assistive technology and enabling digital features

Public provision of technology has traditionally focused on AT, which comprises assistive products and services such as assessment, fitting, training, and follow-up necessary for safe and effective use and "indispensable to helping older people remain healthy, active, and independent as long as possible" (6). According to the international standard ISO 9999, an assistive product is one that 'optimizes a person's functioning and reduces disability' (7). The standard identifies thousands of assistive products across 12 classes and hundreds of subclasses (7). Whether specially made or generally available, a product is classified as assistive if it facilitates activities and participation.

Nordic countries often use the related term Welfare Technology (WT) to delineate the subset of products focused on daily living in social contexts for older people and persons with disabilities. Over time, increasing numbers of assistive products on the market contain digital features. These are often grouped in the literature as information and communication technologies, smart home technologies, or ambient assisted living products, telecare, telehealth, and e-health. Some examples of digital products from the WT arena are videophones, monitoring cameras, global positioning systems (GPS) for sending alarms and tracking users, and digital safety alarms (2).

The impact of assistive technology, including digital assistive technology, is powerful (6). **Table 1** links digital technologies with the activities and participations they can enable. Effective provision systems can deliver a range of healthcare outcomes if policies and procedures can keep abreast of market innovations. It can therefore be said that the provision of a good life through assistive and welfare technology is affected by decisions made at the regional and municipal levels.

The diversification of technology and especially the proliferation of digital products, for example, innovative and smart home technology, which focuses on safety and health for the inhabitant with support from monitors or videophones, represents both an opportunity and a challenge to administrators of public AT funding.

This paper explores the perspective of managers employed in public provision in Sweden upon including new and emerging digital technologies in service provision.

Table 1. Examples of digitally enabled AT

WHO ICF activity & participation domain	Digitally enabled (connected) AT
1 Learning and applying knowledge	Diary and prompt systems Monitoring devices
2 General tasks and demands	Personal organisers Digital medication dispensers Online banking Robotic support Environmental control units IoT-connected home automation (Google Home, Apple SIRI, Microsoft Cortana)
3 Communication	Hearing products, vision supports eg text to speech; AAC Machine learning related apps; digital voicebanks
4 Mobility	Smartphone-controlled wheelchairs/ IoT collected drive data Smart walking frame; Autonomous vehicle
5 Selfcare	digital pressure monitoring products Environmental controls eg A/C + heating; Digital body measurement products
6 Domestic Life	Smart fridge Robot vacuum
7 Interpersonal interactions and relationships	Smartphone-activated sex aids Noise cancelling headphones and virtual reality/ augmented reality applications to manage social interactions and optimise psychosocial wellbeing
8 Major life areas (*education, economic*)	Information and communication technology (ICT) for work
9 Community, social and civic life (*cultural; recreational; spiritual; political*)	Smartphone accessible apps for accessing sports, viewing cultural events, listening to spiritual services Online voting Virtual reality/ augmented reality culture, recreation, etc

3. Method

The selection of participants was based on a stratified purposive sample (8) from the National Network of Assistive Technology Managers, Sweden. In total, 24 managers participated in the study. The criteria for inclusion were managers responsible for or involved in decisions when the purchase or procurement of new AT was being discussed to add to the assortment in their respective AT organizations. Semi-structured interviews focused on the GATE domains of policy, assessment, procurement, technology, environment, usability, sustainability, and rights (9) were conducted during the winter of 2019, recorded and transcribed verbatim. It was then followed by deductive thematic analysis (10) utilizing the World Health Organization-GATE 5P framework for strengthening access to AT (11) (see **Figure 1**).

Figure 1: WHO GATE 5P framework for strengthening access to AT

This paper draws on data from a larger study of public provision in Nordic countries to establish the perspectives and experiences of AT managers regarding identifying and procuring new digital assistive technology (12). This study did not include any personal or sensitive information that required ethical approval under the standards of the Swedish Research Council. The study followed the guidelines for research ethics issued by the Swedish Research Council (13).

4. Results

Seven themes emerged from the data through the lens of the 5P ecosystem model and represented dynamic factors and choices for AT managers. They include:

Currency of products:	Adopting shifting definitions of products.
Where products meet policy:	The tension between mainstream and assistive products.
Where products meet personnel:	Shifting familiarity with digital AT.

Products meet policy and provision:	Challenges with flexible policy.
People and policy:	The rapid change of people and policy in the society.
People's rights meet policy.	
Solutions for products from the people who use them.	

Regarding theme one, ***Currency of products: adopting shifting definitions of products,*** the managers discussed the shifting of unclear definitions of the technologies and products and how this diffusion of concept complicates it. There is a need to stay up to date.

First, I think the concept of Welfare Technology is difficult; it is not simple to define…everyone thinks of different meanings when they talk about it…this is confusing!! I think digital technology is better suited… (Manager 14)

Theme two, where ***products meet policy, the tensions between mainstream products and assistive products***; it was discussed that the AT centers need a living assortment of AT. If they procure new technologies, others have to fade out. The AT should always be prescribed for the patient's need, and in some cases, the AT doesn't need a healthcare provider to assess and prescribe it since it is critical to use the healthcare resources correctly.

I think there will be many devices that you have to buy on your own in the future...maybe the health care will be self-care and devices...and this will always change… we used to get washing machines on prescription before and also electronic toothbrushes, which sounds silly today…. And this development is moving quicker and quicker…what we have today as prescribed AT, we have to fade out…., maybe it's a new paradigm with AT…(Manager 7)

Yes, what should be a prescribed AT? There are so many new technologies.It is a tricky question… technological development is rapid, and you can do more things on your devices than before. We have the applications, and it's a challenge to keep this speed, not only for us decision-makers but also for the providers and, of course, the prescribers that meet the patients...(Manager 10)

Theme three: ***Where products meet personnel: shifting familiarity with digital AT***; the managers said that they have personnel that does not have the competence to help and support their clients or the AT users. This insufficient competence derives from many personnel born in the '50s and not born with the new technology. The managers asked - how they should then be able to prescribe the technology to the users!

Within the cognition and communication area, there is a massive demand for prescribed AT for those with advanced AT; maybe it should be more explicit in our assignments that we need to cater to this…but the healthcare providers are not interested in this, not yes…that's a pity I think… (Manager 20).

Another theme emerged from the data; ***Products meet policy and provision*: *challenges with flexible policy***. The managers reflected on the complexity of how to change to meet the digitized demands in society. They highlighted that they need to change their way of working, not within the organization but on a larger scale.

I have been working for a long time in the region and municipalities with AT questions in different ways... It has also been a discussion about the economy…and they have made the management only think and look at the economy questions, not of what we are supposed to work with (the AT!!) and to whom we are for and what causes…. instead, the financial questions have been in focus. I think that is the main problem here…(Manager 7)

In the theme**: *People and policy: the rapid change of people and policy in society***. The decision-makers deliberated on how the future resources and economy will impact AT provisions- considering increasing demographics and different policies.

Our hands won't cover the needs within next 20 years…and the number of older people increases, and we who work won't have the time, and we will have fewer resources….We have to think that civil society has to act and take responsibility in another way – in Denmark and Norway, they have started this…we have to engage and pay back to the generation before and the society in some ways…(Manager 20)

Theme six is: ***People's rights meet policy.*** This theme highlights that AT centers have a volume assortment and how the patient is involved in the provisioning process. There is a client-centeredness thinking in the encounter between the Occupational therapist and patient. The managers said there is a responsibility to person-centredness and that the prescribers must fulfill this. However, there is no follow-up, and they do not evaluate the process.

In the last theme***: Solutions for products from the people who use them**,* the managers describe a massive challenge here. They have the technical staff to help the AT users, for example, with walkers, scooters, time-management, Ipads, or applications. However, the digital transformation is rapid, and thou they are working on projects in their municipality, having show- apartments with different WT and AT, where occupational therapists work. This does not fill the knowledge gap of advanced technologies today. However, they pinpoint the importance of it.

5. Discussion

The WHO GATE 5P framework for strengthening access to AT was a useful lens through which to view the dynamics of product selection in Nordic funding schemes.

Narratives provided by the interviewees could be understood through the five dimensions of AT user or person, policy, products, personnel, and provision. Staff described the challenges of current knowledge of the vast array of emerging products and the possible outcomes; the importance of understanding and managing policy constraints and resource limitations.

Three broad tensions were evident. Firstly, in balancing the desire to support innovation with responsibilities around the economic impacts of expanding procurement, particularly against the backdrop of increasing demand. Attention to the social return on investment in digital technologies would likely support this decision-making, particularly articulating the outcomes achieved across activities and participation domains.

Secondly,while managers generally were optimistic about procuring and buying new technology into their health organizations, being aware of and comfortable with new and emerging technologies demanded significant effort by managers and their staff. Recognizing the need for time and capacity building to scan the market and evaluate new options is likely to be important to support good decision-making at a local /municipal level.

Thirdly, the confluence of specially made assistive products with enabling mainstream technology raised ethical boundaries. Questions about the social contract were raised, particularly regarding products that may be seen as personal expenditure items, such as mobile phones. Some participants that worked in regional organizations knew the municipalities were struggling with these questions, which represents a significant barrier to agile and current product inclusions in public expenditures.

While this study specifically interviewed managers and staff, consulting with AT users to inform purchasing decisions did not emerge as a topic or theme. We suggest that, in line with the consumer empowerment literature, the voice of the AT user is a valuable addition to inform policy (14).

6. Conclusion

In conclusion, using the WHO GATE 5P framework for strengthening access to AT enabled a global perspective upon digital enabling assistive technology to be applied to the provision in a Nordic context. Findings support an ecosystem view of the varying factors influencing the achievement of agile procurement and excellent provision within rapidly changing contexts. Recommendations include i) attention to the social return on investment in digital technologies; ii providing capacity-building opportunities to managers and staff to scan the market and evaluate new options, is likely to be important to support good decision-making at a local /municipal level.; and iii) as digital technologies challenge standard ideas of the social contract and personal purchase, engagement with the AT user community may support consensus-based decisions as to reasonable provision which meets expectations yet is sustainable for Nordic countries.

References

[1] Eide AH, Josephsson S, Vik K. Participation in health and welfare services: Professional concepts and lived experience. Taylor & Francis Group; 2017. p. 1–19, doi: 10.4324/9781315628554
[2] National Board of Health and Welfare (Socialstyrelsen, 2022) E-hälsa och välfärdsteknik I kommunerna. Redovisning av en uppföljning av utvecklingen inom e-hälsa och välfärdsteknik i kommunerna. (Ehealth and welfare technology in municipalities 2022; reporting a follow-up of e-health and welfare technology in the municipalities.) 2022. Available from: https://www.socialstyrelsen.se/globalassets/sharepoint-dokument/artikelkatalog/ovrigt/2022-5-7897.pdf
[3] Swedish Code of Statutes (SFS) (2014). Swedish Code of Statutes. Patient Act. (Patientlagen) (p. 821). Ministry of Social Affairs
[4] Borg J, Gustafsson C, Landerdahl Stridsberg S, Zander V. Implementation of welfare technology: a state-of-the-art review of knowledge gaps and research needs. Disability and Rehabilitation: Assistive Technology. 2023;18(2):227-239, doi: 10.1080/17483107.2022.2120104
[5] Raphael D. Challenges to promoting health in the modern welfare state: The case of the Nordic nations. Scand J Public Health. 2014;42(1):7–17, doi: 10.1177/1403494813506522
[6] WHO, UNICEF. Global report on assistive technology. Geneva: WHO & UNICEF; 2022. 140 p.
[7] ISO. ISO 9999 Assistive products - Classification and terminology. 2022.
[8] Polit DF, Beck CT. Nursing Research; Principles and methods. 7th ed. Lippincott Williams & Wilkins; 2004.
[9] Khasnabis C, Mirza Z, MacLachlan M. Opening the GATE to inclusion for people with disabilities. The Lancet. 2015;386(10010):2229-30.
[10] Braun V, Clarke V, Hayfield N, Terry G. Thematic Analysis. In: Liamputtong P, editor. Handbook of Research Methods in Health Social Sciences. Singapore: Springer Nature; 2018. p. 1-18.
[11] World Health Organisation. Policy brief: Access to assistive technology. In: GATE, editor. Geneva: WHO; 2020.
[12] Baudin K, Sundström A, Borg J, Gustafsson C. Decision-Making Is in the Making! Aspects of Decision-Making in the Area of Assistive and Welfare Technology—A Qualitative Study. Int. J. Environ. Res. Public Health. 2021;18:4028, doi: 10.3390/ ijerph18084028
[13] Swedish Council of Research. Good Research Practice. Stockholm, Sweden: Swedish Council of Research; 2017. Available from: https://www.vr.se/download/18.5639980c162791bbfe697882/1555334908942/Good-Research-Practice_VR_2017.pdf
[14] Hill S, editor. The Knowledgeable Patient: Communication and Participation in Health (A Cochrane Handbook). Wiley-Blackwell; 2011.

The Advancement of AT and AAC for Children in Eastern Europe and Central Asia

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Reflections on Building a Multi-Country AAC Implementation Guide

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Abstract. Augmentative and Alternative Communication (AAC) implementation at any level is a multifaceted process that requires selection of relevant and appropriate systems to suit individual users who may have complex communication needs and other co-occurring difficulties. Careful and systematic action may be required to develop skills and abilities in the use of chosen technologies with suitable ongoing support within a wide range of settings. The wider milieu in which services are provided must also be considered in order to provide a firm foundation for capacity building alongside considerations for multilingual and multicultural factors. UNICEF with the Global Symbols team supported by local professionals working with AAC users, their families and carers set out to collaboratively provide an implementation guide based on their experiences in several Eastern European countries. The aim of the guide was to illustrate work already being undertaken in the area and to ensure the sharing of knowledge and resources where gaps were discovered. The result became a series of linked webpages in an online framework that covered practical aspects for the development of policies and procedures to support early intervention for those with severe speech, language and communication needs across countries of differing cultures and languages. The actual AAC implementation required ingenuity on all sides with translations for pictographic symbol and software adaptations with Cyrillic and Latin alphabets, new synthetic voices alongside deployment and capacity development. Considerable local support was forthcoming and captured with interviews by those working with AAC users as technology was introduced and outcomes measured. As the guide was completed several videos were shared publicly by carers with examples of AAC and assistive technology use. Policies and procedures were also shared in the form of tables, charts, symbol sets, communication boards and software that illustrated not only the occurrence of knowledge transfer and the use of open licenses, but also differences in strategies and the way they were adapted to suit the range of settings in the various countries.

Keywords. implementation, AAC, Augmentative and Alternative Communication, disability, symbols, assistive technology, multi-country

1. Introduction

Fundamental to the development of a multi-country implementation guide on any subject is a common appreciation of what is being created and for whom. UNICEF has considerable experience in early intervention strategies to support successful outcomes for children across the world [1]. Collaborations between the country offices and those

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participating in the project initially required an understanding as to how early implementation of AAC could help in the support of complex communication needs (CCN) [2,3]. The latter is “a broad term that describes people with severe speech, language and communication impairments. Includes those who are able to speak but have difficulty with comprehension or expressing their wants and needs, and those who are not able to speak but can express themselves through gestures and behaviors. It also includes those who have sensory and physical support needs which affects their ability to engage in communication, and those who require extra time to process what is said and to respond. CCN can include, but is not limited to, those who have been diagnosed with autism spectrum disorder, cerebral palsy, and learning disabilities to name a few.” [4]

There also needed to be a shared understanding about AAC in its widest sense as described by the International Society for Augmentative and Alternative Communication (ISAAC). “AAC is a set of tools and strategies that an individual uses to solve everyday communicative challenges”. It is also helpful to take account of the fact that “communication can take many forms such as: speech, a shared glance, text, gestures, facial expressions, touch, sign language, symbols, pictures, speech-generating devices, etc.” Rather importantly the definition goes on to say that “the form is less important than the successful understanding of the message.” [5] Reflecting on this last statement highlights the importance of setting up policies and procedures that allow for family and carer involvement as well as professional sharing of local knowledge. There is also the need for graphical design expertise for symbol development and translations for training materials plus developers of software and synthetic voices for text to speech. Involvement with government and voluntary groups of individuals or organizations supporting those with communication difficulties can also be invaluable.

2. Methodology

UNICEF officers, teachers, therapists, families and carers along with university academics, developers and government bodies from six Eastern European countries (Croatia, Serbia Montenegro, North Macedonia, Bulgaria and Albania) contributed to the implementation guide[2] with a UNICEF project lead in Geneva. The Global Symbols team contributed their expertise and organization of data, training materials and the repository for pictographic symbol sets with apps for communication board creation. The Cboard open source software app on Android tablets, with touch screens and other access hardware such as switches, was used to provide assistive technology (AT) support for the adapted symbols and other symbol sets. Newly developed computer-generated voices were downloaded plus integration of the Cyrillic alphabet where applicable.

The design of the online framework follows a typical top heading folder layout (such as is experienced in File Explorer) with sections as single web pages – arrow heads denoting unfolding content. The content is not intended to be read in a linear progression as some elements can be worked on in tandem, such as symbol set development whilst training materials are being created or policy documents. There are eight main folders under the following titles: Defining Scope and Stakeholders, Making Symbol Choices, Capacity Development, AAC Symbol Set Design, Introducing Tech AAC, AAC Application Use, Supporting Families, Appreciating Long Term Results. Each of these

[2] https://globalsymbols.com/knowledge-base/4bBoO2wiY9c4BEAKWGnQI1?locale=en

headings has up to nine linked web pages, often with AAC strategies and examples of participant implementation plus a final summary.

3. Reflections

The authors of this paper felt that the implementation guide, that would be made available to a wider community, should provide knowledge that took account of minimal prior AAC experience as stakeholder skill levels could potentially be wide ranging. However, knowledge surrounding the world of AAC is complex so in a short guide comprehensive coverage would be hard to achieve. Therefore, where possible expert local support would still be needed to provide extensions to the published modules. The original resources were designed as a set of online freely available Moodle training modules that had been previously developed with AAC experts in each of the countries that took account of the first three 'European Qualifications Framework (EQF) Levels and Skills'[3]. Additional materials were developed by participants in Bulgaria, North Macedonia and Albania.

The success of the previous project in Croatia, Serbia and Montenegro [6] meant that there was a wish to replicate the way this was carried out in an accessible fashion with minimal cost. This was largely achieved by use of open licensed products and resources and the willingness of those involved in the earlier project travelling to the nearby countries to introduce some of basic concepts and the Global Symbols team working remotely. Social media, emails and sharing of documents allowed interactions to be online and in several languages with considerable use of automatic translations. Automatic translations were considered acceptable for team communications, but manually checked when content was published on local websites or Global Symbols sites especially for AAC symbol text labels, concepts and descriptions. There was also the ongoing need for local technical support where assistive technologies were involved.

In creating the implementation guide it was important to recognize the wide variations in culture and attitudes that occur between communities. These can range from the terminology used to describe disabilities to the models of initial and continuous training for professionals and the roles defined for professionals and the degree to which interdisciplinary working is common.

In many cases, professionals in the West have developed a precise vocabulary and terminology that may be used for clarity in professional communications. Many of these vocabularies have been driven by advocates on behalf of people with a disability and minor variations can create heated debate and argument both in meetings and online. The nuance between these terms has often been driven by specific words or even the sequence of words within a sentence. For instance, the debate between "Persons with a disability" and "People with disabilities" may be of great importance to advocates and activists, but in translation, the nuance can be lost. In some cases, the history of disability inclusion may not have followed the same path, and medical models may dominate, with a greater focus on rehabilitation than accessibility. Equally, the distinction between terms such as "handicap" and "disability" may not be obvious in translation to locally relevant terms.

Such examples illustrate the importance of not only translation but also localization of terminology that is appropriate to context, and which will feel familiar to potential users. Translation and localization therefore need to be undertaken by local teams, supported by the original authors to create a shared vocabulary that can be used, avoiding

3 https://europa.eu/europass/en/description-eight-eqf-levels

assumptions about the type of language used in any given setting. In much of Eastern Europe terms such as "defectologist" are common and do not carry the stigma associated with them in the West. Such variations may also be found within a single language. Many professionals in the United States resist the use of the term "Special Needs" which may be widely and positively used in the United Kingdom.

Equally understanding that the processes around which AAC provision is built may vary. Assessment, training, and funding for solutions may vary significantly from location to location. This is illustrated by understanding the range of funding models that could be applied to the provision of AAC devices and software within a location and community. In a report prepared for the Mobile and Wireless Forum [7] a series of funding models were outlined, drawn from analysis from several countries. These included

- Domain specific funding (employment, education, health etc)
- Public health Insurance
- Private Health Insurance
- Direct Payments to people with a disability
- Not for profit and Charitable Funding
- Philanthropic Grants
- Private and personal funding
- Refurbishment of used devices

Therefore, in seeking to build an implementation guide, allowing flexibility to reflect the reality of current and anticipated models of provision within a country should be considered as a priority if a guide such as the one described is to be grounded in reality.

As has been mentioned the importance of a non-judgmental approach to the use of language was found to be important. It also strengthened the case for materials within the guide to be published under an open, creative commons, license. Adopting such a license gives explicit consent for communities to make such adaptations as necessary to ensure community relevance. The willingness of both authors and funders to distribute under such terms has also been found to facilitate effective dissemination and use of the resources created.

Regard for local cultures and social settings was also considered important when taking a total communication approach [8]. This is where all aspects of interaction are borne in mind alongside personalization and the use of symbols, vocalizations, gestures, facial expressions with for example conversations around eating, playing and taking part in events and celebrations. Five country teams made the decision to create smaller symbol sets of pictographic symbols that would not only work with their language and script, but also open licensed symbols that were already available on the Global Symbols repository and elsewhere around the world. The new symbols tended to portray special days in the calendar, religious ceremonies, festivities, food and dress.

A voting system for acceptance of the new pictographic symbols was developed to involve families, therapists and others working with the potential young AAC users to ensure the results were suitable. All elements of the process were shared in the various sections of the implementation guide[4] with instructions and access to more information to encourage this participatory approach to AAC symbol design and development.

4 https://globalsymbols.com/knowledge-base/7JqLgq4mh9hujztM2AtIEB?locale=en

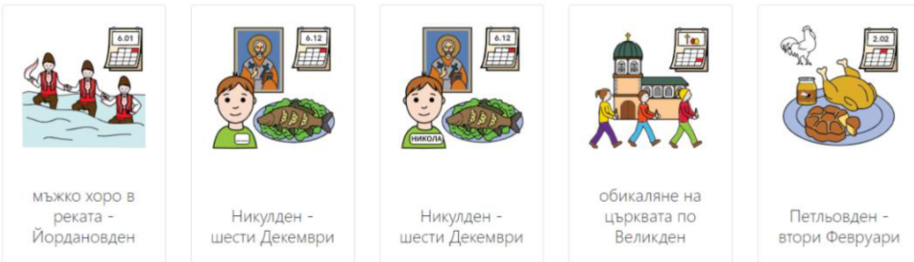

Figure 1. Example of Bulgarian pictographic symbols

A key limitation of the use of open licenses is the lack of awareness of the communities of their usage. Understanding the differences between retaining intellectual property, and allowing open distribution may not be something AAC professionals are familiar with, such subtleties may also cause confusion in understanding the role of open-source technologies, where "Free" and "Open" can be confused and misused. Careful use of the Creative Commons license may be made easier by selecting a license using tools found on the Creative Commons website[5], where users can consider the extent to which they allow open access to their tools, including whether commercial use of the materials is allowed. Once an understanding of the terms of a license has been communicated it has been found that it is also possible to consider the relative strengths and weaknesses of open-source licenses for the development of software. Such choices are important within the implementation process, and local communities will need to weigh up the relative strengths of each. An open source assistive technologies review undertaken by Banes and Reddington [9] noted that open approaches may provide the following benefits:

- Facilitates resilience
  When the iPad was launched in 2010, many companies working with proprietary code for AAC products became unsustainable. For users of these products support disappeared leaving them with unusable tools to support their needs. Open projects by nature are protected against this, and have a lifespan beyond that of those who created the code or software.
- Allows for wide and free distribution.
  The expansion of AAC products into emerging markets is constrained by costs. To address unmet needs much lower cost and openly distributable products are essential. Such products can then be distributed through the channels most appropriate to the location While the developed world might be able to afford all the AAC technology it needs, there are millions of people in developing countries where commercial solutions will never reach.
- Prevents lockout.
  Commercial approaches are invested in seeking to retain customers within an ecosystem. Open approaches are far more invested in building communities of support where other people contribute.

Nevertheless, it should be noted that open approaches have some limitations which include:

- Limited use of open licenses for hardware

5 https://creativecommons.org/share-your-work/

Whilst open software is easy to distribute, open hardware is much more difficult. However, with the advent of 3D printing, there is the beginnings of open distribution of design for local fabrication.

- Legal
  In some locations, the legal status of open software for compliance with medical standards and certification is difficult. Such compliance varies country by country and approval mechanisms are not easily applied to open 'fast iteration' approaches.

These issues were equally relevant to integrating the use of open-source AAC products into the guide. The capacity to fund the development of the AAC devices and software to support a specific community, either through the original authors or by supporting local community-driven initiatives for customization and development gives the funding body the widest possible ways to create a local solution. This allows for code to be created that may be usable for other communities, and software that can be provided to as many potential users as desirable.

Although advice and guidance can be given remotely there will always be the need for hands on AAC support and maintenance of all devices. This includes updates to software and the creation of local materials and shared workspaces for participants to meet experts face to face as well as the ongoing links with government officials for higher level discussions, provision and upskilling of all involved.

4. Conclusion

The authors of this paper were pleased to learn from a UNICEF case study "A Voice for every Child through Open Source Solutions and Resources" [10] that the countries involved with the initial project found that they could already see results from their work over a period of two years. Some of the outcomes included an increased awareness of the value of AAC and AT with strengthened national coalitions to support the use and availability of affordable AAC solutions.

There were enhanced collaborations with global and national experts and universities that allowed for an increase in courses and continuous professional development opportunities, as well as the setting up of national resource centers for AAC and AT support. Professionals (preschool teachers, psychologists, speech and language specialists) began to embrace the social model of disability with increased participation with potential users and their carers for the creation of national design and development activities. These in turn allowed for more accessible and affordable AAC and AT solutions that suited individual users, local settings, cultures and languages.

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References

[1] Clark H, Coll-Seck AM, Banerjee A, Peterson S, Dalglish SL, Ameratunga S, Balabanova D, Bhan MK, Bhutta ZA, Borrazzo J, Claeson M, Doherty T, El-Jardali F, George AS, Gichaga A, Gram L, Hipgrave DB, Kwamie A, Meng Q, Mercer R, Narain S, Nsungwa-Sabiiti J, Olumide AO, Osrin D, Powell-Jackson T, Rasanathan K, Rasul I, Reid P, Requejo J, Rohde SS, Rollins N, Romedenne M, Singh Sachdev H, Saleh R, Shawar YR, Shiffman J, Simon J, Sly PD, Stenberg K, Tomlinson M, Ved RR, Costello A. A future for the world's children? A WHO-UNICEF-Lancet Commission. Lancet. 2020 Feb 22;395(10224):605-658.

[2] Romski M, Sevcik RA, Adamson LB, Cheslock M, Smith A, Barker RM, Bakeman R. Randomized comparison of augmented and nonaugmented language interventions for toddlers with developmental delays and their parents. J Speech Lang Hear Res. 2010 Apr;53(2):350-64. doi: 10.1044/1092-4388(2009/08-0156). PMID: 20360461.

[3] Lüke C. Impact of speech-generating devices on the language development of a child with childhood apraxia of speech: a case study. Disabil Rehabil Assist Technol. 2016;11(1):80-8.

[4] Communication Rights Australia. Glossary website https://www.communicationrights.org.au/resources/glossary/complex-communication-needs-ccn/ (accessed 5 March, 2023)

[5] Burkhart, L.J., The International Society for Augmentative and Alternative Communication (ISAAC). What is AAC website https://isaac-online.org/english/what-is-aac/ (accessed 5 March, 2023)

[6] Draffan EA, Banes D. Open Licensed AAC in a Collaborative Ecosystem. In Computers Helping People with Special Needs. Proceedings of the 18th ICCHP-AAATE 2022; 2022 Jul 11-Jul 15; Lecco, Italy. Part I. p. 483-488. Cham: Springer International Publishing.

[7] Mobile and Wireless Forum. Are smart phones assistive technology? …. the 2021 GARI research project blog (2022) http://blog.gari.info/2022/03/are-smart-phones-assistive-technology.html (accessed 14 May, 2023)

[8] Clarke M, Price K, Griffiths T. Augmentative and alternative communication for children with cerebral palsy. Paediatrics and Child Health. 2016 Sept;26(9):373-377.

[9] Banes, D and Reddington, J., The Future of Open Source and Assistive Technologies Conference Presentation ATIA 2017 https://www.slideshare.net/davebanesaccess/the-future-of-open-source-and-assistive-technologies (accessed 14 May, 2023)

[10] UNICEF ECARO A Voice for every Child through Open Source Solutions and Resources (2022) https://www.unicef.org/eca/media/22051/file/Casestudy1.pdf (accessed 14 May, 2023)

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User Participation in Design

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Assistive Technology to Promote Participation in Sport for People with Disabilities

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Abstract. Participation in sports is identified in the UN Convention on the Rights of Persons with Disabilities as a fundamental right and is facilitated by the use of specialized Assistive Products (AP). However, little is known about the role everyday AP plays in promoting sport participation. Purpose: This study explores how the 50 priority APs on the World Health Organization's Assistive Products List can promote participation in sports. Materials and methods: We used an online survey with AP-users, caregivers, and coaches (n=96). Subsequently, we performed a thematic analysis for qualitative responses describing the use of APs in facilitating sport participation. Results: Our results suggest everyday APs are required for sport participation for persons with disabilities. We present a conceptual model of AP use for sport participation. We found people with disability participate in a range of sports, contributing to community engagement. Conclusions: Access to everyday APs is integral to achieving the rights of persons with disabilities for participation in sport.

Keywords. Assistive products, Assistive Technology, sport, disability, parasport, social inclusion

1. Introduction

According to the Kazan Action Plan, adopted by UNESCO in 2017, sport can be broadly understood as "everything from physical play, recreation, dance, organized, casual, competitive, traditional and indigenous sports and games in their diverse forms"[1]. Participating in sports is important for people with disabilities and is recognized as a fundamental right for persons with disabilities set out by the United Nations Convention on the Rights of Persons with Disabilities (CRPD). In particular, Article 30 of the CRPD supports the engagement of a person with disabilities in mainstream recreational sporting

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activities in addition to disability-specific sporting and recreational activities to the fullest extent possible [2]. Moreover, enhancing participation in sports helps to promote community participation and social inclusion [2, 3]. Therefore, efforts to promote full participation in sport are a means towards promoting social justice [4]. Social justice includes social inclusion, which stands on the two pillars of interpersonal relationships and community participation [9], central to a person's quality of life [5].

Despite the benefits of participation in sports, studies show that overall participation in sports is lower in people with disabilities compared to people without [6]. This low participation rate in sports can be attributed to systemic and social barriers faced by people with disabilities. Lack of access to assistive technologies, which promote or enable participation in sports, also constitutes a major barrier [7]. There has been research on the use of AP to enable elite level parasport [8], however there is substantially less discussion about the potential for everyday AP to promote sports participation.

There is therefore a gap in our understanding with respect to everyday APs and how these can enable participation in sports. The WHO's Global Cooperation on Assistive Technology (GATE) Initiative has published a priority list of 50 assistive products, which the member state governments should provide to citizens who need them [9]. The Priority Assistive Products List (APL) [9] includes 50 items which are designed and aimed for older people and people with disabilities to live a "healthy productive and dignified life" [10]. Understanding how these products promote realisation of rights for persons with disabilities will provide governments and decision makers with additional understanding of how the provision of AT may help to achieve their commitments to the CRPD. Therefore, the objective of this study is to describe how every-day APs impact participation in Sport, answering the research question: How do the WHO GATE‘s Priority Assistive Products impact Participation in Sport?

2. Materials and Methods

We conducted a qualitative online survey, distributed by international disability and sport specific umbrella organizations, using Qualtrics software. The study methods were approved by the Maynooth University Social Research Ethics Committee. Participants included Assistive Product (AP) users, 18 years or over as well as caregivers, coaches or teachers who support, teach or coach AP users, who provided informed consent prior to participation. Participants were asked to answer questions related to: 1) Demographic information; 2) Use of Assistive Products in relation to sport participation; 3) Experience with Assistive Products in relation to sport participation. The survey was piloted amongst a group of AP users for content, language and accessibility and adapted prior to distribution. We conducted an inductive thematic analysis including open, axial, and selective coding to develop a sport pathway framework for further analysis. Using this framework, another round of coding was performed to refine the themes.

3. Results

Responses were included for respondents who answered at least one demographic question and at least one question related to AP and sports. The respondents' (n=96) reported 36 different countries of residence, from all WHO Health Regions. The highest percentage of the respondents (66.23%) were coaches/teachers, followed by AP users

(23.77%) and caregivers 9.84%. The mean age of AT users was 45 years (SD=14.01). Over half (59.10%) of the AP users identified as a man. The majority of AP users reported using their respective APs for over 15 years. Participants engaged in a wide range of sports including boccia, yoga, cycling, powerchair football, cyclocross and rock-climbing.

Analysis of the qualitative data resulted in a series of themes and subthemes. Data for all respondents were combined for analysis as there were no substantial differences between responses from different respondent groups. Considering concepts in relevant literature, and through research team discussions, we developed a model to help explain the relationship between these themes. This model, titled the Assistive Products for Participation in Sport (APPS) Model, can be seen in Figure 1, and illustrates the ways in which every day AP are used to facilitate sport participation. The model illustrates the three overarching themes: 1) sport participation (micro level); 2) support technologies (meso level); and 3) community (macro level). Sport participation is expressed as a pathway, chronologically divided into preparation (pre-), participation (during) and post-participation (post-). Within the pathway, sport participation belongs to the micro-level, while preparation and post-participation happen within the meso-level of supporting technologies. All the three pathway components take place within the macro-level of community.

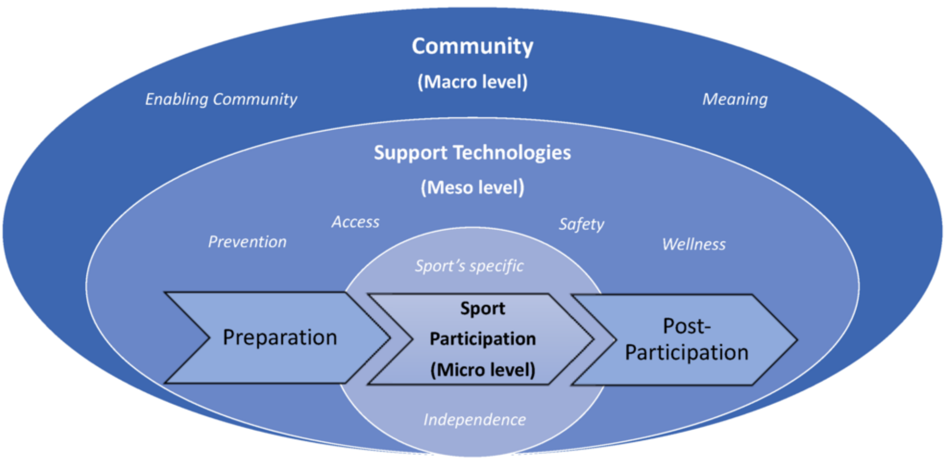

Figure 1. Assistive Products for Participation in Sport (APPS) Model

3.1 Micro Level

The micro-level of the APPS Model, constitutes the core of the framework and focuses on the sport participation itself. This level puts the focus on the moment of sport participation, which includes engagement in sport (i.e., watching or supporting) and sport performance (i.e., playing at a recreational or competitive level). Within the context of sport participation, respondents identified the importance of using assistive products to facilitate *independence*. In addition to those used to support independence, there are APs which are used *specifically for sports performance*.

3.1.1 Independence

Within the context of sport participation, respondents identified the importance of using assistive products to facilitate independence. For example, one coach stated, "The lower limb prosthesis provides independence for the athlete with limb loss… And provides equal distribution of body mass which ensures balance ". This is an example of direct use of the assistive product both in the moment of sport performance, but also to facilitate independence on a day-to-day basis. Assistive products may also be used to promote moments of sport engagement. This was described by one caregiver who indicated the AP user they work with "uses items to maintain independence and dignity while out of the home" and engaging in sport as a supporter or fan. These two examples provide a sense of how assistive products are able to provide a sense of independence for the AP user across the entire spectrum of sport participation.

3.1.2 Sport Specific AP

In addition to those used to support independence, there are APs which are used specifically for sports performance. One participant, who used a wheelchair designed for active use, described how the wheelchair could be used to promote mobility, and allows "accessibility in sports activities like table tennis, badminton, wheelchair cricket, wheelchair basketball". The use of lower limb prostheses was described as being useful for rock climbing by another AP user, who suggested the prosthesis "makes it easier to climb a wall. Also allows me to cycle around or walk around." It was interesting to note this individual's use of their prosthesis for sport, as they also indicated it was used regularly as their every-day AP. Outside of APs for mobility, APs such as incontinence products were also described by both coaches and AP users as support for the moment of sport participation. Although these products may not always be 'seen' during sport participation, one AP-user pointed out they use incontinence products to "pursue sport with confidence". Other APs whose usage was specific to the moment of performance were alarm signallers with light/sound/vibration. These were described by one AP user as being used for "flashing lights on the court to alert the players if the referee blew the whistle as you were not allowed to wear your hearing aids." This was particularly interesting as one AP (hearing aids) was substituted for another (flashing lights) during the moment of sport participation. Those who were engaging in sport as a follower or fan also described using APs, including spectacles for "expansion of participation options".

Assistive Products are employed differently by each AP-user depending on their circumstances. Whilst a certain item might be used by one AT-user when preparing for sport performance, it may not actually be used during sport performance. For another AP user, it may be the opposite, in accordance with their needs. For instance, one AP-user pointed out they used a prosthesis to access the sports venue but indicated they "'on't use it [to perform sports] in fact I take it off for both activities".

3.2 Meso Level

The meso-level of the APPS Model, *Support Technologies*, includes APs used across the entire pathway of sports participation (preparation, participation, and post-participation). While these APs may not be critical to the moments of sport engagement or performance, they play a supporting role in participation. Without these support technologies, many would be unable to participate in sport engagement and/or performance. These APs are used for *prevention* of secondary complications, ensuring *safety, providing access* to sporting venues and environments, and to maintain *wellness*.

3.2.1 Prevention

Multiple participants spoke about the importance of using technology to prevent conditions which impaired their sport performance. For example, a coach describing the use of therapeutic footwear suggested "this protects the foot of an athlete with diabetes from pressure sore". Similarly, a pressure relief cushion may be utilized by an AP user because it "reduces the pain in certain yoga positions". While these technologies are not critical to the performance of the sport, they provide the user with a way to prevent potential negative consequences of their participation.

3.2.2. Safety

Another recurring sub-theme was safety. Safety was important both during sport performance and engagement. For example, one coach described using" straps [in a manual wheelchair] to protect [against] falling and [promote] safety." Safety may also be considered in the larger environment of sport participation or engagement. One AP user described the use of alarm signalers with light/sound/vibration by pointing out that the spaces where they engage in sport' have flashing lights for fire alarm this would alert me to that danger".

3.2.3 Access

Within preparation and support technologies, many respondents also mentioned the importance of access or access to Sport. This was regularly noted for mobility technologies, which are often used to travel to and from the venue, but may not be used directly in the performance of sport. Although we often think about wheelchairs in this context, one caregiver indicated the AP user they worked with used a walking frame or walker "to get around" the sport environment, suggesting this "enhances participation." Other respondents, including one coach, suggested the use of tricycles "mobility in the community", while other coaches described the use of canes or sticks "to be independent before and after training" and to "access the venue". In this case, it is important to remember that both sport performance and sport engagement more broadly both may require independent access to a specific venue, which must often be facilitated by APs.

3.2.4 Wellness

The use of the AP for wellness, particularly during the post-participation period was mentioned by several participants. Wellness can be critical to both sport performance and sport engagement. As one AP-user described, their "pressure relief mattress ensures that I can sleep comfortably and get good rest prior to and during tournaments for powerchair football. Without this, I would wake up many times during the night which would affect my performance when playing". When considering sport engagement, another AP-user suggested their manual wheelchair" give[s] me a chance to relax sometime while enjoying sport as observer". it was echoed by another AT user who stated: "I sit in my wheelchair anytime I am watching sport on tv or am attending a game. This is for comfort; I would not be able to sit on a standard seat in a stadium as it would be too painful and I would be unable to watch the game". The use of AP for this purpose is important to consider, as 90% of the respondents indicated they engage with sports by following sports from home.

3.3 Macro Level

The macro-level of the APPS Model, Community, describes how AP contribute to both enabling participation in a sport community, and contributing to the meaning of sport for participants.

3.3.1. Enabling Community

The themes on Community encompass the other levels and the entire pathway (macro and micro levels). Enabling Community is a subtheme which suggests APs play a role in promoting engagement in a community around sport. For instance, two coaches indicated audioplayers with DAISY capability are used for "socializing independently" and "communication", each of which is critical to opportunities for sport participants to engage with other sport participants. Similarly, the Braille displays (note takers) were described by AP-users and coaches for "reading [the] newsletter" or for "reading the manual or team strategy". For AP users who become engaged in coaching, Braille writing equipment/braillers may also be used for their work sharing "rules and coaching". Each of these enables community surrounding sport which is important to the participants.

3.3.2. Meaning

It was clear from the responses received that sport participation was meaningful, for different reasons. This was described well by one participant who stated "I was very shy and introverted and when I started played sport it took me out of my shell and helped me [gain] confidence. I travelled a lot with sports and was proud to represent my country and also helped develop lifelong friendships with people and also gave me opportunities to work in sports for my career". Similarly, another AT-user described that sport helped them to maintain high levels of fitness to pursue active lifestyle," and further suggested this "provides confidence". The meaning of sport, facilitated by APs, was also multifaceted for many respondents. For example, one respondent shared how sport provides "mental stimulation, Fitness, and acceptance by Society as an active member of a club". Similarly, another AT-user described the benefits as including "social life, fun, friends, adventure, happiness, travel, physical/mental health, purpose". For some, engaging in sports can therefore seen as a way of "empowering me and giving me exposure to the community as it reduces isolation."

In addition to discussing the meaning of sport, respondents also reflected on the role of AT in achieving meaning through sport. Here, it is interesting to consider an unlikely technology – chairs for the shower, bath and toilet – and how it contributed to sport participation and meaning for multiple participants. One AT-user indicated "I feel peace when I get a chance to access washroom so a special chair in toilet environment attracts me to attend sport otherwise, I can fear to go". Another AT user also stated the same technology allows them to "pursue sport with confidence". Moreover, this item was mentioned many times in relation to tournaments and travelling. As ATP-user stated, "when at tournaments, I would need access to a shower chair to shower after games etc.". Without this critical, yet theoretically basic, AP, it is clear that many users may not be able to participate fully, and therefore achieve the benefits of sport participation.

4. Discussion

This is the first study to explore how the use of everyday assistive products facilitate participation in sport. We found that everyday assistive products are highly relevant for sport's performance and engagement in sport at all levels of participation, including pre- and post- participation. The overarching themes of *Sport Participation, Support Technologies* and *Community* are all interrelated. Our research highlights how fundamental the pre- and post- performance aspect of sport are. We highlight the critical role of APs in contributing to *access* and the decision to engage in sports, but also safety and post-participation *wellness*. AP use can also promote a strengthened sense of self, as well as *enable community* through interpersonal communication and enhanced *meaning*.

In most cases when AT is discussed in relation to disability and sport, it is depicted as very technical products aimed mostly at an elite sports level and para-athletes, but not about the vast range of ATs that are needed to engage in sports [11]. Our findings support evidence that people who used AT to engage in sports felt a "sense of belonging", "increased physical fitness", "empowerment", as well as "enjoyment, fun and inclusion" [12]. An assumption could be made that the provision of sport-specific products would enable performance, but this study shows that this is not enough. Many of the non-sport specific technologies are critical to that moment of performance in other ways.

The APPS model provides a clear overview of the ways in which APs can contribute to sport participation and engagement, and with further validation and exploration, could be used as evidence for the need for funding of APs broadly to enable engagement in sport as a right.

5. Conclusion

Assistive Products are relevant to engagement in the moment of sport participation, as well as pre-participation and post-participation, and help to promote community engagement and social inclusion. Access to everyday assistive products is critical to both participation in sports and community engagement, and crucial to the realization of rights of persons with disabilities.

References

[1] UNESCO. Kazan Action Plan. In Proceedings of the Sixth International Conference of Ministers and Senior Officials in Charge of Physical Education and Sports (MINEPS VI). 2017: Kazan, Russia.

[2] UN. Convention on the Rights of Persons with Disabilities (CRPD). 2006.

[3] Bailey R. Evaluating the relationship between physical education, sport and social inclusion. Educational Review 2005;57(1):71-90, doi 10.1080/0013191042000274196.

[4] Allan V, Smith B, Côté J, Martin Ginis K, Latimer-Cheung A. Narratives of participation among individuals with physical disabilities: A life-course analysis of athletes' experiences and development in parasport. Psychology of Sport and Exercise 2018; 37:170-178, doi: 10.1016/j.psychsport.2017.10.004.

[5] Schalock RL, et al. Cross-cultural study of quality of life indicators. Am J Ment Retard. 2005;110(4): 298-311, doi: 10.1352/0895-8017(2005)110[298:CSOQOL]2.0.CO;2.

[6] van den Berg-Emons RJ, Bussmann JB, Stam HJ. Accelerometry-based activity spectrum in persons with chronic physical conditions. Arch Phys Med Rehabil. 2010;91(12):1856-1861, doi: 10.1016/j.apmr.2010.08.018.

[7] World Health Organization. Assitive Technology. Key facts. 2018.

[8] Burkett B. Technology in Paralympic sport: performance enhancement or essential for performance? Br Jf Sports Med. 2010;44(3): 215-220, doi: 10.1136/bjsm.2009.067249.

[9] World Health Organization. Priority Assistive Products List: Improving access to assistive technology for everyone, everywhere. 2016.
[10] World Health Organization. USAID and International Disability Alliance. Priority assistive products list: improving access to assistive technology for everyone, everywhere. 2016.
[11] Matsuwaka ST, Latzka EW. Summer adaptive sports technology, equipment, and injuries. Sports Med Arthrosc Rev. 2019;27(2): 48-55, doi: 10.1097/JSA.0000000000000231.
[12] Bragg E, Pritchard-Wiartc L. Wheelchair physical activities and sports for children and adolescents: A scoping review. Phy Occup Ther Pediatr. 2019;39(6):567-579, doi: 10.1080/01942638.2019.1609151.

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Learning About Assistive Technology from High School

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Abstract. This communication will present an educative and research project that has linked the creation of 3D Assistive Technology (AT) for people with disabilities with the training of students of secondary education. STEMBach educational program aims to provide quality scientific education to secondary school students in the fields of science, technology, engineering, and mathematics (STEM) through research projects. Specifically, the text focuses on one project proposed by the TALIONIS research group, which uses 3D printers to design and create assistive technology (AT) for people with disabilities. The project involves students from eight different high schools and ten individuals with disabilities from four non-governmental organizations. The students design and print the AT using software such as Tinkercad and Cura Software. After testing the AT, outcome measurement instruments are used to validate their effectiveness. The project is based on a Learning-by-doing methodology with a structure of service-learning, and the involvement of the students is voluntary. The objectives of the project are to involve the students in research and innovation, to generate resources and AT for people with disabilities, and to determine the effects of AT on the lives of its users. Finally, the project leads to identifying new needs of people with disabilities that could be addressed through further research work.

Keywords. STEM, Learning-by-doing, Assistive Technology, 3D Printer

1. Introduction

STEMBach is an educational program that seeks to achieve excellence and quality in the training of secondary school students in the scientific field (Science, Technology, Engineering and Mathematics - STEM). Its objective is to promote critical thinking and the acquisition of the students' competencies in science and technology through a research project [1]. The projects are proposed and tutored by professors from the university, with a follow-up from the high school teachers. The students of secondary education join this program voluntarily and can choose the research project that most motivates them and generates concern. Each student can work independently or in a

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group and does her / his project in two academic courses. The final work is presented in public defense in view of a tribunal.

The STEMBach program of the University of A Coruña, in the biennium of 2019-2021, and 2020-2022 offered more than 25 proposals of research projects to the students of secondary education. Among them, is the one that will be presented in this communication: Innovation with 3D printers for the design and creation of AT for people with disabilities [2].

This project was proposed by the TALIONIS research group, based on its field of expertise and the collaboration with different NGOs of people with disabilities in our region. The proposal aims to cover the real demand of these individuals, their families, as well as the NGO that represent them. Thus, the direct beneficiaries of the proposal are the people who present some type of limitation in the activity or restriction in the participation, caused by a functional deficit.

In addition, as a research project and after the assistive product was created and used by the person in their daily activities, students should verify the effectiveness of this device. To do so, the use of outcome measurement instruments is proposed to them. These steps are guided and followed by the teachers of the university.

2. Purposes

The project has several objectives: (1) to involve the students of secondary school in a research and innovation project, from the University, (2) to generate resources and AT with a 3D printer for people with disabilities to improve their performance of daily life activities, (3) to validate and determine the effects of AT on the life of its users. In addition, the development of this project leads to identifying new needs of people with disabilities that could be affordable through research work.

3. Methodology

From the educational perspective, the project has a design based on the methodology of Learning-by-doing, with a structure of service-learning. The research project done by STEMBach's students has a descriptive, observational and cross-sectional design. It was performed between 2020 and 2022, with the participation of 8 students of secondary education (from 4 high schools located in two cities: A Coruña and Ferrol) and 10 persons with disabilities (the users, belonging to 4 NGOs, in the same cities). Being several students, from different schools, 4 working groups were created, with their own support product developments.

For each student, the participation in STEMBach initiative is voluntary, and as a result, he/she can obtain a recognition in their baccalaureate degree. So, the motivation and the implication of the participants are normally high. To start the process and facilitate the contextualization, students assisted a webinar offered by university's teachers, in which the basic concepts of disability, assistive technology and conditioning factors were presented. In addition, during a second webinar session, the students learned how to design simply with 3D software and how to manage the parameters to print with a 3D printer.

After that, the fieldwork was implemented. Students contacted the NGOs selected close to their residences and met with users of these organizations.

Through a small interview, they could obtain a set of data from people with disabilities. This process was useful to know the specific needs of that people, the activities in which they had more difficulties and the priorities to use any AT to solve these problems.

Subsequently, they designed the assistive technology in 3D, using the Tinkercad software [3], that would respond to the identified needs. Then, the AT was printed with the Ultimaker S3 printer, using the Cura Software®[4], and were delivered to persons with disability. They could try them in their daily life activities, during a period from 2 to 4 weeks. After the test time, the students met again with the users and applied two instruments of outcome measures.

The registered variables were: demographic data (gender, age, place of residence, and diagnosis), the activity with limitation or restriction identified by the person with a disability, the satisfaction with the 3D printed AT, and the matching degree between the person and the assistive technology. The tools used to recover the data were a semi-structured interview, the Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST 2.0)[5], and the form for the device of the Assistive Technology Device Predisposition Assessment (ATD PA) of the Matching Person & Technology (MPT) model [6].

The procedure was done in three phases, according to the framework proposed in research previously [7]: Phase 1 – Design (identifying), including the exploration of the needs of the person with disability and the detection of those that could be met with the use of 3D AT printed; phase 2 – develop of the prototype (creating), this step is focused on the creation of a first sample of the AT (or prototype) for testing, that will allow checking if the initial idea answers effectively to the demands of the user; and phase 3 – outcome measures (implementing), when the 3D printed AT is incorporated to the daily life of the person for doing the activities for which had been created, and finally, to assess his/her satisfaction and match with the device.

The data were registered using RedCAP, a secure web application for building and managing online surveys and databases [8], and privacy and data confidentiality were kept during the project. The professor from the university supervised all development of the research project, and guided the work of STEMBach's students, tutoring periodically.

4. Results

Finally, 10 AT were created and printed in the four working groups for 10 people with disabilities. In Table 1 are shown the results with the designed AT during the development of the project. Figures 1-4 shows the assistive technology created by the students during this project.

After delivering and using the assistive technology, the STEMBach's students implemented the scales of outcome measures, obtaining very good results.

In relation to the satisfaction of the designed AT (measured with the QUEST 2.0 – only the items for the device), the mean score obtained was 4 (SD= 0.48), on a maximum of 5 points. The criteria with more importance about the product, and identified from the QUEST 2.0, were "the facility of use" (N= 10), the weight (N= 10), and the dimensions (N= 7). The best-reported satisfaction was for the model cylindrical for low-cost switch with 4.88 points.

Table 1. Distribution of AT created by each group and for the people with disability

Work Group	No. of students	Assistive technology designed in 3D	Diagnosis of the user person and No.
1	2	Low-Cost Switches (3 models were created): Circular / Quadrate / Cylindrical	Amyotrophic Lateral Sclerosis (1)
2	2	Double AT: Page turner & bag opener (2 models were created)	Neoplasia (2)
3	2	Case for TV remote control Handle for brush	Cerebral Palsy (3)
4	2	Support for smartphone Ergonomic handle for comb Door opener	Tetraplegic (2), Muscular Dystrophy (2)

In general, the degree of match between the person and technology (measured with the ATD PA) was moderately high, with a mean of 3.04 (SD= 0.56), on a maximum of 5 points. The items scored with the higher score were "the user feels physically, emotionally and socially secure when using the device" (M= 5), and "the user feels comfortable (not self-conscious) using the device around family" (M= 5). Again the AT that obtained a higher degree of matching was the cylindrical low-cost switch.

Figure 1. Low-Cost Switches created by workgroup 1

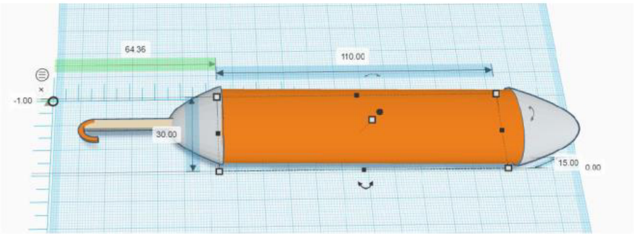

Figure 2. Design of the page turner & bag opener created by workgroup 2

Figure 3. Handle for brush created by workgroup 3

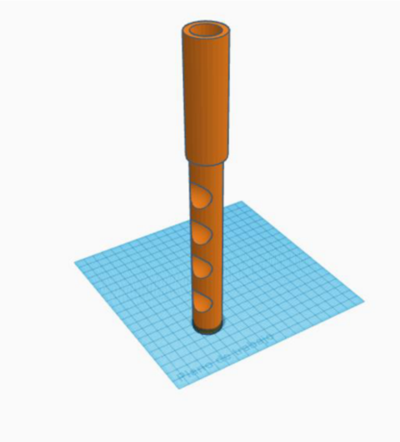

Figure 4. Design of ergonomic handle for comb created by workgroup 4

5. Conclusions

This project has presented an educational program to promote scientific thinking in the students of secondary school. Also, the specific thematic, focused on the life of people with disability, has allowed bringing students closer to the reality and needs of this population.

Ten AT in 3D have been designed and created to meet the needs of 10 persons with disability, based on their identified interests and expectations. The procedure has been done following a structured process, divided into three phases: design, prototype and outcome measures. This fact has given meaning to the research. Further, the use of 3D software has had a positive effect on the imagination and spatial intelligence of the students.

After applying the tools of outcome measures, the level of the user's satisfaction has been high, and the degree of match between person & technology was moderately high.

The development of the program STEMBach, with a research project in the field of assistive technology, has positive results:

- The students of secondary school acquire the awareness of the functional situation and needs of the daily life of people with disabilities.
- The design of low-cost AT with a 3D printer promotes the imagination of the students and the development of ideas to meet the needs identified by people with disabilities.
- The research project responds to a real demand that people with disabilities, their families and NGOs have.
- The implementation of a structured procedure has facilitated the development of AT in which the user is the best important part, with his/her implication from the beginning, and prioritizing his/her opinions, preferences and needs.

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References

[1] University of A Coruña. STEMBach Presentation [Internet]. 2022 [cited 2022 Feb 1]. Available from: https://www.udc.es/en/stembach/presentacion/
[2] University of A Coruña. STEMBach Projects [Internet]. 2020 [cited 2022 Feb 4]. Available from: https://www.udc.es/en/stembach/proxectos-2019-2021/
[3] Autodesk. Tinkercad | Crea diseños digitales 3D con CAD en línea | Tinkercad [Internet]. 2022 [cited 2022 Feb 4]. Available from: https://www.tinkercad.com/
[4] Ultimaker. Ultimaker Cura: Powerful, easy-to-use 3D printing software [Internet]. 2022 [cited 2022 Feb 4]. Available from: https://ultimaker.com/software/ultimaker-cura
[5] Demers L, Weiss-Lambrou R, Ska B. Development of the Quebec User Evaluation of Satisfaction with assistive Technology (QUEST). Assist Technol. 1996;8(1):3-13. https://doi.org/10.1080/10400435.1996.10132268.
[6] Scherer M, Craddock G. Matching Person & Technology (MPT) assessment process. Technol Rehabil. 2002;14:125–31. https://doi.org/10.3233/TAD-2002-14308.
[7] Pousada García T, Garabal-Barbeira J, Porto Trillo P, Vilar Figueira O, Novo Díaz C, Pereira Loureiro J. A Framework for a New Approach to Empower Users Through Low-Cost and Do-It-Yourself Assistive Technology. Int J Environ Res Public Health [Internet]. 2021 Mar 16 [cited 2021 Mar 18];18(6):3039. https://doi.org/10.3390/ijerph18063039.
[8] Harris PA, Taylor R, Minor BL, Elliott V, Fernandez M, O'Neal L, et al. The REDCap consortium: Building an international community of software platform partners. Vol. 95, Journal of Biomedical Informatics. Academic Press Inc.; 2019. p. 103208.

Cognitive Disabilities and Accessibility

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JournalMate: An Accessible Academic Reading Tool for Third-Level Students with ADHD

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Abstract. This paper outlines the research activities undertaken to design and evaluate an accessible academic reading tool to support third-level students with attention deficit hyperactivity disorder (ADHD). This research project was conducted in three phases, using a User Centred design (UCD) approach. The initial research phases explored cognitive processing difficulties related to reading habits and user needs that are associated with ADHD. A series of interviews with 3 subject matter experts and 8 students with ADHD aimed to identify pain points and problems hindering users from carrying out academic reading efficiently and confidently. Phase two involved ideating solutions based on data collected in the first phase and applying universal design principles while focusing on developing an electronic reading tool. After the ideation activity, the resulting prototyped solution was evaluated by 10 users. The data gathered during this evaluation provides insight into the performance of the application and will aid in any subsequent design iteration. The output of the study is an accessible academic reading tool for third-level students with ADHD, using a user-centred design process. Future practical implications and limitations are discussed. Results will provide additional data to build on current study findings and existing theories.

Keywords. ADHD, Accessibility User centered design, academic reading

1. Introduction

The purpose of this mixed methods study is to create an accessible academic reading tool for third-level students with attention deficit hyperactivity disorder (ADHD) and to understand whether customisation impacts usability, user satisfaction and ease of use. In research from Alabdulakareem & Jamjoom [1], cognitively challenged students cope with pressure in a different way to other students and require pressure-free environments. In the academic year 2019/2020 in Ireland, students with ADHD represent 6.3% of the total undergraduate student's population and 2.5% of the total postgraduate student population [5]. It is important to note that these numbers may not be fully accurate due to students not disclosing their disability for a myriad of reasons, including the perceived stigma they might feel and a desire for independence [5]. Mooney et al. [10] state that third-level institutions can be more accommodating to and inclusive of alternative learning styles. With the number of third-level students in Ireland registering with student disability services increasing by 220% over the past eleven years, there is a need

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for conducting further research, particularly in the context of third-level students with ADHD to strengthen existing but limited evidence.

User centred design (UCD) can be defined as a process in which designers focus on user needs in each phase of the design process (The Interaction Design Foundation). Firstly, this study aimed to explore and describe the lived experience of 8 third level students with attention deficit hyperactivity disorder (ADHD). Five main themes were generated and identified. Based on a qualitative analysis of this data, an accessible reading tool was then designed and finally evaluated by 10 third level students with ADHD. Using an inductive approach, the results and discussion aim to expand existing theories as well as supporting them

2. Literature review

2.1 Attention Deficit Hyperactivity Disorder (ADHD)

ADHD is a neurodevelopmental disorder often associated with poor results in academic achievement and work performance. ADHD primarily affects concentration and attention. The main symptoms of ADHD are inattention, hyperactivity, and impulsivity [14]. It is important to note that there are three types of ADHD. They are classed as the inattentive type, the hyperactive type, and the combined type [3]. With the inattentive type of ADHD, the individual will struggle with organisation, finishing tasks, paying attention to details, and following instructions. An individual with the hyperactive-impulsive type will often fidget and talk excessively. They will find it difficult to sit still for a long period of time and will regularly feel restless. The combined type is a mix of both the inattentive and the hyperactive-impulsive. ADHD is one of the most impairing and costly neurodevelopmental disorders [9]. Silva & Toner [17] state that ADHD is the most common mental health condition in children across the world but Supangan et al. [18] remark that it can also develop during teenage and adult years

2.2 ADHD and Education

Naturally, due to the symptoms of ADHD, those diagnosed will find it challenging when it comes to education. According to Alabdulakareem & Jamjoom [1], ADHD can affect an individual's attention span and educational attainment. ADHD can negatively impact day-to-day tasks and while hyperactivity tends to decrease with age, symptoms of inattentiveness tend to remain the same into adulthood [6]. Inattention, disorganisation, and difficulty with time management can make it extremely difficult in an educational setting [17]. According to Edwards [4], children with ADHD are often considered underachievers or lazy. While medication such as stimulants are a popular treatment for people with ADHD, there is little evidence to illustrate improved academic performance in adolescents [9]. Many parents avoid medication as a treatment for their child and opt for psychosocial or alternative interventions instead [9].Research states that college students with ADHD experience less academic success and greater psychological and emotional difficulties than other students. Reading is a struggle for adults and children with ADHD. Both adults and children with ADHD are likely to become disinterested or distracted, miss details and lose track of where they are on the page [8]. Adults with ADHD obtained significantly worse results than the neurotypical adults on reading speed and responses to literal questions [8]. Additionally, Reaser, Prevatt, Petscher, & Proctor

[14] found that college students with ADHD detailed greater levels of difficulty than their neurotypical peers in outlining, note taking and summarising information. Interestingly, Lewandowski, Gathje, Lovett & Gordon [7] found that students with ADHD performed similarly to neurotypical students when it comes to timed reading tests, but they think they perform badly and experience more anxiety than other students without ADHD. This indicates lower self-perception, which leaves students at a disadvantage and an expectation that they will perform badly before any task is carried out. There have been limited qualitative studies, providing in-depth insight into individuals' with ADHD's own experience, particularly in a third-level educational setting. It is known that many adults with ADHD learn to depend on external resources, such as apps to help support their organisational skills [2]. If students with ADHD are dependent on resources, it is imperative that these resources are designed with the user at the core of the design process.

2.3 Research Questions

1. What are the main challenges faced by third-level students with ADHD in Ireland?
2. How can academic journal websites be made more user-friendly to third level students with ADHD through customisation?
3. Is JournalMate, a user centred designed educational tool, satisfying, useful and easy to use in supporting third-level students with ADHD with their study challenges?

3. Methodology

This study implemented a mixed-method approach for gathering user research. This entailed a survey, semi structured interviews and desk research. The type of user data collected was both qualitative and quantitative in nature. Ethical approval to conduct the research was obtained from the Institute of Art, Design and Technology's (IADT) Research Ethics Committee.

Table 1. Project phases

	User Survey	Subject Matter Expert Interviews	User Interviews	Usability Testing
Participants	35	3 (CEO of ADHD Ireland, Psychologist, Assistive Technology Officer)	8	10
Measures	Single answer & free text	Qualitative questions	Qualitative	USE (Usability, Ease of Use, Ease of Learning & Satisfaction) Scale
Analysis	Thematic Analysis	Thematic Analysis	Thematic Analysis	Convergent parallel mixed methods analysis

The first iterations of the design system were informed by primary and secondary data gathered in the project's first phase. The primary research methodologies conducted during the first phases of the project involved a series of semi- structured Subject Matter Expert (SME) interviews and a user survey on 35 students in third level education diagnosed with ADHD, which provided questions for in-depth interviews with 8 students with ADHD. See table 1 for project phase summary. The secondary research activities were made up of an initial literature review, followed by competitor analysis and task analysis of academic journal tools. While the data collected from the survey provided high quantities of quantitative data regarding user demographics and the difficulties faced with ADHD and academic reading, it shed little light on the reasoning and rationale behind such answers. Following on from the survey and SME interviews, the next stage in the research process involved inviting eight survey respondents to take part in follow up user interviews. See participant demographics in Table 2.

Table 2 Participant demographics

Participant	Age	Gender	ADHD Diagnosis	College background
P1	28	Female	26 years old	Social Work
P2	29	Female	29 years old	Occupational Therapy
P3	36	Female	35 years old	Speech & Language Studies
P4	23	Male	22 years old	Law
P5	28	Non-binary	23 years old	History
P6	31	Female	26 years old	Medicine
P7	24	Female	23 years old	Sociology
P8	29	Male	13 years old	Accounting & Finance

A thematic analysis was carried out to interpret the data from the 8 user interviews. Braun and Clarke's [16] thematic analysis process consisting of 6 phases formed the basis of the research. The qualitative data from the interviews indicated that each student with ADHD experienced academic difficulty to some degree. The main five themes that were identified were (1) academic struggle (2) executive dysfunction (3) experience with academic reading (4) poor UX and (5) strategies.

4. JournalMate's Interface Design Framework

Customisation involves the user making changes to their experience to meet their particular needs by altering the layout, content or system functionality [17]. Customisation allows users to control their interaction with a website and set preferences for how content is organised and information is displayed. According to the National Center on Accessible Educational Materials, by customising the display of information, the effort it takes for users to read the information can be reduced [17]. This allows more time for users to focus solely on understanding what is being discussed. Customised e-reading platforms have the potential to address some of the major challenges related to academic reading for third-level students with ADHD, particularly when based on the seven principles of Universal Design: (1) equitable use, (2) flexibility in use, (3) simply and intuitive to use, (4) perceptible information, (5) tolerance for error, (6) low physical effort and (7) size and space for approach and use [18]. JournalMate's interface design applies these principles as follows:

4.1 Equitable Use

The design of JournalMate is useful and marketable to all college students, including people with diverse abilities. The goal of JournalMate is to enhance the academic reading experience for students with ADHD. This is achieved through the custom settings toolbar options such as font type, font size, line spacing, summaries, dark mode and read aloud. Neurotypical students can also use the site and can benefit from the accessibility options. For example, a personal preference for a student could be a sans serif font such as Arial or Helvetica and double line spacing as seen below. The design of JournalMate places students with ADHD at the core of the design process but is accessible to all students.

4.2 Flexibility in Use

The custom settings give the user the freedom to customise the appearance of the article to suit their needs. While all the accessibility options may not be relevant to everyone, it gives students the option to adjust the look and feel of the article instantly and with minimal effort. Currently, if students want to customise the appearance of a journal article, they must copy the article, paste it into Word which usually creates formatting issues, then they can finally change the font size, line spacing and letter spacing and print the document. JournalMate allows students to choose their individual preferences and print directly from the site within seconds. This frees up more time for the student to focus on their research. Now, with current websites available to students, there are 19 steps to this user journey from beginning to end. From the research, is it clear that students with ADHD are more likely to become distracted, miss details and lose track of where they are on the page. Therefore, when the number of steps to complete a task increases, the chance of the student with ADHD getting distracted also increases. JournalMate has reduced this user journey by over 50%.

4.3 Simple and Intuitive Use

The design of JournalMate took inspiration from websites that students are comfortable and familiar with using. Inspiration was taken from Google Drive for the overall design and note-taking tools such as Microsoft OneNote and Notion for the navigation and toolbar layout. From the qualitative research during the first phase of the project, these are the websites and tools that are popular amongst participants and therefore the design of JournalMate would be easy for the user to understand. A number of students mentioned they regularly used a Kindle to read for pleasure. It was important to look at the functionality and UI of the Kindle interface as a reference point.

4.4 Perceptible Information

The clear navigation structure of JournalMate allows for effective communication of necessary information. The focus is always on the journal article but the custom settings are available in the side navigation bar, which is visible to students at all times. As students with ADHD were at the centre of this design process, an important focus was placed on a clutter free design. Clutter can majorly impact the focus and concentration of students with ADHD in a negative way. The summary feature within each article reiterates the key points and important findings from the previous section, which helps students with ADHD, who may struggle with memory retention and recall. To clearly distinguish between the article text, the summaries are contained within a blue rectangle to help the user quickly find them throughout the article.

Another example of the perceptible information of JournalMate is the consistent use of icons throughout the interface. This allows users to quickly find and scan content. Each icon is also accompanied by descriptive text when the user hovers over the option.

4.5 Tolerance for Error

The citation copier allows students to cite and reference journal articles correctly, leaving little room for error. Referencing was mentioned by participants during the interviews as a source of stress and frustration as they often forgot how to reference correctly. With JournalMate, referencing can be completed accurately and with ease.

4.6 Low Physical Effort

The three-tier layout of the left menu, the middle sub menu and the main body of the article guide the user and can be used efficiently with minimal effort. When the user wants to view the custom settings, the custom settings toolbar replaces the article navigation. This is to maintain the clutter-free design and avoid information overload for users, by giving them too many options at once.

5. Results and Discussion

As there needed to be a control and a variable to successfully conduct A/B testing, it was necessary to design two prototypes – one with elements of customisation and one without. The standard version was based on current academic journal websites as they exist currently. There are limited customisation options available from which users can choose. These options include a screen reader and a zoom in/zoom out function. Users cannot alter the font type, font size or line spacing. That is unless they choose to copy and paste the article into a separate document, which often creates formatting issues for users. The testing was conducted using the Usefulness, Satisfaction, and Ease of Use Questionnaire [19]. Ten users were also asked to list any positives and negatives from each of the designs. In addition to the USE Questionnaire, users were asked some further questions to gather qualitative data and provide more in-depth feedback on the designs. To ensure an unbiased result, the order of the prototypes was changed with each of the participants. This resulted in five participants testing Prototype A first and Prototype B second, and vice versa for the other five participants.

A paired samples t-test was conducted to examine the effect of customisation on the usefulness of JournalMate. The test reached statistical significance, $t(10)= -5.89$, $p=0.0002$. This indicates that participants found the customised version more useful than the standard version. A paired samples t-test was conducted to examine the effect of customisation on the ease of use of JournalMate. The test reached statistical significance, $t(10)= -4.05$, $p=0.003$. This indicates that participants found the customised version easier to use than the standard version. A paired samples t-test was conducted to examine the effect of customisation on the ease of learning of JournalMate. The test reached statistical significance, $t(10)= -2.42$, $p=0.039$. This indicates that participants found the customised version easier to learn how to use than the standard version. A paired samples t-test was conducted to examine the effect of customisation on the satisfaction of JournalMate. The test reached statistical significance, $t(10)= -4.745$, $p=0.001$. These results indicate that participants found the customised version more satisfying than the standard version.

The first research question 'What are the main challenges faced by third-level students with ADHD in Ireland in the context of academic reading?' was answered during the initial survey and interviews with participants. The five themes that emerged were academic struggle, executive dysfunction, experience with academic reading, poor UX, and strategies. The data illustrated the academic struggle of students with ADHD, which included, underachieving, fear of failure and mental exhaustion. This backs up the literature, which states that college students with ADHD experience less academic success and greater psychological and emotional difficulties than other students [19]. The executive dysfunction consisted of disorganisation, time blindness and trouble with concentration. Participants often felt trapped in a cycle of disorganisation and lateness, which accelerated their mental exhaustion further. The poor user experience with academic reading was a strong theme. This corresponds to the literature stating that college students with ADHD report several challenges academically, especially with regard to reading comprehension. The leading factors of poor UX were confusing layouts of academic journal websites, and the articles themselves, the inaccessibility of the articles, and photophobia (light sensitivity) when required to read articles. The qualitative analysis allowed for a deeper insight of why the user experience with academic reading was so poor.

The second research question 'How can academic journal websites be made more user-friendly to third level students with ADHD, through customisation?' was answered by applying Universal Design principles to the prototype. In the user interviews, participants discussed a number of strategies and tactics they have adopted to be able to complete their academic reading. These tactics included reformatting the document by changing the font size and line spacing, colour coding, using visuals, note-taking and using alternative methods of consuming information, for example, through listening and watching videos. These strategies helped to inform the design and focus on the features that mattered most to the target users, as per the user-centred design process.

The third research question 'Does customisation improve the user experience of academic reading for third-level students with ADHD?' was answered in the testing section with both qualitative and quantitative data. The results indicate that participants found the design with customisation easier to use than the standard version. This implies that the customised version is more user friendly, easier to use and more flexible. This is an interesting implication as the prototype design with customisation had more complexity involved with the addition of the custom settings toolbar. Additionally, participants also found the ease of learning to be more effective with the customised version. This illustrates that participants learned how to use the prototype and became skilful with it at a faster pace, than the version without customisation. This is a notable result as 50% of the participants tested the customised prototype design before the standard version. This implies that the customised version of JournalMate is more intuitive for users, as they quickly learn how to use it and they easily remember how to use it. This corresponds to the literature, which states that for customisation to be successful with users, tools must be simple to use, easy to find and with clear intent and benefit to users [15].

6. Conclusion

The data contributes a clearer understanding of the academic reading experience of students with ADHD. Furthermore, the results of the study should be taken into account when considering how to design educational tools for individuals with ADHD. These results build on existing evidence that ADHD can affect an individual's attention span and educational attainment [1]. Although neurodiversity is considered a spectrum, future work into developing a design framework for users with ADHD could be developed. Furthermore, to imlement the seventh Universal Design principle of Size and Space for Approach and Use, a mobile and tablet version of JournalMate could be designed and tested to ensure a seamless user experience for all students, regardless of the device they use.

References

[1] Alabdulakareem E, Jamjoom M. Computer-assisted learning for improving ADHD individuals' executive functions through gamified interventions: A review. Entertain Comput 33, 2020 March, 100341. DOI:https://doi.org/10.1016/j.entcom.2020.100341

[2] Canela C, Buadze A, Dube A, Eich D, Liebrenz M. Skills and compensation strategies in adult ADHD – A qualitative study. PLoS One 12, 9 September 2017 e0184964. DOI:https://doi.org/10.1371/journal.pone.0184964

[3] Chinawa J.M, Herbert A. Obu H.A. Epidemiology of Attention Deficit/Hyperactivity Disorder. In ADHD - New Directions in Diagnosis and Treatment. InTech, 2015 New South Wales. DOI:https://doi.org/10.5772/61016

[4] Edwards K. Beyond the controversy of the labels: Gifted/ADHD: The learning experiences and preferred teaching strategies of children who have been identified as Gifted with ADHD. 2011 LAP LAMBERT Academic Publishing.

[5] Hynes C, Kelly Y. Students with Disabilities Engaged with Support Services in Higher Education in Ireland 2021.

[6] Ibadin MO, Ambuabunos EA , Ofovwe EG. Community survey of attention-deficit / hyperactivity disorder among primary school pupils in Benin City, Nigeria. Ann Afr Med 10, 2 2011, 91. DOI:https://doi.org/10.4103/1596-3519.82065

[7] Lewandowski L, Gathje RA, Lovett BJ, Gordon M. Test-Taking Skills in College Students With and Without ADHD. J Psychoeduc Assess 31, 1 February 2013, 41–52. DOI:https://doi.org/10.1177/0734282912446304

[8] Low K. How to Read, Retain, and Focus When You Have ADHD. Very well Mind. 2022.

[9] Maniadaki K, Kakouros E. The Complete Guide to ADHD. Routledge, New York. 2017.

[10] Mooney J, Cole D,Hallowell E. M. Learning Outside The Lines: Two Ivy League Students With Learning Disabilities And Adhd Give You The Tools For Academic Success and Educational Revolution (1st ed.). 2008; Simon & Schuster, New York.

[11] Re A.M, Capodieci A. Understanding ADHD - A Guide to Symptoms, Management and Treatment (1st ed.). 2020. Routledge, Oxfordshire.

[12] Silva D, Toner M. ADHD Go-to Guide (1st ed.). 2017.UWA Publishing, Perth.

[13] Supangan R.A, Acosta L, Lorenzo J, Amarado S, Blancaflor E. B.,. Samonte M. J.C. A gamified learning app for children with ADHD. In Proceedings of the 2nd International Conference on Image and Graphics Processing- ICIGP 2019: ACM Press, New York, New York, USA, 47–51. DOI:https://doi.org/10.1145/3313950.3313966

[14] Reaser A, Prevatt F, Petscher Y, Proctor B. The learning and study strategies of college students with ADHD. Psychol Sch 44, 6 July 2007: 627–638. DOI:https://doi.org/10.1002/pits.20252

[15] Schade A. Customization vs. Personalization in the User Experience. Nielsen Norman Group. Retrieved March 1, 2023 from https://www.nngroup.com/articles/customization-personalization/

[16] Braun V, Clarke V. Using thematic analysis in psychology. Qual Res Psychol 3, 2 January 2006; 77–101. DOI:https://doi.org/10.1191/1478088706qp063oa

[17] n/a. Personalizing the Reading Experience. National Center on Accessible Educational Materials. Retrieved May 7, 2023 from https://aem.cast.org/use/personalizing-reading

[18] Burgstahler S.. Universal Design: Process, Principles, and Applications. Disabilities, Opportunities, Internetworking, and Technology. 2021: Retrieved May 7, 2023from https://www.washington.edu/doit/universal-design-process-principles-andapplications#:~:text=Equitable%20use.,are%20blind%2C%20employs%20this%20principle.

[19] Lund A. Measuring Usability with the USE Questionnaire. Retrieved from https://www.researchgate.net/publication/230786746 2001

[20] Lisa L. Weyandt and George J. DuPaul. 2008. ADHD in college students: Developmental findings. Dev Disabil Res Rev 14, 4 (2008), 311–319. DOI:https://doi.org/10.1002/ddrr.38

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AI Supporting AAC Pictographic Symbol Adaptations

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Abstract. The phenomenal increase in technological capabilities that allow the design and training of systems to cope with the complexities of natural language and visual representation in order to develop other formats is remarkable. It has made it possible to make use of image to image and text to image technologies to support those with disabilities in ways not previously explored. It has opened the world of adaptations from one picture to another in a design style of a user's choosing. Automated text simplification alongside graphical symbol representations to enhance understanding of complex content is already being used to support those with cognitive impairments and learning difficulties. Symbol sets have become embedded within applications as dictionaries and look up systems, but the need for flexibility and personalization remains a challenge. Most pictographic symbols are created over time within the bounds of a certain style and schema for particular groups such as those who use augmentative and alternative forms of communication (AAC). By using generative artificial intelligence, it is proposed that symbols could be produced based on the style of those already used by an individual or adapted to suit different requirements within local contexts, cultures and communities. This paper explores these ideas at the start of a small six-month pilot study to adapt a number of open licensed symbols based on the symbol set's original style. Once a collection has been automatically developed from image to image and text descriptions, potential stakeholders will evaluate the outcomes using an online voting system. Successful symbols will be made available and could potentially be added to the original symbol set offering a flexible personalized approach to AAC symbol generation hitherto not experienced by users.

Keywords. artificial intelligence, pictographic symbols, cognitive impairment, augmentative and alternative communication, symbol adaptations

1. Introduction

Although it is thought that globally 0.05-1.55% of the population have a form of intellectual disability [1], the data around the various difficulties related to cognitive impairment has proved hard to capture worldwide. Many of those with these types of disabilities may also have written and spoken receptive and expressive language impairments requiring additional support to aid understanding, speech and literacy skills. The types of support may include assistive technologies such as simple message systems combined with some speech, gestures or signing, others will use text to speech for reading digital content aloud. Where there are more complex communication needs (CCN) the use of speech generating devices with pictographic symbols may be

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introduced to encourage communication, language and literacy [2]. Pictographic symbols can also be used alongside simplified text to help explain complex printed information or embedded within digital systems to enhance the understanding of online content such as web pages.

Augmentative and alternative communication (AAC) and literacy skill strategies tend to be personalized and customized to suit user needs, but this takes time and is not always easy to achieve if suitable pictographic symbols or images are not available and in particular if they do not suit local contexts, cultures and communities. There is also the issue of graphic design skills to create the symbols which cannot happen in a 'just in time' fashion without considerable cost and effort. AAC users tend to use one symbol set in early childhood and this is then developed to align with their needs over time. However, adults who have a sudden traumatic brain injury affecting cognition and/or loss of communication skills such as a stroke with aphasia, often respond better to photographs and symbols to suit their age and milieu, that are adapted to work with visual scene displays [3]. These usually represent daily life activities and emotions. This is where it is particularly hard to find appropriate freely available multicultural and multilingual representations.

This paper is the result of the beginnings of a short six-month project that still has two months to run. The aim has been to explore ideas around the use of generative artificial intelligence (AI) models for open license symbol-to-symbol style transformation based on a repository of freely available AAC pictographs. The importance of developing images in a style that matches already developed symbols allows users to recognize them more easily as part of their personalized symbol set. It has also been found that those who have cognitive disabilities may have difficulty understanding concepts that involve visual representations and remembering their meaning. However, when people are completing an action in an image they tend to find these images easier to understand. For example, a picture for 'baking' with a cake beside an oven works better when a person is putting the cake into the oven [4]. For that reason, as part of the following methodology, a symbol set that has representations of actions with people has been chosen for the adaptation of symbols.

2. Methodology

Initially an English core vocabulary of 100 commonly used words was chosen and matched to the visual image of a pictograph from the Mulberry symbol set. A visual description of each symbol was provided to test the type of prompt that might be needed to successfully create training data for symbol generation in the style of the symbol set. These words were selected as being examples of frequently used pronouns, verbs, adverbs, adjectives and prepositions plus greetings rather than concrete nouns that tend to be considered as fringe vocabulary that may be easier to portray such as a dog, man etc. During the pilot phase DALL·E 2[2] was used and each time a prompt was written the word 'symbol' was also added to provide an indication of the style required. Prompts were adapted as the images appeared until a reasonable representation of a potential symbol was created. The prompt for Figure 1 was a five-pointed pink star symbol.

[2] https://openai.com/product/dall-e-2

Figure 1. illustrates how simple text prompts for nouns can produce relatively acceptable symbols e.g. star compared to a symbol in the Mulberry set (last star).

This was not in the perfect style of Mulberry when one considers the width of the black outline and specific pink color based in the original symbol set schema. At this stage no image to image styling had been provided as training data and DALL·E 2 is not an open system for creating specifically personalized data training resources. Table 1 contains samples of symbols chosen from the Mulberry set with their initial visual description to start the process of training and to learn more about what makes a good prompt when the subject matter can be rather abstract. Making improvements to the prompts is ongoing and includes the need for additional adjectives, specific colors plus an indication of positioning and an awareness that symbols tend to have no backgrounds and need to have defined outlines.

Table 1. Example image descriptions to aid recognition acting as potential prompts.

Symbol Label	Image visual description	Part of Speech	Definition
go	front view of a man wearing grey trousers, black shoes and a pale blue top standing with an arrow going away from his body from left to right	verb	change location; move, proceed
good	left hand thumbs up	adjective	having desirable or positive qualities especially those suitable for a thing specified
good-bye / goodbye	back view of a man wearing grey trousers, black shoes and a pale blue top standing with an outstretched right arm held up with a hand waving	noun	a farewell remark
happy	front view of the face of a man with brown hair smiling	adjective	enjoying or showing or marked by joy or pleasure
have	palm of an upturned right hand with a small red ball in the middle	verb	have or possess, either in a concrete or an abstract sense
he	front view of two male faces and one man standing to the side wearing grey trousers, black shoes and a pale blue top with an arrow pointing down at his head	pronoun	the male person or animal being discussed
help	the back of two hands coming together but not touching	verb	assist, aid, give help or assistance; be of service
here	pale blue dotted outlined square with a black thin lined arrow pointing down to the top and a black outlined square in the background.	adverb	in or at this place; where the speaker or writer is
hi or hello	front view of the torso of man with brown hair wearing a red top with his right arm raised palm forward	noun	an expression of greeting
new	pale pink rectangle with thin black lines radiating out from the sides	adjective	not of long duration; having just (or relatively recently) come into being

As the co-design aspects of the project evolved, the participation of image design experts and AAC professionals supporting those with cognitive impairments and CCN, provided input. In particular they helped with the criteria for the evaluation of sample symbols. These included visual aspects such as: Does the symbol reflect the concept required and the label or gloss suggested? Are design features (for instance color, contrast, shape and outline) consistent with the original symbol set? Where there are combined symbols (such as an action with an arrow to denote direction, as is seen with the word 'go' in Table 1) are the elements logical and based on the schema and style of the original symbol set? The process involved comparisons being made to ensure consistency as well as a good match (Figure 2).

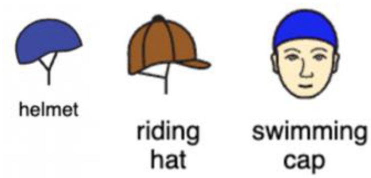


Figure 2. Comparison of Mulberry Symbols for head gear with one having a face and the others just showing the hat which may affect the training data

Those symbols that were a good fit with similar patterns and features as part of the symbol set schema were used (with their labels) as training data for the image recognition algorithms. Open AI models, such as Generative Adversarial Networks [5] and Stable Diffusion Models as [6] were used to investigate how style transformation and generation of AAC symbols can be supported by deep learning and unsupervised artificial neural networks. Uploading the pictographic symbols to the system to work alongside image prompts or visual descriptions will be part of the next stage in generating adaptations and testing the process.

Finally, as a quick and simple evaluation process due to time constraints a link to an online voting system, that had been developed for previous AAC symbol design projects [7] will be sent to five experts known to work in the field. The aim will be to evaluate the acceptance of the pictographic symbols that result from the use of the AI technologies. Five experts have been asked to look at each symbol and select a checkbox based on a 1-5 scale Likert scale, where 1 is 'completely unacceptable' and 5 is 'completely acceptable'. The criteria require a selection based on:

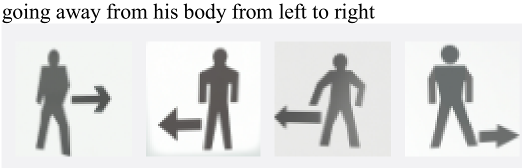
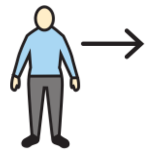
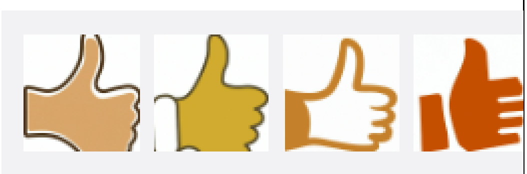
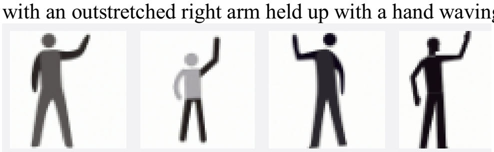
- feelings about the symbol as a whole (immediate reaction, iconicity, transparency, ease of recognition)
- represents the word or phrase (referent/concept)
- color contrast (outline and colors used for clarity and visually impaired)
- cultural sensitivity (not liable to offend, appropriate and relevant)

Participants will also be asked to add a general comment on ideas not mentioned in the list above, such as size or background etc.

3. Findings and Discussion

Initially attempts to make adaptations to symbols were based on text to symbol systems such as DALL·E 2 with short phrases or sentences used as prompts. It was found that even when the subject had adjectives and prepositions with the symbol guide most outcomes were unacceptable unless the symbol was a very simple object. So, where it was possible to have simple accurate phrases successes occurred, but not in the style of the Mulberry Symbols. There was also the complication that unless the system captured the fact that a symbol or outline was required, the image tended to appear in one color or came with a background (Table 2).

Table 2. Samples of text to symbol without the image to image support so lack the style input

go	front view of a man wearing grey trousers, black shoes and a pale blue top standing with an arrow going away from his body from left to right Sentence changed to A pictograph symbol of a man standing wearing grey trousers, black shoes and a pale blue top with an arrow going away from his body from left to right  https://labs.openai.com/e/eZLvmTpyxrt3lS9inkZerjkK	verb	change location; move, proceed Mulberry symbol 
good	left hand thumbs up Sentence changed to A pictograph symbol of a cream colored left hand thumbs up  https://labs.openai.com/e/KW1ifFa27cofdjJ5b2RVlTn2	adjective	having desirable or positive qualities especially those suitable for a thing specified Mulberry symbol 
good-bye / goodbye	back view of a man wearing grey trousers, black shoes and a pale blue top standing with an outstretched right arm held up with a hand waving Sentence changed to A pictograph symbol of a back view of a man wearing grey trousers, black shoes and a pale blue top standing with an outstretched right arm held up with a hand waving  https://labs.openai.com/e/tkIQuED0r0QP9datqtUlvvQQ	noun	a farewell remark Nothing in Mulberry so maybe reverse hello 

The Mulberry Symbol set has over 3,500 images, but within each category, such as parts of speech or topic categories such as professions, animals, buildings etc. the style, color and composition vary as mentioned in the methodology. Additional symbol sets could have been incorporated within the training data, but once again the variations in schemas or rules for design differ to such a degree that they could further skew results.

Further investigation is needed to see how these effects can be ameliorated in the coming months and the results will be forthcoming at the conference.

Some applications using Stable Diffusion provide an interface that makes it possible to adapt images on an individual basis by using various parameters, examples include img2img[3] and pix2pix[4]. This is achieved by controlling the amount of 'denoising strength' required when working out how much change is needed in order to make adaptations to an original symbol so that it can represent a different meaning or look. There is also the 'Classifier Free Guidance (CFG) scale' which is an indicator of how much the model should take account of the text prompt and finally it is possible to set the number of steps needed to achieve an acceptable image, but once again results are variable. It is possible to make several iterations but they do not necessarily achieve better results.

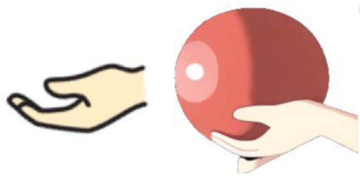


Figure 3. Mulberry symbol of a hand that needed to be adapted to a 'hand with a flat palm holding a small red ball' for the verb 'to have' which is not present in the symbol set.

There is the chance that by using concepts such as those described by Ruiz et al [8] it would be possible to solve some of the issues experienced in the early trials. The authors' Dreambooth application appears to not only use personal images, but also set them into different positions with objects, this could help with combination symbols such as a man mowing a lawn for 'to mow'. The examples from Dreambooth tend to use photographs and have backgrounds, but the latter can be removed and if the style if the Mulberry symbol can be picked up in an accurate way there could be a breakthrough for personalizing some symbols in an easier way.

4. Conclusion and Future Recommendations

At present the results indicate that the generation of open licensed symbols using image to image with supporting text prompts using AI models requires further work. It is possible to achieve basic concrete symbols from the stable diffusion models, but to develop acceptable results in the style of a particular symbol set is much harder. However, with time it is felt that improvements can be made to the proposed models so that AI can support AAC pictographic symbol adaptations. There may need to still be some human intervention to tweak the final versions for publication, but perhaps more simply than in the past. By the end of this project the intention is that this research will provide more informed future recommendations for the support of AI automated AAC symbol adaptations in a target style with the support of prompts.

[3] https://huggingface.co/spaces/fffiloni/stable-diffusion-img2img
[4] https://huggingface.co/spaces/timbrooks/instruct-pix2pix

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References

[1] McKenzie K, Milton M, Smith G, Ouellette-Kuntz H. Systematic review of the prevalence and incidence of intellectual disabilities: current trends and issues. Current Developmental Disorders Reports. 2016;3: 104-115.
[2] Light J, McNaughton D, Caron J. New and emerging AAC technology supports for children with complex communication needs and their communication partners: State of the science and future research directions. Augmentative and Alternative Communication. 2019;35(1):26-41.
[3] Light J, Wilkinson KM, Thiessen A, Beukelman DR, Fager SK. Designing effective AAC displays for individuals with developmental or acquired disabilities: State of the science and future research directions. Augmentative and Alternative Communication. 2019;35(1): 42-55.
[4] Thiessen A, Brown J, Beukelman D, Hux K, Myers A. Effect of message type on the visual attention of adults with traumatic brain injury. American journal of speech-language pathology. 2017;26(2):428-442.
[5] Creswell A, White T, Dumoulin V, Arulkumaran K, Sengupta B, Bharath AA. Generative adversarial networks: An overview. IEEE signal processing magazine. 2018;35(1):53-65.
[6] Nichol AQ, Dhariwal P. Improved denoising diffusion probabilistic models. In: International Conference on Machine Learning. PMLR. 2021. p. 8162-8171.
[7] Draffan EA, Wald M, Zeinoun N, Banes D. Democratisation of AAC Symbol Choices Using Technology. In: Harnessing the Power of Technologies to Improve Lives, AAATE Conf. Studies in Health Technology and Informatics 242. IOS Press. 2017. p. 355-362.
[8] Ruiz N, Li Y, Jampani V, Pritch Y, Rubinstein M, Aberman K. Dreambooth: Fine tuning text-to-image diffusion models for subject-driven generation. 2023. arXiv preprint arXiv:2208.12242. [cited 2023 May 20]. Available from: https://arxiv.org/pdf/2208.12242.pdf

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Cognitive Accessibility of Indoor Navigation Apps

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Abstract: Advances in smartphone technology have made it possible to develop mobile apps that assist people with cognitive or learning disabilities in navigating indoor spaces more easily and independently. This paper reviews the state of the art in smartphone-based indoor navigation for this population and describes a usability trial that was conducted with four individuals in a German city hall. The trial was based on simulated tasks that required the use of the indoor navigation app *XXX*, during which data about different use cases were gathered. A guided interview was conducted to gather further feedback about the accessibility and the perceived usefulness of the app. The paper highlights the potential of smartphone-based indoor navigation apps for enhancing the independence and quality of life of individuals with cognitive or learning disabilities. The usability trial provided insights into the effectiveness and usability of these apps in real-world settings.

Keywords: Indoor navigation, Accessibility, People with cognitive disabilities, Smartphone-based navigation, Human-computer interaction, Usability testing

1. Introduction

Navigation technologies are increasingly important in many areas of life and contribute significantly to facilitating work and everyday tasks. A variety of devices and software applications are available that can be used for indoor and outdoor navigation. These technologies are especially important for people with disabilities as they can help them in wayfinding, avoiding obstacles and overcoming architectural barriers [1]. However, if the user interfaces are not accessible, navigation technologies can also create new barriers [2]. In addition to the structural accessibility of urban environments and buildings [3], the accessibility of navigation apps plays an important role in the participation of people with disabilities [4].

The prevalence of mobile technologies such as smartphones, tablets and wearables provide new opportunities for participation in almost all areas of life [4]. For people with disabilities to benefit from the participation potential of mobility and navigation apps and to achieve a higher degree of autonomy, they must be independently available and usable. The legal requirements for equal participation and accessible information technology demand that manufacturers of navigation systems in public spaces are made responsible for designing navigation systems so that they are comprehensible and usable for all users [5].

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The development of smartphone-based mobility and navigation aids for people with disabilities is attracting increasing attention from industry and academia [6]. However, due to the heterogeneity of users and their interests, situations, and support needs, there are no universal solutions yet.

Independent mobility, and the corresponding participation opportunities and barriers for older people and people with cognitive disabilities is recently getting more attention in scientific discourse [7]. In a study by Trescher on cognitive disabilities and accessibility, different barriers in access to public offices and agencies were identified. In addition to difficult to understand language and complexity of concerns, a lack of orientation was also mentioned. This was related to both spatial confusion and non-transparent processes and areas of responsibility [8, 9].

In the work presented here, together with a group of people with cognitive disabilities, an indoor navigation app was tested for its accessibility. In the following, the method and the participants are presented first. Subsequently, the most important results are presented and finally, the implications for the development of cognitively accessible navigation apps derived from the results and the limitations are discussed.

2. Method

In the context of work presented here, the cognitive accessibility of an indoor navigation app was evaluated together with a group of people with cognitive disabilities. In preparation for the study, a mobile app was identified that was developed for navigation in public institutions (contagt) and further adapted for special use in a city hall of a large German city (Rathaus Navi app). The app was designed to help visitors find their way inside the city hall and find their appointments. Although both the contagt app and the Rathaus Navi app were developed with certain accessibility requirements in mind, there have been no targeted studies to verify their actual accessibility and usability for people with disabilities, especially for those with cognitive disabilities [10]. The aim of the presented work was to assess the potential of how effectively, efficiently and satisfyingly the contagt app can be used to solve navigational challenges by people with cognitive disabilities.

2.1. Participants Data Collection

The researchers received support from an extracurricular educational institution focusing on inclusive workshops to empower people with disability with the necessary skills and knowledge to navigate the digital world effectively and safely. Through them four voluntary participants (B1-B4) could be recruited. Prior to the actual assessment, a joint meeting was held to install the app on the participants' devices, provide them with basic instructions and survey their existing skills and support needs. B1 (age: 31), B2 (age: 35) and B3 (age: 33) have a cognitive disability. These three participants are engaged in employment through a workshop for people with disabilities and run their own household with ambulatory support. As additional support needs B2 requires support with administrative tasks and B3 mentioned that he has Down Syndrome and requires personal assistance with railway transfers. All participants mentioned that they had previously used map-based wayfinding apps like Google Maps.

Participant B4, the youngest at 16 years old, lives with their parents and attends a special school for socio-emotional development. She has a physical disability that necessitates using a wheelchair for mobility. Although participant B4 does not fit the intended target group, she was included in the study to provide a more comprehensive understanding of the app's usage issues.

2.2. Testing material and design

In the city hall itself, user-centered usability tests were conducted using simulation tasks based on the app's features and involved the use of the elicitation methods of thinking aloud and observation [11–13]. The tasks were designed to simulate scenarios of a regular visit to the city hall and could be solved by a person working individually with the app.

The tasks were divided into three difficulty levels to ensure a flexible response to the level of knowledge of the respective participants and to avoid under- or over-challenging (see **Figure 1**).

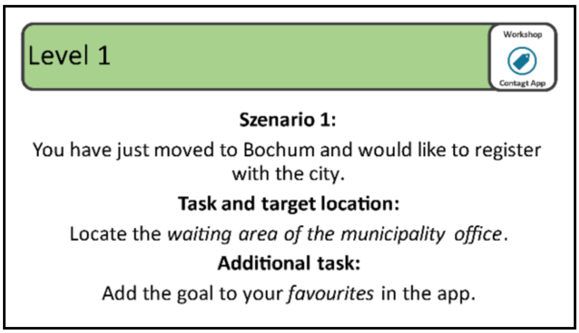

Figure 1 Task card used in the on-site usability test.

The tasks were used to give structure to each test run, because it required the user to determine their location, search for a target, and utilize wayfinding features to navigate to their goal. The participant was instructed by the tester to vocalize their thoughts and experiences throughout the entire walk through the city hall.

To ensure the safety and assistance of the participant, two researchers were present. One researcher conducted the test, recorded the audio, and helped when requested by the participant. This researcher also ensured the participant's safety when they became distracted by looking at their phone. In cases where participants stopped thinking aloud for an extended period, the researcher asked prompting questions to encourage the continuous vocalization of thoughts [12]. The second attending researcher observed the test procedure and made detailed records of it.

During the usability test, two types of data were recorded. The first type involved an observer who utilized a checklist based on an event-sample scheme to document observe app-user interactions from eight main categories (Table 1). Each interaction was assigned to a specific use-case category based on predefined rules for independent use (Table 2). The observer also noted relevant context information and the time stamps for each observation. To facilitate further analysis, it was crucial to timestamp the documentation. This allowed for the examination of the context within the thinking aloud data, enhancing the understanding of the participant's interactions and experiences throughout the test [12, 13].

Table 1 Interaction categories and included user interactions.

Interaction category:	Among included interactions:
Device Settings (G)	Enabling Wi-Fi (G.1), Bluetooth (G.2), GPS (G.3)
Preparation (V)	Downloading, opening App, and enabling guide (V.1-4)
Map (K)	Manipulating the virtual map (K.1-5)
Location-Related Functions (S)	Enabling and testing location tracking (S.1-4)
Destination Search (Z)	Using search tool (keyboard, symbols) to plan route (Z.1-5)
Navigation (N)	App-user-environment interactions during wayfinding: N.1 Starting navigation N.3 Using the line/route for guidance N.4 Perceiving and implementing navigation prompts N.5 Reorient and "Recalculate route" N.6 Navigating pop-up windows N.7 Change floors (stairs/elevator) N.8 Reach the destination N.9 Confirm arrival at the destination N.10 End navigation
QR-Scanner (Q)	Enabling scanner and accessing data (Q.1-3)
Accessibility options (U)	Activating voice output for navigation (U.1-2)

Table 2 Codes and scheme to assign use-cases for each documented app-user interaction.

Code:	Use case:
0	Interaction successfully completed independently
1	Successfully completed with hints from the environment (e.g., signs and arrows)
2	Completed with short feedback from the test conductor (e.g., "Okay, yes")
3	Completed with activation prompts (e.g., "Have you tried tapping button x?")
4	Completed only after intervention or explanation from the test conductor.
5	Not completed or trial terminated

By using this coding system, the observer was able to assess the level of independence and assistance required by the participants during their interactions with the app.

Subsequently, a group discussion with a feedback session was held, in which the survey method guided group interview was used. The group interview was held after all tests in the town hall had been completed, using a prepared guideline. In the general context of the study, the interview was intended to contextualize and supplement the test data. The setting allowed the participants to discuss and explain the encountered problems from their own perspective and to discuss them with the other participants.

2.3. Evaluation Methods

Through the application of two different methods, usability testing, and group interview, two separate data sets were generated. The recordings of both data sets were transcribed according to content-semantic rules [14]. The first step in data analysis was the preparation and transformation, or "quantification" of the usability data using MS-Excel [15]. The time stamps from the observation allowed to combine the thinking aloud data with the according use-cases (0-5). For example: In the task L2.9 (level 2, scenario 9) participant B1 was challenged to find the nearest public bathroom. The observer noted the use case ‘0’ for the interaction *starting navigation* (N.1), which means that B1 was able to activate the interactive wayfinding by tapping the “start navigation” button in the app. The transcribed reference from the thinking aloud recording reads:

"B1: I have already selected the destination in advance, "WC Damen" (Women's restroom), and now I simply press "Start navigation". [Starts walking.]"[2]

The interview was evaluated by means of a content-structuring qualitative content analysis using the data analysis software MAXQDA. The evaluation was conducted category guided [16].

3. Results

A total of 19 usability tests were conducted. The participants could choose to voluntarily do more tests or to pause their tests, yet every participant accomplished the set minimum of three tests. An overview of the conducted tests is given in table 3. All participants B1-B4 managed to solve most of their tasks and navigate through the city hall.

Person:	B1	B2	B3	B4*	Total count
Count	7 (6)	5	3	4	19 (18)
Successful	6/6	4/5	3/3	3/4	16/18

Figure 2 Overview of the conducted tests

The observation data suggests that the users were able to execute the interactions from the category *preparation (V)*, *map interaction (K), determining current location (S), target search (Z)* without assistance. Most problems were encountered in navigation as can be seen in table 3. The QR-Scanner (Q) and the accessibility options (U) couldn't be comprehensively documented in the usability test.

The group interview was analyzed using the previously established deductive categories and the categories inductively identified during data analysis. The following aspects were evaluated: 1. previous experiences and navigation strategies; 2. problems encountered during the trial; 3. barriers in the app; 4. motivation; 5. further possibilities for usage; and 6. suggestions for improvement.

B1 terminated one test run because of confusion about the task. When trying to navigate towards the closest exit, B2 terminated the task because he was unsure whether he was allowed to open the emergency door like the app suggested. Parallelly, participant B4 chose to ignore the app all together when navigating towards the exit and relied on her memory.

4. Discussion

As described above, cognitively accessible support services are essential for self-determined access to information and services and for increasing the participation of people with disabilities.

The evaluation of the test results for the investigated indoor navigation app showed that there are considerable problems in cognitive accessibility. The analyzed navigation app requires a high degree of digital literacy and fails to meet the support needs of users who need complexity-reduced information due to the lack of content in plain language.

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2 Translation of transcript *03_B1_L2.9, paragraph 2*

Additionally, the app misses important self-explanatory features, such as tutorials and instructions on how to deal with problems when changing floors. However, the trial demonstrated a high motivational effect among the participants. In general, navigation apps seem to be considered as highly acceptable assistance systems that can avoid stigmatization and exclusion through the proximity to life and naturalness of smartphone use.

Due to the underlying positioning technology via Bluetooth beacons, there is also a technological potential that, in combination with augmented reality guided navigation, may become an effective method for promoting the mobility of people with cognitive disabilities [17].

One potential criticism of the data collection method used in this study is that it may still be overwhelming for participants due to the nature of the tasks and the potential cognitive challenges faced by individuals with cognitive disabilities. The navigation tasks using the app, coupled with the need to think aloud and verbalize their experiences, could potentially put additional cognitive load on participants and make the process mentally demanding. To address the acquired feedback and observations in the field and to ensure a more comfortable testing environment for participants, some ideas for implementing usability tests with the target group under real-life conditions without causing overwhelm or interference are as follows:

1. Familiarization Phase: Begin the usability test with a familiarization phase, where participants can explore the app and become acquainted with its features and functionalities. This phase allows participants to gain confidence and familiarity with the app before engaging in the actual navigation tasks.

2. Simplified Tasks: Simplify the navigation tasks by breaking them down into smaller, more manageable steps. This approach helps reduce cognitive load and allows participants to focus on specific aspects of the app's functionality at a time.

3. Supportive Environment: Create a supportive and non-judgmental environment for participants by emphasizing that the purpose of the test is to evaluate the app's usability, not their individual capabilities. Encourage participants to ask for assistance or take breaks if needed to alleviate any potential stress or overwhelm.

4. Mixed Methods Approach: Supplement the think-aloud approach with other data collection methods, such as interviews or questionnaires, to gather additional insights into participants' experiences and perceptions. This can provide a more comprehensive understanding of the usability challenges faced by individuals with cognitive disabilities.

5. Iterative Testing: Conduct iterative testing with the target group, allowing for multiple rounds of testing and refinement of the usability test process. This approach enables the identification and resolution of any issues or concerns that may arise during the initial testing phases.

By implementing these suggestions, the usability tests can be conducted in a way that minimizes potential overwhelm for participants, ensuring a more comfortable and effective evaluation of the app's usability under real-life conditions for individuals with cognitive disabilities.

References

[1] Prandi C, Barricelli BR, Mirri S, Fogli D. Accessible wayfinding, and navigation: a systematic mapping study. Univ Access Inf Soc 2021. doi:10.1007/s10209-021-00843-x.
[2] W3C Web Accessibility Iniative. Accessibility, Usability, and Inclusion. 2022. https://www.w3.org/WAI/fundamentals/accessibility-usability-inclusion/. Accessed 15 Aug 2022.
[3] Mora H, Gilart-Iglesias V, Pérez-del Hoyo R, Andújar-Montoya MD. A Comprehensive System for Monitoring Urban Accessibility in Smart Cities. Sensors. 2017; 17:1834. doi:10.3390/s17081834.
[4] Miesenberger K, editor. Computers helping people with special needs: 18th International Conference, ICCHP-AAATE 2022, Milan, Italy, July 11-15, 2022, proceedings. Cham: Springer; 2022. doi:10.1007/978-3-031-08648-9.
[5] Loitsch C, Müller K, Weber G, Petrie H, Stiefelhagen R. Digital Solutions for Inclusive Mobility: Solutions and Accessible Maps for Indoor and Outdoor Mobility. In: Miesenberger K, editor. Computers helping people with special needs: 18th International Conference, ICCHP-AAATE 2022, Milan, Italy, July 11-15, 2022, proceedings. Cham: Springer; 2022. p. 95–101. doi:10.1007/978-3-031-08648-9_12.
[6] Domingo MC. An Overview of Machine Learning and 5G for People with Disabilities. Sensors 2021. doi:10.3390/s21227572.
[7] Comai S, Bernardi E de, Masciadri A, Matteucci M, Salice F, Veronese F. ALMA: An Indoor Localization and Navigation System for the Elderly. In: Guidi B, Ricci L, Calafate C, Gaggi O, Marquez-Barja J, editors. Smart Objects and Technologies for Social Good. Cham: Springer International Publishing; 2018. p. 82–91. doi:10.1007/978-3-319-76111-4_9.
[8] Delgrange R, Burkhardt J-M, Gyselinck V. Difficulties and Problem-Solving Strategies in Wayfinding Among Adults with Cognitive Disabilities: A Look at the Bigger Picture. Front Hum Neurosci. 2020; 14:46. doi:10.3389/fnhum.2020.00046.
[9] Trescher H. Kognitive Beeinträchtigung und Barrierefreiheit: Eine Pilotstudie. 1st ed. Bad Heilbrunn: Verlag Julius Klinkhardt; 2018.
[10] Stadt Bochum. Aktuelle Pressemeldung vom 4. November 2021: Ab sofort hilft eine App zur Indoor-Navigation bei der Orientierung im Rathaus. 2021. https://www.bochum.de/Pressemeldungen/4-November-2021/Ab-sofort-hilft-eine-App-zur-Indoor-Navigation-bei-der-Orientierung-im-Rathaus. Accessed 5 Jul 2022.
[11] Dumas JS, Redish JC. A practical guide to usability testing. Exeter, England [etc]: Intellect; 1999.
[12] Rubin J, Chisnell D, Spool J. Handbook of usability testing: How to plan, design, and conduct effective tests. 2nd ed. Indianapolis, Ind.: John Wiley & Sons; 2008.
[13] C. Lewis. Using the „thinking aloud"method in cognitive interface design: Lewis, C. (1982). Using the „thinking aloud"method in cognitive interface design. New York: Elsevier 1982.
[14] Kuckartz U. Qualitative Evaluation: Der Einstieg in die Praxis. 2nd ed. Wiesbaden: VS Verlag für Sozialwissenschaften; 2008.
[15] Vogl S. Quantifizierung. Köln Z Soziol. 2017;69:287–312. doi:10.1007/s11577-017-0461-2.
[16] Kuckartz U. Qualitative Inhaltsanalyse. Methoden, Praxis, Computerunterstützung. 3rd ed. Weinheim: Beltz Verlagsgruppe; 2016
[17] Hudson L, Folmer E, Dascalu, S. HARIN: HoloLens Augmented Reality Indoor Navigation. 2023. In: Proceedings of the 9th International Conference on Applied Computing & Information Technology (ACIT '22). Association of Computing Machinery, New York, NY, USA. 30-35. Doi:10.1145/3543895.3543938.

Attachments

Table 3 Comprehensive task list with all documented instances

			Use-Cases						
Nr.	**Interaction**	**Code**	0	1	2	3	4	5	**Total**
1	Enable WiFi or mobile data	G.1	0	0	0	0	0	0	0
2	Activate GPS	G.2	0	0	0	0	0	0	0
3	Activate Bluetooth	G.3	0	0	0	0	0	0	0
4	Download contat app	V.1	0	0	0	0	0	0	0
5	Open contagt app	V.2	13	0	0	0	0	4	17
6	Read and confirm permissions	V.3	0	0	0	0	0	0	0
7	Select Guide (Bochum Rathaus)	V.4	0	0	0	0	0	0	0
8	Open the map view	K.1	18	0	0	0	0	0	18
9	Card interaction	K.2	1	0	0	0	0	0	1
10	Move the map in one dimension	K.3	2	0	0	0	0	0	2
11	Pinch zoom	K.4	0	0	0	0	0	0	0
12	Pinch turning	K.5	0	0	0	0	0	0	0
13	Determine location	S.1	17	0	1	0	0	0	18
14	Testing the direction	S.2	0	0	0	0	0	0	0
15	Test the direction of movement	S.3	0	0	0	0	0	0	0
16	Predict route verbally	S.4	1	0	0	0	0	0	1
17	Entry in search line	Z.1	15	0	0	0	1	0	16
18	Quick selection	Z.2	2	0	0	0	0	0	2
19	Selection from map view	Z.3	0	0	0	0	0	0	0
20	Add/select the target location from favorites	Z.4	2	0	0	0	0	2	4
21	Tap the goal ("Plan Route")	Z.5	17	0	0	0	1	0	18
22	Start navigation	N.1	14	0	0	4	0	0	18
23	Tap the steps manually <>	N.2	0	0	0	0	0	0	0
24	Line/route guidance follow	N.3	9	0	0	0	1	5	15
25	Implement navigation notice	N.4	11	1	0	1	2	1	16
26	Reorientation, "recalculate the route"	N.5	4	0	1	1	3	0	9
27	Pop-up window	N.6	2	0	1	0	0	0	3
28	Change of floor (stairs/elevator)	N.7	7	1	0	1	2	0	11
29	Reach the goal from the task	N.8	11	3	0	3	0	1	18
30	Confirm target location	N.9	6	6	0	2	2	2	18
31	End navigation	N.10	3	0	0	0	0	0	3
32	Read and confirm permission for QR function	Q.1	1	0	0	0	0	0	1
33	Fotograph/scan	Q.2	1	0	0	0	0	0	1
34	Access content	Q.3	1	0	0	0	0	0	1
35	Activate voice output	U.1	0	0	0	0	1	0	1
36	Voice guided navigation	U.2	3	0	0	1	0	0	4
		Total	**161**	**11**	**3**	**13**	**13**	**15**	**216**
		%	74,5%	5,1%	1,4%	6,0%	6,0%	6,9%	100,0%

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Neuro Service Dogs Impacts on Community-Dwelling Persons with Mild to Moderate Dementia and Their Caregiver

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Abstract. Since there were no research data on the use of neuro service dogs (NSD) in 2018, a comparative case study research design was done. The cases comprised of a caregiver with a person with mild to moderate dementia, and either an NSD (n=5), a companion dog (n=28), or no dog (n=23). Monitor activity and online questionnaires were administrated. Interesting qualitative data on the roles of a NSD, advantages and inconvenients were fully described and published. Quantitative data could not confirm that NSD is benefit-cost, neither that it increases quality of sleep or level of exercise, compared to companion dogs.

Keywords. service dog, Alzheimer, dementia, living at home, caregiver, assistive dog

1. Introduction

In Canada, the estimated annual cost of dementia is 10.4 billion dollars and of unpaid caregiving is $25 billion [1]. A 2012 survey [2] found that, of the 8.1 million Canadian caregivers (28% of population), 44% were between the ages of 45 and 64 years, 10% provided more than 30 h of support a week and 60% continued to work while providing care. Caregivers are at increased risk of physical, emotional, and financial burden if: they provide more than 21 h per week of care; care for persons with depression, cognitive decline, behavioural change; or care for persons with terminal conditions [1-3]. Stress can result in health challenges, social isolation, loss of income, and family conflict [3-4]. Hopefully, canine assistance like neuro service dogs (NSD) may help, but we have to prove scientifically the grey literature that show so much enthusiastic testimonies [5]. A systematic review of trained assistance dogs for people with dementia was published by Marks and McVilly in 2020 [6] confirming that no papers specifically addressed the issue

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of assistance dogs for those with dementia living at home. They found 24 papers about interventions with dogs in nursing homes, day care facilities and long-term facilities or hospital geriatric psychiatric unit, but the person with dementia is never the owner of the dog. A first qualitative study by Ritchie et al (2021) [7], was published shedding light on the relationships between the context, mechanisms, and outcomes (CMO) when training and placing 4 NSD with couples where one partner had a diagnosis of dementia. The three key mechanisms are human–animal bond, relationship dynamics, and responsibility for caring and carer wellbeing (See Figure 1 for the CMO model). Based on this model, Marks and McVilly (2023) [8] are the first that published results about assistance dogs for people with early onset dementia only in Australia. Their qualitative study involved 14 people of 53 to 65 years old matched with trained assistance dogs over a two-year period. The 11 participants also experienced the same key mechanisms and the 6 outcomes as presented in figure 1, except for 3 persons with dementia that went into care during the study.

In 2023, Vincent et al. [9] have presented qualitative results about "roles and usages" of NSD for caregivers living at home with persons with dementia. Phone interviews were done with 5 caregivers (mean age 54.8 years) who had an NSD, 28 caregivers (63.6 years) who had a companion dog, and 23 caregivers (63.8 years) without dog. There were 5 roles and usages of the dog. 'Socialisation' and 'Help with a sense of direction' were the most addressed roles for dyads with the NSD. For dyads with companion dog and without dog, 'Engagement-and-meaning of life' as well as 'Physical activity with the dog' were the most discussed roles. The 'Sleep or wake up' role was the least discussed role across three cases. There were 7 advantages and 10 inconvenients for canine assistance. There were 3 qualitative hypotheses [10] that were confirmed. [H1] For home care support, the presence of NSD has more positive impacts on both the person with dementia and their caregiver compared to the presence of a companion dog; [H2] the presence of a NSD results in the person with dementia accessing more indoor and outdoor public sites than with a companion dog; and [H3] dyads with a dog are informally socially engaged more frequently than those with no dog.

This manuscript presents quantitative results from the comparative case study of Vincent et al. [9] that have not been published. **Objectives** were ─ To characterize sleep efficiency and the physical activity level around the home during 7 consecutive days of persons with mild and moderate dementia, and ─To conduct a cost-effectiveness analysis associated with having canine assistance in the home of the community-dwelling person with dementia**.** Quantitative **hypotheses** were: [H4] The quality of sleep and the level of exercise are better with a NSD or a companion dog than without a dog. [H5] NSD are a cost-effective, value-added alternative (i.e. additional benefits in terms of quality of life outweigh additional costs) relative to companion dogs, and companion dogs are a cost-effective alternative relative to having no dog.

Methods

1.1. Research design and participant selection

A **comparative case study** research design had been used to address objectives and test our hypotheses. This type of design is relevant when knowledge is unavailable and scientific evidence of level 1 quality (i.e., exploratory). To answer our objectives, we had compared three data set collected using the following methods: phone interviews and qualitative thematic analysis [9], cost-benefit analysis, and activity monitoring (*motion watch ActiGraph*). All cases include a dyad of a caregiver and a person with dementia. Case 1 included 5 NSD. The phone recruitment was done by the intermediary of Wilderwood Service dogs. Case 2 included 28 companion dogs. Recruitment was done with the help of Alzheimer and Caregiver associations. Case 3 included no dog but 23 dyads. For this recruitment, we had access to the Quebec rehabilitation center archives to contact people that may have dementia.

Selection criteria: 1-Caregivers had a canine assistance for more than one year. 2-Caregivers agreed to discuss their experience of having a canine assistance or their reasons why they did not have a dog. 3-Persons with dementia were community-dwelling, seeing the caregiver every day and 4- had a mild or moderate stage of dementia.

1.2. Animal as an assistive technology and intervention

Krause-Parello et al. [11] claimed that service dogs are exhaustively trained to respond precisely to specific disabilities of their owners and are typically allowed entry into public facilities under the protection of the Americans with Disabilities Act. Alzheimer Scotland [12] indicates that, "dementia assistance dogs are highly trained dogs, helping their forever family with specific tasks such as fetching medication pouches. The dogs have full public access rights and live with the family at home, full time." Paws for life USA-Services and therapy dogs [13] announces NSD for Dementia, Alzheimer's, Parkinson's, Huntington's, Brain Injury, Lupus, Narcolepsy and Psychological Disabilities. Our partner for the research projet was Wilderwood service dogs in US, Maryville, Tennessee (https://wilderwood.org/Neuro). This picture shows a person being independant with a service dog in the city (source: https://www.gofundme.com/fr-fr/c/blog/service-dog-fundraising).

1.3. Data collection

At the end of the phone interview [9], the caregiver was asked about the best timing to do the monitoring of the person with dementia for sleep and physical activity using an actimeter. This motion watch ActiGraph's GT3X-BT would be attached to the person's wrist for 7 consecutive days. It was mailed to them (including instructions, a log sheet and a prepaid envelop) and had to be returned to the research team following data collection. In the days following the interview [9], online questionnaires were sent to the caregivers for the cost benefice analysis. These included the ICECAP-O [14], the ASCOT-SCRQoL [15], and a cost questionnaire, the Resource Utilization in Dementia (RUD 3.2) questionnaire [16].

1.4. Activity monitor analyses

GT3X-BT data were analysed using the Actilife software (v6.13.4). First, there was a wear time validation using the Troiano (2007) [17] algorithm and the log sheet completed by participants. Second, the cut points used to distinguish between physical activity levels were those of Freedson (1998) [18] designed for adults. Finally, sleep was analysed by the Cole-Kripke algorithm and manually supervised to ensure data quality. Non-parametric analyses (Kruskall-Wallis and Mann-Whitney) were used to compare group data. The first part of the Caregiver's Burden Scale (administered at the end of the interview [19] was also used as a complement to this analysis. It is about the caregiver's perception of capabilities and is comprised of five questions about what daily activities or mobility the person with dementia.

1.5. Cost benefit analysis (CAD$)

The first measure (med cost caregiver) is the medical costs of the caregiver in the last 30 days. It includes the costs of hospital stays in the last 30 days, as well as the costs related to visits to general practitioners, geriatricians, neurologists, psychiatrists, physiotherapists, occupational therapists, social workers, psychologists and others. The second measure (med cost patient) is the medical costs for the person with dementia. It includes the same components as the previous measure and, in addition, the costs related to the receiving help from a district nurse, from a healthcare assistant, or using day care. The third measure (cost helping) captures the value of the help provided by the caregiver on activities of daily living, instrumental activities of daily living and on supervision. The fourth measure (cost of lost work) is the amount of lost revenue because of the time the caregiver had to leave its work to care for the person with dementia.

1.5.1. Assumptions to compute costs

All costs are computed based on the prices in place in the province of Quebec. For hospital stays, we used a value of 1,305.94 CAD per day which is the average price of a hospital day in the different health units of Quebec [20]. A visit to a general practitioner is priced at 42.85 CAD [21]. Visits to geriatricians, neurologists, and psychiatrists are respectively priced at 51.20 CAD, 101.60 CAD and 215.00 CAD [22]. Visits to physiotherapists and occupational therapists are priced at 47.00 CAD and 46.00 CAD respectively based on applicable rates set by CNESST [23]. Visits to social workers and psychologists are priced based on the hourly wage for these professions reported by the government of Quebec (respectively 33.13 CAD and 48.00 CAD) [23-25]. Furthermore, based on Hollander et al. (2009) [26], we priced an hour of help with activities of daily living at 21.63 CAD, and an hour of help with Instrumental Activities of Daily Living or supervising at 15.00 CAD. We also value receiving help from a district nurse, from a healthcare assistant, or using day care at 21.63 CAD [24].

2. Results

2.1. Sleep and physical activity

The table 1 shows the results of the sleep analyses. The sleep efficiency consists of the percentage of the time sleeping (hours of sleep), detected by the device, and the total time passed in bed (hours in bed). The sleep efficiency was similar between groups. For the “hours of sleep” and the “hours in bed”, the statistical analysis did not find a difference between groups. There is no difference in the number of awakenings per night on average and it cannot be concluded that the number of minutes of “wake after sleep onset” and of “time of awakening” are different. The same results were obtained for the "sleep fragmentation index". It represents the restlessness during the sleep and the higher the index, the more sleep is disrupted.

Table 1. Results about the sleep analyses of people with dementia

	Neuro service dogs n=4	Companion dogs n=18	No dog n=15	Kruskal-Wallis *p*-value
Hours in bed	6.7 (0.7)	8.3 (2.0)	8.5 (1.4)	0.133
Hours of sleep	6.6 (0.9)	7.6 (2.0)	7.6 (1.1)	0.365
Sleep efficiency (%)	93.1 (3.3)	92.4 (5.5)	90.3 (8.1)	0.921
Number awakenings	9.2 (4.6)	9.3 (5.0)	8.7 (4.3)	0.926
Wake after sleep onset (min)	23.1 (12.4)	36.9 (28.1)	47.0 (43.7)	0.707
Average awakening length (min)	2.7 (0.6)	3.7 (2.4)	4.8 (3.5)	0.499
Sleep fragmentation index (%)	19.8 (5.4)	23.2 (12.9)	20.3 (11.4)	0.855

The table 2 presents the physical activity results of people with dementia. Data are presented as the percentage of the time the person passed in activity levels. The sedentary level consists of low-level activities done, for example, when sit down (eating, watching TV, reading, etc.). No difference was detected between groups. The activity monitor was able to measure that people who do not have a dog spend a larger portion of their day doing light activities (e.g. quiet standing activities). Even though there is no statistical difference in the moderate intensity activities (e.g. brisk walking) between groups, when we combine this result with the observations of caregivers we can observe a tendency for those with a neuro service dog to spend more time in moderate activities than those without dogs. As shown in table 3, caregivers tended to notice less that their loved one spent the majority of their time sitting or lying down.

Table 2. Physical activity results of people with dementia

	Neuro service dogs n=4	Companion dogs n=18	No dog n=15	Kruskal-Wallis
	%	%	%	*p*-value
Sedentary level	63.3 (8.1)	64.2 (12.3)	58.7 (7.8)	0.379
Light level	28.2 (4.1)	29.2 (9.5)	37.1 (8.8)	0.038*
Moderate level	8.5 (4.4)	6.6 (5.2)	4.2 (2.5)	0.262
Vigorous level	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1

* $p \leq 0.05$

Table 3. Perception of capabilities mean of % (SD in %)

	Neuro service dogs n=5	Companion dogs n=28	No dog n=23	Kruskal-Wallis
	%	%	%	*p*-value
Passes more than half of the day in bed for in a chair	20 (45)	57 (50)	73 (46)	0.090 β
Is practically completely confined to bed or chair	0 (0)	7 (26)	27 (46)	0.088 β

β $p \leq 0.10$

2.2. Cost benefit analyses

The results of the cost-effectiveness analysis were not conclusive. First of all, questionnaires that measured quality of life show no difference between the groups, indicating that having a dog does not increase nor decrease the aspects measured: ICEpop

CAPability for older people (p=0.668) and Adult Social Care Outcomes Toolkit (p=0.425) each evaluating 5 and 7 items. The Resource Utilization in Dementia (RUD) was the main questionnaire used for the economic analyses. Table 4 shows that there was no statistical difference between groups for medication costs of caregivers (p=0.860) and people having dementia (p=0.744), neither for the costs of helping (p=0.927) and total costs without work (p=0.848). The mean value of the help provided by the caregivers in each group was more similar between groups (3799$ to 4396$ per month) than costs for medication that were highly variable. The table 5 presents the results of the cost of the lost work, in the last month, by the caregivers which was not different between groups (p=0.0.360). One more thing that should be considered in this analysis is the price of a neuro service dog. Based on the two sources of this study, the cost for the client can be around 25 000 CAD but donations can reduce this payment to 0$. Also, the cost of maintaining a service dog at home was estimated to 1549 CAD per year, in 2016 [23].

Table 4. Medical costs and value of the help provided in the last month

	Neuro service dog n=5		**Companion dog n=27**		**no dog n=22**		**Kruskal Wallis**
	Mean	SD	Mean	SD	Mean	SD	*p*-value
Med cost caregiver	$55	$78	$68	$98	$2 022	$9 025	.860
Med cost patient	$99	$174	$296	$661	$1 752	$6 696	.744
Med cost total	$155	$251	$363	$682	$3 774	$10 913	.752
Cost helping	$3 799	$3 715	$4 349	$3 944	$4 396	$4 371	.927
Total cost without work	$3 954	$3 821	$4 713	$4 146	$8 171	$13 219	.848

Table 5. Cost of missing work and total cost

	Neuro service dog n=3		**Companion dog n=9**		**no dog n=6**		**Kruskal Wallis**
	Mean	SD	Mean	SD	Mean	SD	*p*-value
Cost of lost work	$1 440	$1 270	$724	$903	$413	$974	.360
Total cost with work	$5 151	$4 476	$5 009	$4 471	$12 792	$22 033	.972

3. Discussion and Conclusion

This is the first study that has examined sleep quality, level of physical activity and cost-effectiveness for having a neuro service dog compared to having a companion dog or no dog. The quantitative data obtained do not confirm the ‘reduction stress and worry’, ‘increase in activity’ and ‘maintenance of a routine’ from the CMO model [8] presented at figure 1. Hypotheses H4 and H5 could not be confirmed either. Statistically, there is no difference whether you have a NSD, a companion dog or no dog. Since we only have 5 NSD, the standardised measures that we have used (questionnaires, actimeter) did not reveal significant difference between the dyads with NSD, companion dog or no dog. The fact that the dog school was closed for 2 years due to the Covid is one of the reasons for such a little sample. Also, wearing the *ActiGraph* for only 7 days also did not reveal whether the person that week was at their maximum or minimum activity in the community. Interestingly, qualitative data show difference between dyads in favor of having a NSD [9] for all the six outcomes and mechanisms mentioned in figure 1.

The interviews revealed that NSD permit more moderate-intensity physical activity in the routine of the person with dementia [28], in part due to its public access, while the companion dog encourages more quiet walks and play in the house.

Quantitative measurements showed that people who do not have a dog showed a higher light-level activity percentage but failed to show any other difference despite other results pointing to a higher moderate physical activity level of people with a NSD.

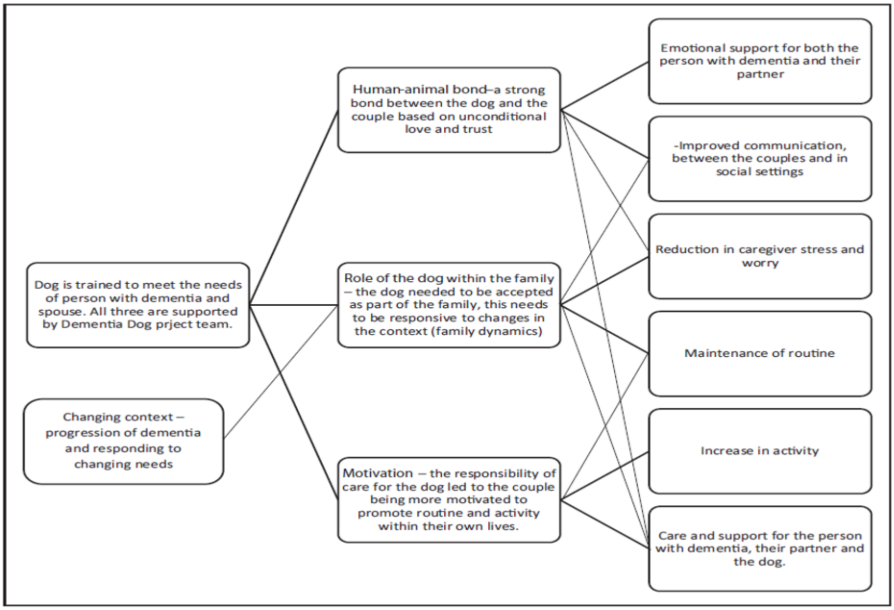

Figure 1. Context, mechanisms, and outcomes model (CMO) by Ritchie et al 2021

The fact that the cost of medication was very high for some people in the group without a dog and the fact that the number of participants with an NSD was lower then the other two groups play an important role in the fact that no statistical difference could be seen in the economic analyses. As demand increases, we might see an increase in the number of dog training schools providing NSD and a possibility to increase the number of participants in a follow-up study. A recommendation would be to include only participants with a mild stage of dementia as it can help to reduce the variability in help needed and medical expenses.

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References

[1] Alzheimer Society of Canada. Prevalence and monetary costs of dementia in Canada, Toronto (ON). 2016.

[2] Sinha M. Results from general social survey 'portrait of caregivers'. statistics Canada. 2012. http://www.statcan.gc.ca/pub/89-652-x/89-652-x2013001-eng.pdf

[3] Kitts J Health council of Canada Report on homecare priorities. Seniors in need. Caregivers in distress. 2012. http://www.alzheimer.ca/durham/~/media/Files/on/Media%20Releases/2012/April%202012/

[4] Stajduhar K, Funk L, Toye C, Grande G, Aoun S, Todd C. Part 1: Home-based family caregiving at the end of life: a comprehensive review of published quantitative research (1998-2008). Palliat Med. 2010 Sep;24(6):573-93.

[5] Wilderwood Service Dogs. Changing the lives of families. 2020. http://www.wilderwood.org/
[6] Marks G, McVilly K. Trained assistance dogs for people with dementia: a systematic review. Psychogeriatrics. 2020 Jul;20(4):510-521.
[7] Ritchie L, Quinn S, Tolson D, Jenkins N, Sharp B. Exposing the mechanisms underlying successful animal-assisted interventions for people with dementia: A realistic evaluation of the Dementia Dog Project. Dementia (London). 2021 Jan;20(1):66-83.
[8] Marks G, McVilly KR. Assistance Dogs for People with Younger (Early)-Onset Dementia: The Family Carer's Experience. Animals (Basel). 2023 Feb 21;13(5):777
[9] Vincent C, Dumont F, Rivard A, Rogers M, Brémault-Phillips S, Brown C, Achou B. Roles and usages of neuro service dogs for caregivers living at home with persons with dementia: an exploratory comparative case study. Dementia: the international journal of social research and practice DEM-22-0298. Final revision May 2023.
[10] Chigbu U. Visually Hypothesising in Scientific Paper Writing: Confirming and Refuting Qualitative Research Hypotheses Using Diagrams. Publications, 2019;7(1):22. MDPI AG. Retrieved from http://dx.doi.org/10.3390/publications7010022
[11] Krause-Parello CA, Sarni S, Padden E. Military veterans and canine assistance for post-traumatic stress disorder: A narrative review of the literature. Nurse Educ Today. 2016 Dec;47:43-50.
[12] Dementia Dog. Dementia dog family provides educational workshops to guide families affected by dementia who have, or would like to get, their own pet dog. 2022. http://dementiadog.org/dementia-family-dog/
[13] Paws for life USA-Services and therapy dogs. Master service dog trainer. https://animalsdeservebetter.org/neurological-alert-dogs/ (Accessed June 10, 2023).
[14] Grewal I, Lewis J, Flynn T, Brown J, Bond J, Coast J. Developing attributes for a generic quality of life measure for older people: preferences or capabilities? Soc Sci Med. 2006 Apr;62(8):1891-901.
[15] Malley JN, Towers AM, Netten AP, Brazier JE, Forder JE, Flynn T. An assessment of the construct validity of the ASCOT measure of social care-related quality of life with older people. Health Qual Life Outcomes. 2012 Feb 10;10:21.
[16] Wimo A, Wetterholm AL, Mastey V, Winblad B. Evaluation of the resource utilization and caregiver time in Anti-dementia drug trials - a quantitative battery. in: Wimo A. Karlsson G. Jönsson B. Winblad B (eds). The Health Economics of dementia. 1998. Wiley´s. London. UK.
[17] Troiano RP, Berrigan D, Dodd KW, Mâsse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. Med Sci Sports Exerc. 2008 Jan;40(1):181-8.
[18] Freedson PS, Melanson E, Sirard J. Calibration of the Computer Science and Applications, Inc. accelerometer. Med Sci Sports Exerc. 1998 May;30(5):777-81.
[19] Dumont S, Jacobs P, Fassbender K, Anderson D, Turcotte V, Harel F. Costs associated with resource utilization during the palliative phase of care: a Canadian perspective. Palliat Med. 2009 Dec;23(8):708-17.
[20] Gouvernement du Québec. Circulaire 2021-021 sur les tarifs pour les services rendus en externe. prix de journée pour la courte et la longue durée ainsi que prix de journée pour la réadaptation. les nouveau-nés et les services aux jeunes (03.01.42.19) Annexe 2
[21] RAMQ- Régie de l'assurance maladie du Québec. (11-08-2021) Manuel rémunération à l'acte pour les médecins omnipraticiens. Régie de l'assurance maladie du Québec. code 15803.
[22] RAMQ - Régie de l'assurance maladie du Québec. (11-08-2021) Manuel rémunération à l'acte des médecins spécialistes. numéro 150. codes 00030. 09127 and 08920.
[23] CNESST (09-16-2022) Tarification et facturation en physiothérapie ou ergothérapie. https://www.cnesst.gouv.qc.ca/fr/demarches-formulaires/professionnels-intervenants-sante/physiotherapeutes-technologues-en-physiotherapie/tarification-facturation-en-physiotherapie
[24] Gouvernement du Québec (09-16-2022) Explorer des métiers et des professions : Travailleurs sociaux / travailleuses sociales https://www.quebec.ca/emploi/metiers-professions/explorer-metiers-professions/4152-travailleurs-sociaux-travailleuses-sociales
[25] Gouvernement du Québec (09-16-2022) Explorer des métiers et des professions : psychologues https://www.quebec.ca/emploi/metiers-professions/explorer-metiers-professions/4151-psychologues
[26] Hollander MJ, Liu G, Chappell NL. Who cares and how much? The imputed economic contribution to the Canadian healthcare system of middle-aged and older unpaid caregivers providing care to the elderly. Healthc Q. 2009;12(2):42-9.
[27] Vincent C, Gagnon D, Dumont F. Effets d'un programme de chiens d'assistance auprès de la clientèle ayant subi une lésion médullaire et utilisant un fauteuil roulant. Rapport déposé aux Fonds de recherche du Québec – Santé (FRQS). 2016. 1-37 (p21)
[28] Dumont F, Vincent C. Dementia dogs: Their impact on community-dwelling persons with mild to moderate dementia and their caregiver. 2022. https://www.cirris.ulaval.ca/wp-content/uploads/Final-report-Alzheimer-society_Dementia-Dogs.pdf

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The Assistive Potential of Digital Consumer Technology

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Understanding the Potential of Home-Based Digital Voice Assistants for People with Disabilities

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Abstract. As the numbers of people with disabilities actively using technology to support their day-to-day activities increases the benefits afforded by these technologies are ever more evident. Much of the technology used by people with disabilities is often characterised as Assistive Technology (AT) which is designed and developed to address the specific needs of people with disabilities. In contrast to AT which is focused on serving the needs of people with disabilities, consumer digital technology refers to those technologies that are developed for use by the general public. The aim of this study was to explore the assistive potential of a range of exemplar consumer digital technology, namely, digital voice assistants and internet of things. A qualitative study was conducted in the context of a field-trial of a range of digital consumer technologies which included a Digital Voice Assistant alongside voice-operated Internet of Things technologies.

Keywords. Consumer Technology, Assistive Technology, Digital Voice Assistant, Internet of Things

1. Introduction

As the numbers of people with disabilities actively using technology to support their day-to-day activities increases the benefits afforded by these technologies are ever more evident [1]. This extends the opportunities available for communication, accessing information, and engaging with online services. Much of the technology used by people with disabilities is often characterised as Assistive Technology (AT) which is designed and developed to address the specific needs of people with disabilities. Such AT is often designed for a specific group of people with disabilities and aims to address a specific need or requirement. For example, people with visual disabilities may seek to use specialist text-to-speech software to present text-based information available in auditory form. For many people with disabilities however, they are excluded from using AT by factors such as, the awareness of the technology, the prohibitive cost of specialist technology and the

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requirement for installation, training, and support [2,3,4] In contrast to AT which is focused on serving the needs of people with disabilities, consumer digital technology refers to those technologies that are developed for use by the general public. Increasingly, digital consumer technologies are building ever greater functionality in efforts to appeal to as wide a range of users as possible.

The use of DVAs as a therapeutic tool for autistic children is also well represented, for example Safi *et al.*'s recent study identifying their use as a tool to improve verbal and social interaction skills [5]. Other studies have examined ways to exploit DVA technology to develop social-communication skills for autistic children [6,7] and to maintain engagement in speech and language therapy during events such as the COVID pandemic [8].

The time efficiencies that voice-based interaction offers over keyboard-based text entry also suggests that this technology may emerge as an alternative to voice-guided virtual keyboard commonly used by users who are blind or visually impaired [9,10]. Furthermore, the interoperability of DVAs with home based IoT technologies offer the potential to make hitherto inaccessible devices such as touchscreens usable and within the sphere of control of people who have a visual impairment [11]. One such study examined the use of DVAs to support individuals who are blind and also identified a number of outstanding barriers to their use including synchronizing the presentation of both visual and non-visual cues and challenges in recognizing names and interpreting complex commands [12]. Further studies report on the development of bespoke DVA applications for those who are blind or have a visual impairment [13]. Similarly, McNally and colleagues [14] reported on the development of an educational DVA application supporting access for people with visual impairments to study texts, listening content and addressing basic queries. The literature draws attention to the fact that most of the currently available DVA technologies on the market were not designed with users with visual impairments in mind. They do however offer a platform for developers to continue developing and deploying specialist apps that offer functions that may be of benefit to users with specific needs including those with visual impairments [15].

The prospect of voice input and control of technology is of interest for anyone (including people with intellectual disabilities) who might have difficulties engaging with technology via keyboard or text entry or who might find reading text presented onscreen challenging. Feng *et al.* (2008) [16] highlights that young people with intellectual and learning challenges get less opportunity to use technology and as a result are often less likely to develop digital skills. Indeed, completing online tasks such as finding a recipe, booking a restaurant, or purchasing a concert ticket may be challenging for many people who have difficulty with remembering and understanding. Equally there those who may have difficulty spelling the words to enter a typical search bar [17].

A limited number of studies have examined the potential of DVAs for people with intellectual disabilities to access information and services from the web [18]. These explore the general potential of DVAs and the advantages that could be accrued through having access to internet-based information resources and to services [19]. Other studies have looked at DVAs as a tool to help those with intellectual disabilities complete productivity tasks, for example, helping with concentration and attention [20]. Bespoke development of DVAs to provide assistive functions include a system to support voice-based information retrieval for those living with intellectual disabilities and declining cognitive functions [21]. Despite an absence of published evidence suggesting benefits that can be accrued by people with dyslexia by using DVA's there are a number of web-based resources that suggest some practical ways in which these can serve as a functional support tool[2].

Supporting older people is a feature of several studies. For example, the development of a DVA app that uses the Amazon Alexa conversation agent to support information retrieval and control of smart televisions [22]. Amazon's Alexa has also been used to support the well-being of older adults [23] and as a cognitive assistant for those with dementia [24]. Other novel applications of the technology for older people include helping support their management of Type II Diabetes [25] and assisting them avoiding sedentarism through monitoring and prompting for regular physical activity [26]. Although some questions are raised across the various sources listed here as to the general accessibility of DVA technologies, a recent study did conclude that the devices most commonly found on the market can be used effectively by those with motor, linguistic and cognitive challenges given specific levels of residual cognitive and linguistic skills [27,28].

Finally, the examples of the use of DVA or IoT technologies for those managing their mental health are more limited across the literature. In their systematic review of voice-based technology interventions for addressing chronic and mental health conditions, [29] found that three of the studies they reviewed used DVA's to deliver interventions.

The aim of this study was to explore the assistive potential of a range of exemplar consumer digital technology, namely, digital voice assistants and internet of things. Additionally, the study aimed to reveal some of the incumbent risks that consumers with disabilities may need to be aware of and consider when making decisions about using such technologies to support them in their day to day lives.

2. Methodology

A qualitative study was conducted in the context of a field-trial of a range of digital consumer technologies which included a Digital Voice Assistant alongside voice-operated Internet of Things technologies including, smart bulbs, sockets, and a TV controller. This field-trial saw a total of ten participants with disabilities recruited to use and evaluate this technology in their homes for a six-week period from April till June 2022. Purposive sampling was used as a proactive and pragmatic approach to recruiting participants for the study. This involved identifying and contacting representative organizations of people with disabilities in Ireland that could support the process of identifying and recruiting participants matching the inclusion criteria.

Of those participating, six identified as male, three as female and one did not identify as either male or female. The average age of participants was 43.3 years, and the median age was 40 years. Seven reported that they were in employment, three of which were determined to be part-time or short-term employment. Of the remainder, two indicated that they were retired and one reported that they were working in the home. As part of their self-completed survey participants were asked to complete an exercise to indicate if they perceived themselves to have a functional limitation such that they are aware that it impacts or can impact their ability to perform certain tasks or participate in activities.

[2]Information about DVA's and dyslexia: https://www.voicesummit.ai/blog-old/how-voice-assistants-are-helping-people-with-dyslexia, and https://www.wired.com/story/end-of-dyslexia/

Participant Number	Mobility	Vision	Hearing	Self-Care	Communication	Interpersonal Skills	Work Skills/ Tolerance	Memory/ Thinking/ Cognition
1		✓						
2	✓			✓				
3	✓							
4			✓		✓	✓		
5		✓						✓
6	✓							
7	✓						✓	
8					✓		✓	
9	✓							
10	✓		✓	✓			✓	✓

Table 1. Participants Reported Activity Limitations

Table 1 presents a visual representation of this exercise and highlights that half of the participants indicating they had a limitation in mobility that hindered their activity participation. Three self-reported that they had a visual impairment while two participants separately considered that difficulties with hearing, communication, and their memory, thinking and cognition impacted their participation in activities. Finally, two participants indicated that their activity participation was limited by their self-care with one highlighting interpersonal skills as the issue.

Each participant engaged in pre- and post-trial, semi-structured interview. All interviews took place either in person or online using video-conferencing technology[3]. Both the pre and post interview data were analysed, thematically using the method outlined by Braun and Clarke [30].

3. Results

Thematic analysis yielded three major themes; 1) how technology changes the nature of the home, 2) the joy of exploring possibilities and 3) technology as a member of the family. Further depth of analysis revealed several sub-themes associated with these major themes. These uncovered participants' views and perceptions as to how people with disabilities made optimal use of the technology available, the processes by which they set-up and embedded technology use in the routines of the household and ways in which technology changed their lives and the functioning of their homes.

3.1. Theme 1: How technology changes the nature of the home

Participants in this study expressed opinions regarding the 'place' that DVA and IoT technology took within their home environments. They valued their homes and how important it was for them to take time to make clear and considered decisions about what technology to "bring into" (Jim[4]: Interview Round 2) their home. It was interesting to

[3]All online interviews were conducted using Microsoft Teams available to staff and students at University College Cork, Ireland.

[4]Pseudonyms used throughout to associate quotations provided with anonymized participant.

note that the reports were in the main, negative, and highlighted a dislike for technology that was large, took up a lot of space or was not to the person's aesthetic tastes.

"... I was very conscious of it and just thought it looked terrible and that for anyone visiting it was all you could see and was just embarrassing...." (Jim: Interview Round 2).

In their descriptions about using the DVA and IoT technologies, participants reports revealed a shared expectation that it should fit unobtrusively within a family home.

"... if you have a house full of wheelchairs and hoists, the last thing that you want is anything else taking up space" (Henry: Interview Round 2). These discussions revealed a broader series of the factors that impact the decision making that people with disabilities and older people have regarding decisions to purchase, install, use, and continue to use technology in their home.

3.2. Theme 2: The joy of exploring possibilities.

This theme reflects the journey described by participants as they got to know their technology, what it did and how best they could adapt to its presence in their homes. Participant's spoke of the nature of using voice as a means of accessing and using the technology.

"... it does feel strange at first, my initial reaction was to look for a button that I should press or something..." (Geri: Interview Round 1).

During the first round of interviews participants who had previous experience using a DVA in their homes described during the first round of interviews using their voice as; "very natural" but required "a bit of getting used to" (Henry: Interview Round 1).

The process of 'getting used to' using their voice to control their technology was echoed in the responses gathered during the second round of interviews after participants used the DVA in their homes during the trial period. Some participants described their initial impressions as "sort of embarrassing" (Joanne: Interview Round 2) and making them feel "very self-conscious" (Paul: Interview Round 2). Participants who were new to controlling technology using their voice described the process of learning to use it as "a matter of getting used to it" (Jackie: Interview Round 2) and a process that "didn't take too long" (Paul: Interview Round 2). Other participants were more specific stating that "a day or two and I was definitely used to it and think I knew what I had to do" (Jackie: Interview Round 2).

Participants highlighted the novelty of finding new functionalities in the technology and an enthusiasm for finding it themselves:

"... it sounds silly, but I was so chuffed with myself that I had figured out how to find and install the skills that I wanted to use, mainly because it was completely new and nobody ever had to tell me what to do, it was wonderful really..." (Sam: Interview Round 2).

3.3. Theme 3: Technology as a member of the family

A strong sub-theme that emerged, particularly through the second round of interviews was of the group communicating a shared belief that the technology presented benefits to others within the household and that people with disabilities or older people may not necessarily be the primary beneficiaries. One participant who lived alone and quite a distance from other family members described how his daughter felt the benefit of being able to speak to him via the DVA.

"... once her husband set it up that my Alexa could talk to her Alexa it was like a load lifted off her shoulders, she said being able to talk to each other just like that was like 'we're in the same room'.... That's what she got out of it" (Paul: Interviews Round 2).

Similarly, participants described that benefits they accrued were shared, particularly for other family members.

"... I do know that using Alexa for the lights is mainly for me being able to stay in bed at night and not have to call someone to switch them off, but it really works for my carer [name removed] who gets me up in the morning, she just says it and they go on..." (Sam: Interview Round 2).

Participants also reported that as the devices provided a functionality and utility to others within the household it made them less conscious of the ways in which they used the technology to address some of the functional limitations that they experience in their home.

The function of using the DVA to access information also highlighted the value of such technology for a whole family beyond just a member with functional limitations.

4. Discussion

The use of Digital Voice Assistants and other consumer Internet of Things technologies by people with disabilities is likely to increase over the forthcoming years as the interconnectedness and assistive functionality of such devices increases. Although the development of such technology is not aimed explicitly at meeting the needs of people with disabilities and older people, developers and manufacturers of consumer technologies understand that reflecting the diversity of users will increase their market share. Accommodating a greater diversity of users embedding a broader range of functionality, not just on devices such as Digital Voice Assistants but also smartphones may result in people with a disability and older people being less reliant on traditional, bespoke assistive technologies. Furthermore, this study showed also that there are hitherto unanticipated benefits that can be accrued by people with disabilities and older people simply by making the technology available to them and supporting them to use it. As developments in networked capacities increase people with disabilities and older people will look to extend their use of voice-controlled technology for convenience, entertainment, and for connecting with real and virtual communities. Developers and manufacturers of consumer technologies will see further dividends and increased market share by ensuring that their designs continue to recognize the value of accessibility and inclusion.

References

[1] Enable Ireland & Disability Federation of Ireland. Assistive Technology for People with Disabilites and Older People: A Discussion Paper; 2016. Available from: https://www.enableireland.ie/sites/default/files/publication/AT%20Paper%20final%20version.pdf.

[2] Boot FH, Owuor J, Dinsmore J, MacLachlan M. Access to assistive technology for people with intellectual disabilities: a systematic review to identify barriers and facilitators. Journal of Intellectual Dis-

ability Research. 2018;62(10):900-21. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1111/jir.12532.

[3] Copley J, Ziviani J. Barriers to the use of assistive technology for children with multiple disabilities. Occupational Therapy International. 2004;11(4):229-43. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1002/oti.213.

[4] Draffan E, James A, Cudd P, Bentley C. Barriers and Facilitators to Uptake of Assistive Technologies: Summary of a Literature Exploration. Studies in health technology and informatics. 2015;217:350-6. Available from: http://europepmc.org/abstract/MED/26294496.

[5] Safi MF, Sadrani BA, Mustafa A. Virtual voice assistant applications improved expressive verbal abilities and social interactions in children with autism spectrum disorder: a Single-Subject experimental study. International Journal of Developmental Disabilities. 2023;69(4):555-67. Available from: https://doi.org/10.1080/20473869.2021.1977596.

[6] Porayska-Pomsta K, Alcorn AM, Avramides K, Beale S, Bernardini S, Foster ME, et al. Blending Human and Artificial Intelligence to Support Autistic Children's Social Communication Skills. ACM Trans Comput-Hum Interact. 2018 dec;25(6). Available from: https://doi.org/10.1145/3271484.

[7] Tanaka H, Negoro H, Iwasaka H, Nakamura S. Embodied conversational agents for multimodal automated social skills training in people with autism spectrum disorders. PLOS ONE. 2017 08;12(8):1-15. Available from: https://doi.org/10.1371/journal.pone.0182151.

[8] Kulkarni P, Duffy O, Synnott J, Kernohan WG, McNaney R. Speech and Language Practitioners' Experiences of Commercially Available Voice-Assisted Technology: Web-Based Survey Study. JMIR Rehabil Assist Technol. 2022 Jan;9(1):e29249. Available from: https://rehab.jmir.org/2022/1/e29249.

[9] Bai YW, Hsu WC, Chan CC. Design and implementation of a four-quadrant and voice interaction user interface of a smartphone for the visually impaired users. In: 2016 IEEE 6th International Conference on Consumer Electronics - Berlin (ICCE-Berlin); 2016. p. 190-2.

[10] Bouteraa Y. Design and Development of a Wearable Assistive Device Integrating a Fuzzy Decision Support System for Blind and Visually Impaired People. Micromachines. 2021 Sep;12(9):1082. Available from: http://dx.doi.org/10.3390/mi12091082.

[11] Vtyurina A, Fourney A, Morris MR, Findlater L, White RW. Bridging Screen Readers and Voice Assistants for Enhanced Eyes-Free Web Search. In: The World Wide Web Conference. WWW '19. New York, NY, USA: Association for Computing Machinery; 2019. p. 3590-4. Available from: https://doi.org/10.1145/3308558.3314136.

[12] Abdolrahmani A, Howes Gupta M, Vader ML, Kuber R, Branham S. Towards More Transactional Voice Assistants: Investigating the Potential for a Multimodal Voice-Activated Indoor Navigation Assistant for Blind and Sighted Travelers. In: Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems. CHI '21. New York, NY, USA: Association for Computing Machinery; 2021. Available from: https://doi.org/10.1145/3411764.3445638.

[13] Marvin E. Digital Assistant for the Visually Impaired. In: 2020 International Conference on Artificial Intelligence in Information and Communication (ICAIIC); 2020. p. 723-8.

[14] McNally B, Mauriello ML, Guha ML, Druin A. Gains from Participatory Design Team Membership as Perceived by Child Alumni and Their Parents. In: Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems. CHI '17. New York, NY, USA: Association for Computing Machinery; 2017. p. 5730-41. Available from: https://doi.org/10.1145/3025453.3025622.

[15] Weeratunga AM, Jayawardana SAU, Hasindu PMAK, Prashan WPM, Thelijjagoda S. Project Nethra - an intelligent assistant for the visually disabled to interact with internet services. In: 2015 IEEE 10th International Conference on Industrial and Information Systems (ICIIS); 2015. p. 55-9.

[16] Feng J, Lazar J, Kumin L, Ozok A. Computer Usage by Young Individuals with down Syndrome: An Exploratory Study. In: Proceedings of the 10th International ACM SIGACCESS Conference on Computers and Accessibility. Assets '08. New York, NY, USA: Association for Computing Machinery; 2008. p. 35-42. Available from: https://doi.org/10.1145/1414471.1414480.

[17] Lussier-Desrochers D, Normand CL, Romero-Torres A, Lachapelle Y, Godin-Tremblay V, Dupont ME, et al. Bridging the digital divide for people with intellectual disability. Cyberpsychology: Journal of Psychosocial Research on Cyberspace. 2017 May;11(1):Article 1. Available from: https://cyberpsychology.eu/article/view/6738.

[18] Balasuriya SS, Sitbon L, Bayor AA, Hoogstrate M, Brereton M. Use of Voice Activated Interfaces by People with Intellectual Disability. In: Proceedings of the 30th Australian Conference on Computer-

Human Interaction. OzCHI '18. New York, NY, USA: Association for Computing Machinery; 2018. p. 102-12. Available from: https://doi.org/10.1145/3292147.3292161.

[19] Chadwick D, Wesson C, Fullwood C. Internet Access by People with Intellectual Disabilities: Inequalities and Opportunities. Future Internet. 2013;5(3):376-97. Available from: https://www.mdpi.com/1999-5903/5/3/376.

[20] Mechling LC, Gast DL, Seid NH. Evaluation of a Personal Digital Assistant as a Self-Prompting Device for Increasing Multi-Step Task Completion by Students with Moderate Intellectual Disabilities. Education and training in autism and developmental disabilities. 2010;45:422-39.

[21] Baldauf M, Bösch R, Frei C, Hautle F, Jenny M. Exploring Requirements and Opportunities of Conversational User Interfaces for the Cognitively Impaired. In: Proceedings of the 20th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct. MobileHCI '18. New York, NY, USA: Association for Computing Machinery; 2018. p. 119-26. Available from: https://doi.org/10.1145/3236112.3236128.

[22] Meliones A, Maidonis S. DALÍ: A Digital Assistant for the Elderly and Visually Impaired Using Alexa Speech Interaction and TV Display. In: Proceedings of the 13th ACM International Conference on PErvasive Technologies Related to Assistive Environments. PETRA '20. New York, NY, USA: Association for Computing Machinery; 2020. Available from: https://doi.org/10.1145/3389189.3397972.

[23] Duque M, Pink S, Strengers Y, Martin R, Nicholls L. Automation, wellbeing and Digital Voice Assistants: Older people and Google devices. Convergence. 2021;27(5):1189-206. Available from: https://doi.org/10.1177/13548565211038537.

[24] Wolters MK, Kelly F, Kilgour J. Designing a spoken dialogue interface to an intelligent cognitive assistant for people with dementia. Health Informatics Journal. 2016;22(4):854-66. PMID: 26276794. Available from: https://doi.org/10.1177/1460458215593329.

[25] Balsa J, Félix I, Cláudio AP, Carmo MB, Silva ICe, Guerreiro A, et al. Usability of an Intelligent Virtual Assistant for Promoting Behavior Change and Self-Care in Older People with Type 2 Diabetes. Journal of Medical Systems. 2020 Jun;44(7):130. Available from: https://doi.org/10.1007/s10916-020-01583-w.

[26] Valera Román A, Pato Martínez D, Lozano Murciego A, Jiménez-Bravo DM, de Paz JF. Voice Assistant Application for Avoiding Sedentarism in Elderly People Based on IoT Technologies. Electronics. 2021;10(8). Available from: https://www.mdpi.com/2079-9292/10/8/980.

[27] Masina F, Orso V, Pluchino P, Dainese G, Volpato S, Nelini C, et al. Investigating the Accessibility of Voice Assistants With Impaired Users: Mixed Methods Study. J Med Internet Res. 2020 Sep;22(9):e18431. Available from: http://www.jmir.org/2020/9/e18431/.

[28] Brewer RN, Findlater L, Kaye JJ, Lasecki W, Munteanu C, Weber A. Accessible Voice Interfaces. In: Companion of the 2018 ACM Conference on Computer Supported Cooperative Work and Social Computing. CSCW '18. New York, NY, USA: Association for Computing Machinery; 2018. p. 441-6. Available from: https://doi.org/10.1145/3272973.3273006.

[29] Bérubé C, Schachner T, Keller R, Fleisch E, v Wangenheim F, Barata F, et al. Voice-Based Conversational Agents for the Prevention and Management of Chronic and Mental Health Conditions: Systematic Literature Review. J Med Internet Res. 2021 Mar;23(3):e25933. Available from: https://www.jmir.org/2021/3/e25933.

[30] Braun V, Clarke V. Using thematic analysis in psychology. Qualitative Research in Psychology. 2006;3(2):77-101. Available from: https://doi.org/10.1191/1478088706qp063oa.

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HRI and Personality Perception: Comparison of the Personality Evaluation of a Teleoperated Humanoid Robot and Human Interlocutor

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Abstract. This paper deals with the personality perception of a humanoid robot when talking to it in a natural manner, using the wizard of Oz. An experiment involving 20 subjects was performed, to compare two heteroevaluation characteristics: identity perception of human vs. humanoid, and identity perception differences when interacting with a human directly or with the same human through the robot mediation. The experiment was organized in three interactions: with a woman, with a man, and with a humanoid robot. The evaluation uses the OCEAN inventory. The results show that the subjects create for the teleoperated robot an identity of its own, which differs from the one attributed to the teleoperator. The robot was generally perceived as having less interest in art, lacking more imagination or ingenuity, being less open-minded than the human controlling it. The perception of emotional stability is greater: the absence of the human envelope allows a person to appear more stable. We identified two statistical groups in the robot evaluation, depending on the consideration of the robotic technology by the subjects: their perception of the robot conscientiousness, extroversion and agreeableness varies according to the subjects, unlike the personality of the teleoperator.

Keywords. HRI, humanoid robot, personality evaluation, wizard-of-oz

1. Introduction

The humanoid robot was defined as a social actor: an artificially intelligent system, autonomous or semi-autonomous (if teleoperated), with a corporeality and able to interact. It makes human feel it has empathy for them [1]Personality is the combination of characteristics or qualities that form an individual's distinctive character. It is influenced by genetic and psychosocial factors. By definition, a machine does not have a personality other than programmed, but human beings can give to humanoid personality traits or emotions, without realizing it and beyond what they observe from the machine abilities or behavior [2]. When dealing with human-robot social interactions, the use of a teleoperated robot allows to realized a natural behavior. Two sides of the teleoperation must be

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pointed out: the interlocutor's, who is facing the humanoid and interacting with it while not seeing the operator, and the operator's, who is acting through the robot and has at all time full awareness of its semi-autonomous characteristics. Straub *et al*. [3] showed that human interlocutors tend to give an identity specific to the robot and independent from the personality of the operator. Defining robots as actors of the social environment increases the feeling of their having a personality [4]. They appear as socially capable, and may be considered as persons. Artificial emotions mechanisms can be created and guide social interaction up to intensification and solidification of the emotive links with interacting human beings. In order to communicate a sufficient degree in the expression of emotions, it is possible to design and use familiar expressions based on classical metaphors [5]. From the operator's point of view, perceiving the humanoid robot as having an independent personality allows dissociating from the experience lived by their puppets [6]. The cognitive impact of the long term use of robots in society is unknown [7]. The studies are short, they have different methodologies and a limited number of subjects, most of them being familiar with the robots. It was observed that using a humanoid as a medium facilitates interactions with human beings, which is promising in terms of repairing social or psychoaffective deficiency, particularly when establishing an interaction is difficult [8,9].

In this study, we focused on the personality attributed to a teleoperated robot to evaluate the human capability to attribute an identity to a humanoid. We focus on a) the study of the differences in heteroassessments between the personality of the operator, either interacting directly with the subjects or interacting with the robot teleoperation; b) the study of the different linguistic and body codes used to address the humanoid. Two hypotheses were made: 1) The subject anthropomorphizes the robot, creating a specific personality for it, that differs from the estimated personality of the operator. 2) The personality given to the robot varies among subjects, whereas the evaluation of the human personalities are common to all subjects. Section 2 presents the experimental framework, section 3 presents the technical content of the experiment. Section 4 exposes the qualitative results, section 5 the quantitative results and section 6 concludes the article.

2. Experimental framework

20 adults from 30 to 50 years old (average 41), 10 males, 10 females, participated in this study, answering a public call for participation. Before starting the experiment, they all signed an informed consent document, describing the experiment and the data registered for the study. The subjects came from different professional areas: engineers, teachers, human resources, artisans, architects, etc. They have no particular knowledge of the robotic technology.Three stages were realized:

1. Before experiment: All subjects together. Session dedicated to explaining the context and the experiment, introducing personality evaluation and practicing the personality evaluation test, signature of the informed consent;
2. Experiment: one per one subject.
   (a) Discussion with a woman (15mn), evaluation test;
   (b) Discussion with a man (15mn), evaluation test;
   (c) Discussion with the robot (15mn), evaluation test.

3. After experiment: one per one subject. Explanation of the used technology, demonstration of the operator, free observations.

A staff member managed the timing of the interactions: led the subjects and interlocutors in and out the room, give and take a pad with the evaluation test for the subject to fill, made sure the subjects could not talk to each other.Each subject stayed in one room for the complete duration experiment. The robot was a PEPPER humanoid robot (Softbank Robotics Europe). it is 1.40m high, equipped with 17 motors and omnidirectional wheels. The used sensors are the two cameras, the microphones, the loudspeakers and the encoders. The operator was equipped with a motion capture xSens MVM wireless. The wifi transmission of data between the robot and the operator was a) the motion and the filtered voice of the operator, transmitted to the actuators and the loudspeakers of the robot; b) the microphones and the 2 cameras data are sent to the operator's earphones and visual headset. The software for motion imitation is based on kinematics tasks prioritization described in [10]. The total transmission time is less than a half a second: the interlocutor waited less than a second to obtain an answer from the robot when a question was asked.

3. Experiment setting and evaluation

3.1. Registered data and heteroevaluation

The group of data per subject can be summarize as follows: a) Audio recordings to study linguistic codes during interviews and free observations at the end of the experiment; b) Video recordings to study postures and motions when interacting with human beings and with the robot; c) Answers to the three inventories for the personality heteroevaluations. We used the model OCEAN [11], which is a French equivalent of the Big Five Inventory (BFI)):**O**penness: having appreciation of art, emotion, adventure, uncommon ideas, curiosity and imagination; **C**onscientiousness: having moral consciousness, self-discipline, respect of obligations, organization rather than spontaneity, responsibility and an interest in achievement; **E**xtroversion: being outgoing, talkative, sociable, enjoying social situations, bringing positive energy and emotions, tendency to look for stimulation and presence of others; **A**greeableness: being affable, tolerant, sensitive, trusting, kind, cooperative and warm; **N**euroticism: being anxious, irritable, temperamental and moody, feeling vulnerable.

3.2. Discussion topics

The discussions topics were grouped into two main categories: a) Knowledge of the participant in robotics and technology (meeting with a robot, opinion on the generalization of robots in our society, place of the humanoid robot in our daily life, personal questioning, etc.), attraction for new technologies (connected objects, what they use at home, etc.); b) Classic conversation topic, "trivialities": profession, association, hobbies, interests, news, first participation in a study, etc. Both the woman and man interlocutors were trained in simulated situations beforehand to facilitate the exchange and avoid moments of silence: Encourage open questions; Address the subjects directly (remember and use their name); Focus the discussion on the feelings and memories of the subject; Rephrase, paraphrase the subjects' formulations; Discuss common areas of interest; Keep eye contact, nod head, move torso and arms; Show empathy towards the subjects and imitate their postures to strengthen the relationship. The woman interlocutor also had the instruction to behave the same way when talking directly to the subjects and talking to them with the robot teleoperation, and she was also trained in that way before the experiment.

4. Results: qualitative observations

Qualitative observations were performed from the video recordings of the whole experiment (entry, interactions (x3), technology revelation, exit and free exchange).

4.1. Linguistic codes

We highlight the appearance of linguistic codes demonstrating the perception of the robot as having an identity. We were particularly interested in the following points: a) Familiarity (tutelage) and address as *vous* (French familiar/polite formulation); b) Gender differentiation; c) Sense of belonging attributed to the robot; d) Personification of the robot when talking to it (emotion, personality traits, etc.); e) Questions asked directly to the teleoperator. Except from the two youngest subjects (30 years old), all the subjects addressed as *vous* the two human interlocutors. Talking to the robot: 36% of the subjects addressed as *vous*, showing their respect for the humanoid robot; 60% of them admitted being favorable to robotics and new technology. 36% of the subjects used tutelage with the robot, with three distinct attitudes: a) the way of talking was adapted to a child; b) The robot was considered as a confident; c) familiarity to talking to AI: all the subjects with SIRI or similar systems at home used familiarity with the robot. 28% of the subjects wondered about the choice of familiarity/address: they all initially familiarized with the robot before realizing and addressing it, alternating between the two or even asking the robot for its opinion (e.g. choice of familiarity if the robot refers to it in return). 75% of these subjects admitted during the interviews being skeptical with respect to new technology. 36% of the subjects adopted a tone and diction specific to a conversation with a child (with familiarity or address). More than 35% of the subjects made a comment to the robot on its face, about details that disturbed them: the absence of facial expressions or gaze, and the presence of the red laser sensor in the left eyes. 35% made a comment on the fluidity of the interaction with the robot.60% of the subjects made remarks to the robot reflecting its personification, through attribution of thoughts, emotions or hobbies. As example citations: "I totally trust you, Pepper", "Do you play sports?", "Aren't you unhappy if you are left alone?", "I'm fine and you ?", "What do you think of human beings?", "Are you curious about the results of the study?", "You are the first person I meet who is a robot", "Are you happy to meet me?", etc.

4.2. Behaviors and interaction content

40% of the participants smiled widely at Pepper during the complete interaction. Dealing with a human interlocutor, 40% of the subjects' postures were sitting back, legs crossed and arms crossed, and 40% were sitting straight, legs crossed and arms on the table. Dealing with the robot, all subjects leaned forward and 60% kept their arms on the table, showing an intense concentration and their presence in the interaction. We also observed that 36% of the subjects frequently touched their lower face, crossed and uncrossed their arms or anchor their feet in the ground. Their face expression showed either an intense concentration or an attitude of defense. Three profiles were identified from their sayings: 36% have an open profile to generalization of the robots and new technologies; 29% have a close or skeptical profile to the current and future technology; 35% have a neutral profile and little knowledge/interest about current technology. We observed a phenomenon during the interactions with the robot that was not present in any of the interactions with human beings: at some point, all the subjects seemed to go through an euphoric period, during which we could see them smile, and during which they said personal things to the robotthey did not share with the human beings. Their speech got inappropriate for social conventional situations, and their behaviors made them look like disconnected. We observed a loss of coherence (some answers where not connected to the previous talking) and a loss of vigilance (stories they would not say to unknown human beings). This situation may be related to the fact that the robot acts like a mirror, it expresses emotions or reflects a reaction to the interlocutor speech with its body, but has no gaze nor facial expression. It is also free from chemical (hormonal) communication.

4.3. Free observations

None of the subjects thought about the woman interlocutor during the interaction with the robot, but admitted this situation seemed “evident” when they discovered she was the operator of the robot. They also admitted that seeing the man interlocutor operating the robot would have been acceptable too. The general impression was positive: the experience was qualified as “funny”, “surprising”, “interesting”. Three subjects admitted having been “troubled”. All subjects felt comfortable, and described Pepper as “cute”, “sympathetic” and “childish”. We observed during the experiment the desire to see some abilities that were not present.The subjects were all questioned about the observed loss of vigilance, but did not seem to have recollection of it or of what they had told the robot.

5. Quantitative results

5.1. Heteroevaluations: human beings vs. robot

This section analyzes the OCEAN inventories filled by the subjects. Each question found at least two extreme answers. For some questions, the extreme answers reached 60% of the results. Only one subject never used an extreme answer. The average scores obtained for each dimensions of the OCEAN inventory, for the woman, the man and the robot interlocutor, are reported in Fig. 1 left using a radar representation. The two human interlocutors have similar results for the (O), (C), (A) and (N) dimensions; the woman interlocutor presents a consequent lower score for (E) than the man interlocutor. The robot shows quite similar results than the human interlocutors in terms of (C) and (A). Its score for (E) is similar to the man interlocutor. The robot scores for (O) and (N) were consequently lower than the ones of the humans. To determine whether the differences between the scores obtained for each of the three interlocutors are significant, we performed an analysis of variance (ANOVA) with one factor: the interlocutor, and three levels: the woman, the man and the robot. Figure 2 illustrates the obtained frequency

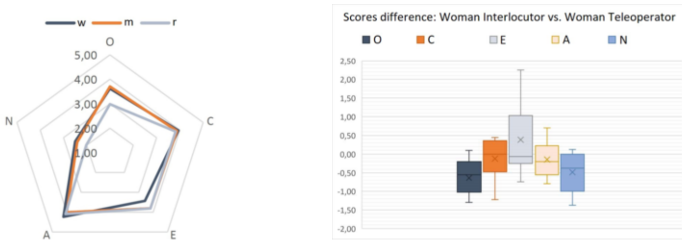

Figure 1. Left: Radar diagram of OCEAN average scores for the woman (w, dark blue), the man (m, orange) and robot (r, light grey) interlocutor. Right: Comparison of the OCEAN scores obtained by the woman as human interlocutor or as robot.

distribution of the scores. A first observation is that the human beings have a Gaussian distribution of the variance, whereas the robot results show two peaks of distributions, except for the dimensions (O) and (N). The stochastic hypotheses formulated to create

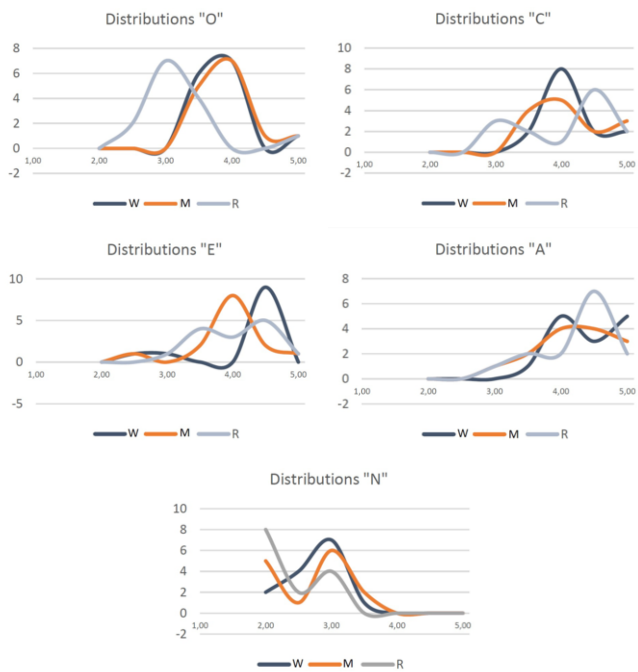

Figure 2. Distributions (in frequency) of the scores of the Woman (W), the Man (M) and the Robot (R).

a ANOVA are H1: the samples are from a normal (Gaussian) population; H2: The variances in each subpopulation are identical: homoscedasticity. In theory, both hypotheses should be checked to perform a statistical analysis of the results. In practice, ANOVA presents a good robustness as long as the subpopulations show similar forms of distribution. This situation is met for the dimension (O), ambiguous for the dimension (N), and not met for the dimensions (C), (E) and (A). The calculation of the *p*-value for each dimension confirms this situation : $p = 3.39E - 04 < 0.05$ for the dimension (O): the difference is significant, the interlocutor has an influence in the observed results. For the (N) dimension, $p = 7.78E - 02 > 0.05$. The p-value is close to the threshold (0.05) but still too important to point significant difference. For the (C), (E) and (A) dimensions, $p > 0.25$ confirms the previous observations. Still, the probability that the difference observed graphically is due to chance remains low. In terms of statistical analysis, finding two peaks in a synthesis usually points out that two populations were studied in the same folder. We have therefore further analyzed the (C), (E) and (A) data in order to locate the source of the non normal distribution of the robot data, considering at first hypothesis that the size of the population was sufficient. Crossing the heteroevaluation answers with the characteristics of the subjects, we located two populations, depending of the profile of the subject: a) Subjects with a profile open to the generalization of robots and new technologies assign higher (O), (E) and (A) scores; b) Subjects with a reluctance or skepticism about the technology assigned higher (C) scores and lower (N) scores. It looked like the subjects open to the generalization of robots tend to personify more the robot, giving it distinct characteristics such as extroversion, sensitivity or openness to others. On the contrary, those who were more skeptical of the technology will attribute to the robot more mechanical characteristics, such as conscientiousness and emotional stability, or even a lack of emotion. For the (C), (E) and (A) dimensions, two distinct groups of answers were identified, whereas the (O) and (N) answers were more diffuse and seemed to depend on a degree of acceptance or refusal of the robotic technology. In addition, the study of the scores distribution among subjects showed that women gave higher scores in (E), (C) and (A) dimensions, and older subjects gave higher scores for the (C) dimension.

5.2. heteroevaluations: woman interlocutor vs. woman teleoperator

Figure 1 right shows the difference in scoring for the woman and the robot interlocutors. A positive difference for one dimension means that the robot received a higher score than that of its human operator. The diagram leads to the following observations: a) The robot interaction generated a feeling less open and less prone to neuroticism than the human interaction; b) The robot seemed more extroverted than the human interlocutor; c) The conscientiousness and the agreeableness of the robot do not differ from those of the human interlocutor. A bilateral test of Student was performed (ANOVA 1 factor, 2 levels), showing a significant difference in (O) and (N) dimensions, respectively $p_O = 3.03E - 03 < 0.05$ and $p_N = 2.5E - 02 < 0.05$. We observed that these two scores were lower for the robot than for the human interlocutor, illustrating the perception of a greater emotional stability for the robot. The dimensions (C), (E) and (A) did not show significant differences for the same reasons as in the previous section.

6. Conclusion

This study analyzed the personality heteroevaluation of a humanoid robot with natural social behavior, using teleoperation. We compared two aspects of the robot heteroevaluation: a) robot interaction with respect to similar interactions with human interlocutors; b) human heteroevaluation as human or as robot interlocutor. All the subjects felt comfortable and benevolent towards the humanoid.No subject suspected a human operator controlling the robot behavior during the experiment, even though they had talked to the human operator in a similar manner 25 minutes before. The robot was perceived as less open and more emotionally stable. We can thus *partially* validate hypothesis 1: The subjects anthropomorphized the teleoperated robot, creating for it an identity of its own, which differs from the one attributed to the human being. There is indeed creation of an identity specific to the robot different from that attributed to the teleoperator. However, the term *anthropomorphization* may not be appropriate as the differences observed came from the technological nature of the robot, and not from an emotional sensitivity. The robot was generally perceived as having little interest in art, lacking imagination or ingenuity, being less open-minded than the human controlling it. We can propose another conclusion from the results: the perception of emotional stability is greater for the teleoperator in a robotic form. The absence of the human envelope allows a person to appear more stable. We identified two statistical groups in the robot heteroevaluation, depending on the consideration of the robotic technology by the subjects: although they all agreed in the representation of the (O) dimension, their perceptions in the (N) dimension was fuzzier (degree in acceptance of the robot) and their perception of the (C), (E) and (A) dimensions were separated radically. These results allow us to validate the second hypothesis: The personality attributed to the teleoperated robot varies according to the subjects, unlike the personality of the teleoperator. This variation is mainly due to the acceptance or refusal of the robotic technology. These observations allow us to highlight the power of the imagination in humans and the subjectivity of observation: the robot will induce in the observer a general positive or negative impression which depends on his or her own opinion on robotics and the technology.

References

[1] Dautenhahn K. Robots as social actors: AURORA and autism. In: Cognitive Technology Conf; 1999. .

[2] Edwards C, Edwards A, Stoll B, Lin X, Massey N. Evaluations of an AI instructor's voice: Social Identity Theory in human-robot interactions. Computers in Human Behavior. 2019;90:357-62.

[3] Straub I, Nishio S, Ishiguro H. Incorporated identity in interaction with a teleoperated android robot: A case study. In: Int Symp in Robot and Human Interactive Communication; 2010. p. 119-24.

[4] Duffy B. Anthropomorphism and the social robot. Robotics and Autonomous Systems. 2003;42(3):177-90. Socially Interactive Robots. Available from: https://www.sciencedirect.com/science/article/pii/S0921889002003743.

[5] Izui T, Milleville I, Sakka S, Venture G. Expressing emotions using gait of humanoid robot. In: IEEE Int Symp on Robot and Human Interactive Communication (RO-MAN); 2015. .

[6] Rea D, Young J. It's All in Your Head: Using Priming to Shape an Operator's Perceptions and Behavior during Teleoperation. In: ACM/IEEE Int Conf on Human-Robot Interaction; 2018. p. 32-40.

[7] Robert L, Alahmad R, Esterwood C, Kim S, You S, Zhang Q. A Review of Personality in Human–Robot Interactions. Available at SSRN: https://ssrncom/abstract=3528496 or http://dxdoiorg/102139/ssrn3528496. 2020.

[8] Johanson D, Ahn H, Broadbent E. Improving Interactions with Healthcare Robots: A Review of Communication Behaviours in Social and Healthcare Contexts. Int J of Social Robotics. 2020.

[9] Sakka S, Gaboriau R. A Robotic Puppet Master Application to ASD Therapeutic Support. Int J of Mechanical, Aerospace, Industrial and Mechatronic Engineering. 2017;11(8):1502-10.

[10] Sakka S, Penna Poubel L, Cehajic D. Tasks prioritization for whole-body realtime imitation of human motion by humanoid robots. In: Digital Intelligence Int Conf; 2014. .

[11] Lignier B, Petot J, Plaisant O, Zebdi R. Validation du Big Five Inventory français (BFI-Fr) dans un contexte d'hétéro-évaluation. Annales médico-psychologiques. 2015;4919(6):415-519. Available from: http://www.sciencedirect.com/science/article/pii/S0003-4487(15)00234-6.

Assistive Technology: Shaping a Sustainable and Inclusive World
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Digital Assistive Technology: The Online Assistance for a Peaceful Driving in Automated and Connected Vehicles

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Abstract. In line with the progressive development of digital technologies, this theoretical article is about the conception of a digital twin - based assistant to increase the serenity of the journey of the occupants of a connected car, automated or not. Its main functions are (i) to manage the Human (driver and/or passenger) - Machine (vehicle) Interaction, (ii) to inform the occupants and support decision-making by avoiding stressful situations. This is done by appropriate prevention and remediation. We advocate that the virtual assistant functions for being empathetic can be done by taking the user's point of view. Thanks to the knowledge about tasks, practices, needs and constraints, we describe how car-user's individual features can be used to get her digital twin description. Based on ontologies, this features model, providing assistance is then to simulate online the next steps of the task realization, informing about conditions, prerequisites, post-requites and subtasks to be fulfilled. Expected effects of this cognitive technology dedicated to personalized assistance are a decrease in stress, in frequency of incident and accident situations, according to a monitoring, as complete as possible, of the car-driver's conditions and situations dedicated to a serene driving.

Keywords. Digital Assistant, User Needs, Automotive User Interface, Ontologies, Digital Twin

1. Introduction

Digital technologies integrate many functionalities with the aim of appealing to the widest possible range of users. To do so, their design is to be personalized and adapted to daily specific uses. Among digital technologies dedicated to driving tasks, there are assistive technologies [1]. These assistive technologies introduce a new interaction paradigm into the mainstream, they make possible a different communication and cooperate with information systems [2,3]. They are assistants of conversational type (Amazon Alexa, Google Assistant or Apple Siri) which can invite themselves into the interiors of our

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vehicles via Application Programming Interfaces (API) such as Android Auto or Apple Car Play. Some automakers have recently developed their own digital assistants such as Mercedes, Ford, Fiat Chrysler or for example BMW with the BMW Intelligent Personal Assistant which responds to the command ”Hey BMW”.

These virtual agents can help users accomplishing their daily trip tasks [4,5]. They could be designed to match users' requirements and support accessibility for vulnerable users, such as people with disabilities and older adults with cognitive impairments, while allowing them to be more independent [6,7]. This assistance is also intended to be deployed in autonomous cars with a dedicated interface for the interaction between the occupants (driver and/or passenger) and the car. It is supposed to facilitate the adaptation of the manual mode to the autonomous mode. This assistance can be of help for the task's completion by providing the right information in a timely manner: navigation advices, trip updates, vehicle status warnings, infotainment services, etc. [8]. For this, the virtual assistant must "put itself in the shoes of the occupants", taking their point of view, thanks to knowledge of their cognitive and emotional states [9,10], their personality [11] and the different facing situations and scenarios [3].

As intended benefits, Jeon and colleagues [12] demonstrated that, indeed, digital agents, by communicating in an appropriate and empathetic way, can reduce anger and perceived workload of drivers and then improve driving safety. The more activities a digital assistant can accomplish for users, the less it will distract them from their actual task (i.e., driving the car). Nevertheless, listening and speaking still adds cognitive distraction, which explains how an agent should provide clear messages that focus on the most important information. To not overwhelm users while they communicate with a digital assistant, it makes sense to break down information and explain next steps sequentially [3]. It is recommended that a virtual in-vehicle assistant proactively tells the user something that makes the user's life easier or that prevents the user from unpleasant situations. In addition, in some situations, "proactively addressing the user can even improve driving safety". For instance, if the user is not concentrating on the road and a critical traffic situation occurs ahead, the digital agent can warn the user to prevent a possible accident. Especially during long travels, an in-car assistant can help to keep the driver awake and attentive.

The research is therefore to run a digital twin assistant that is an empathetic and reassuring, which induce a serenity level while driving, improve driving comfort, reduce accidents, and improve traffic flow on the road. We present below the objectives and the method of the research.

2. Objectives

As part of interdisciplinary research, our work is about the design of an efficient virtual assistant for vehicles driving. Our proposals are that this digital assistant, with the figure of an avatar, might be, as a servant or a driving instructor, accessible and inclusive, a virtual figure that knows as much of possible about the driver(s) and other possible passenger(s) and about the car properties. The assistant is based on digital twins [13] i.e., the user having a digital profile stored in a cloud. This profile connects the car to the user and to his/her digital world with for example a digital safe with his dematerialized ID documents.

The concept of Companionship introduced by Strohmann et al. [5] matches the concept of digital twin. The virtual assistant must know about the human needs as well as about the context (car/road/traffic) of the tasks to be reached with the car, having the proper definition of the driving tasks (why and how the car is being used). It will model, simulate and anticipate concerns of the occupants of the vehicle, the progress and the anticipation of the stages of the ongoing task (Goal-to-Subgoals Task decomposition).

This real-time modelling simulation begins upstream of the journey. When the user is still at home, even before getting into the car, the agent can ensure, by having access to the shared agenda, that the task that requires the use of the vehicle is properly prepared: necessary checks, by giving the alert on the time of departure for example or by reminding the documents, objects or instruments that it is necessary to carry; anticipating the completion of sub-tasks. Actions such as reading, sending messages, emails, making calls, being able to rest when tired without interrupting the traffic/journey could be possible in automated vehicles with such assistants. It is an extension of assistance; it would behave like an escort or a helper who ensures that occupants needs are met during the car trip. Based also on the SOLID model [14,15], it is expected that the intelligent personalized agent can "read" the profile of the user and thus knows the reasons and motivations for travel. By doing so, it "knows" when to spread useful and essential information to the user based on needs. When dialoguing, the agent, endowed with empathy by taking the other's point of view, aims to reassure, explain, calm, or trigger help or intervention at the right time in order to lead users to their destination, safely and in the most serene way possible.

3. Method - Design

Based on the recommendations of Strohmann et al. [5] regarding the design and implementation of virtual in-vehicle assistants, the design of a proactive assistant should minimize as possible the driver's mental load, and through emotion recognition and empathy, improve the user's comfort and avoid unpleasant situations to ensure the safety and quality of user experience. Ontologies and assistance interface are its main components.

3.1. Ontologies

To design the assistant, we first examine behavioral (nature of the task and types of tasks), Cognitive and Conative (motivation/effort) and physiological (stress) variables. To get a specification of the interaction logic, the design method is built on a User eXperience (UX)-oriented design of a SMART cognitive technology system, based on the knowledge hierarchical graphs of expressions, intentions, objectives and tasks [16]. This hierarchy is modelled making ontologies in the form of a knowledge hierarchical trees. We list all the objects of the situation and then all the actions that can potentially be applied to these objects. Depending on the task or the scenario, the running assistant model browses the tree to instantiate the variables to optimally achieve the goals and sub-goals of the ongoing task.

3.2. The Assistant Model's Interface

Once the ontologies instantiated, from the assistant main window, the user-assistant interactions fall into three distinct components: (i) setting up the assistant, (ii) planning trips, and (iii) supervising the current trip, that are implemented according to driving temporalities and modalities. The supervision of the trip favours verbal interactions, ideally in natural language, so as not to divert the driver's attention from the road scene.

3.2.1. Assistant Setup

Without parameterization, the virtual agent provides minimal assistance for a default driver.

Parameterizing the assistant allows it to be associated with a pair (vehicle, authorized driver) in order to provide personalized and extended assistance (e.g., memorization of usage history, driving preferences, driver and vehicle specific constraints, etc.).

The parameterization is divided into five sections:

1. Association of the assistant with a vehicle. Once associated with a vehicle, the assistant can be aware of data specific to the vehicle, likely to influence the trip or its planning (e.g., fuel level requiring refuelling, deadline for technical inspection, mileage, occurrence of malfunction, etc.).

2. Association of the assistant with an authorized driver. Once associated with an authorized driver, the assistance becomes personalized: taking into account the specificities of the associated driver, which may modify the planning of the trip (e.g., night blindness, phobia of driving in bad weather, etc.) or its supervision (need to take frequent breaks to prevent health problems, etc.). The association also allows for the designation of a smartphone to send text messages informing of the imminence of departure in order to respect the constraints of the trip, notably the time constraints.

3. Creation/modification/deletion of an authorized driver. An authorized driver is likely to drive the vehicle on a recurring basis (i.e., regularly) in addition to the holder(s)/owner(s) of the vehicle. However, depending on the situation, the vehicle may be driven occasionally by a non-regular driver. A digital safe will allow the authorized driver to save a digital copy of his/her documents, including driver's license, ID card, car registration, insurance policy, etc. The information on the authorized driver can be used to specify the specificities of the driver, which can be used to adapt the interaction modalities (e.g., deafness, speech disorders, etc.) or the supervision of the trip (e.g., night blindness, urinary disorders, etc.) The creation of an authorized driver may allow the registration of biometric identification data (e.g., fingerprint, voice print, facial recognition, etc.).

4. Creation/modification/deletion of a regular passenger. A regular passenger can be a spouse, a child, a parent or a close friend. The advantage of creating a regular passenger is to take into account his/her specificities that may modify the planning (e.g., address and itinerary for pickup, etc.) and the organization of the trip (e.g., frequency of breaks due to health problems, etc.).

5. Personalization of the assistant. The personalization of the assistant will allow to set various parameters of interaction, such as:

    - pseudonym allowing to initiate a dialogue with the assistant (such as ”ok google”),
    - choice of a female or male voice among several possible ones,
    - level of assistance (e.g., novice, expert, etc.),
    - *etc.*

3.2.2. Trip Planning

The agenda is composed of three types of tasks,: (i) superordinate tasks defining the user’s activity (e.g., attend a concert), (ii) the driving subtasks associated with each superordinate task (e.g., pick up a passenger at the North Station, go to the concert venue, drive the passenger home, return home) and (iii) the tasks proactively proposed by the assistant when they are necessary for the smooth running of the superordinate task (e.g., filling up with gas, taking breaks during a long trip, checking tire pressure or doing an overhaul before a long highway trip, etc.)

The agenda allows the digital assistant to remind the user of the imminence of a trip (deadline management) and to supervise the proper progress of the superordinate task by integrating the driving sub-task(s) (precedence management). Trip planning can be done outside the vehicle, in a custom web service type calendar, on a personal computer, tablet or smartphone.

As the agenda is hosted in the cloud and permanently connected to third party web services informing it about the evolution of the driving context (e.g., state of the highway network, traffic flow, weather conditions, etc.), it must be able to rearrange the driving subtasks associated with the next superordinate task, in particular to be able to warn the driver of the moment of departure.

3.2.3. Supervision of the Current Trip

At end, the deadline logic is being implemented by (i) the web agenda, when a planned task becomes current, i.e., when the departure time necessary to respect the time constraints of the superordinate task (e.g., arriving before the beginning of a concert) is approaching and (ii) the in-vehicle assistant, to ensure the smooth running of the current task. According to the setting of the agenda, the driver and/or the passengers are notified by text or via a smartphone app of the imminent departure, early enough to allow them to prepare themselves; ”early enough” depends on each individual (driver and passengers), according to the individual specificities and reactivity known by the driving assistant, the individual specificities being explicitly filled in during its setting, and the reactivity being implicitly deduced from the history.

The assistant supervises the smooth running of the trip by verifying the respect of the conditions (e.g., having acquired the entrance tickets to the concert), and prerequisites (e.g., tickets with you, knowing where to park) induced by the elements forming the trip planning (e.g., the type of the superordinate task, carried passengers, etc.) Once the conditions and prerequisites of the trip are met, the assistant combines:

- the requirements induced by the type of the superordinate task (e.g., imperative respect of a schedule, need to find parking, etc.)

- the preferences and constraints of the driver or passengers (e.g., route preference, desired or required frequency of breaks, etc.)
- vehicle data (e.g., gas gauge may need to be filled, trunk condition may need to be emptied before shopping, presence or absence of a required baby seat, etc.)
- the context of the trip (e.g., traffic density, weather conditions, detours, etc.).

The driving subtasks must be dynamically adjusted according to the evolution of the driving context, in particular to respect the deadlines. For example, in case of a traffic jam on the pick-up path at a passenger's home, the assistant should be able to propose a pick-up at another location, (at a subway station that is easily accessible for the passenger and the driver, e.g., via the HERE Public Transit API), so as to respect the temporal constraints of the superordinate task.

When supervising the current driving task, the digital in-vehicle assistant checks in real time the remaining travel time and, if necessary, the respect of time constraints. When the driving context induces a risk of detrimental delay for the user (e.g., traffic density), the driving assistant should propose an alternative route to remedy this.

4. Conclusion

When the current task has been completed, the digital assistant must verify the post-requisites (e.g., don't forget the purchases made during the concert) which allows the users to come back home safely and serenely. Eventually, expected effects of this digital personalized assistance are a decrease in stress, in frequency of incident and accident situations, thanks to a better and complete monitoring of the driver's state (detection of reduced alertness) and through driving concentrated and calm.

The expected result of this research is the validation of our design propositions and therefore the deployment of this automatic assistance that we hope will be effective for the User eXperience.

References

[1] Kinsella B, Mutchler A. In-Car voice assistant consumer adoption report. Voicebot ai. 2020.

[2] Clark L, Pantidi N, Cooney O, Doyle P, Garaialde D, Edwards J, et al. What Makes a Good Conversation? Challenges in Designing Truly Conversational Agents. In: Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems; 2019-05-02. p. 1-12. Available from: http://arxiv.org/abs/1901.06525.

[3] Pearl C. Designing voice user interfaces: Principles of conversational experiences. O'Reilly Media, Inc.; 2016.

[4] Gnewuch U, Morana S, Maedche A. Towards Designing Cooperative and Social Conversational Agents for Customer Service. In: Proc. of the 38th International Conference on Information Systems (ICIS), Seoul, ROK, December 10-13, 2017. Research-in-Progress Papers. AIS eLibrary (AISeL); 2017. .

[5] Strohmann T, Siemon D, Robra-Bissantz S. Designing Virtual In-vehicle Assistants: Design Guidelines for Creating a Convincing User Experience. THCI. 2019:54-78. Available from: http://aisel.aisnet.org/thci/vol11/iss2/1/.

[6] Brinkley J, Daily SB, Gilbert JE. Implementing the ATLAS Self-Driving Vehicle Voice User Interface. The journal on technology and persons with disabilities. 2019;7:8.

[7] Pradhan A, Mehta K, Findlater L. Accessibility Came by Accident" Use of Voice-Controlled Intelligent Personal Assistants by People with Disabilities. In: Proceedings of the 2018 CHI Conference on human factors in computing systems; 2018. p. 1-13. Available from: https://dl.acm.org/doi/10.1145/3173574.3174033.

[8] Lo VEW, Green PA. Development and Evaluation of Automotive Speech Interfaces: Useful Information from the Human Factors and the Related Literature. International Journal of Vehicular Technology. 2013-03-07;2013:1-13. Available from: https://www.hindawi.com/journals/ijvt/2013/924170/.

[9] Large DR, Burnett G, Anyasodo B, Skrypchuk L. Assessing Cognitive Demand during Natural Language Interactions with a Digital Driving Assistant. In: Proceedings of the 8th International Conference on Automotive User Interfaces and Interactive Vehicular Applications. ACM; 2016-10-24. p. 67-74. Available from: https://dl.acm.org/doi/10.1145/3003715.3005408.

[10] Pape AA, Cornelsen S, Faeßler V, Ihme K, Oehl M, Drewitz U, et al. Empathic assistants - Methods and use cases in automated and non-automated driving. In: Bargende M, Reuss HC, Wagner A, editors. 20. Internationales Stuttgarter Symposium. Springer Fachmedien Wiesbaden; 2020. p. 435-49. Series Title: Proceedings. Available from: http://link.springer.com/10.1007/978-3-658-29943-9_34.

[11] Braun M, Mainz A, Chadowitz R, Pfleging B, Alt F. At Your Service: Designing Voice Assistant Personalities to Improve Automotive User Interfaces. In: Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems. ACM; 2019-05-02. p. 1-11. Available from: https://dl.acm.org/doi/10.1145/3290605.3300270.

[12] Jeon M, Walker BN, Gable TM. The effects of social interactions with in-vehicle agents on a driver's anger level, driving performance, situation awareness, and perceived workload. Applied Ergonomics. 2015-09;50:185-99. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0003687015000484.

[13] Tijus C, Bessaa H, Ruggieri F, Jouen F, Chang CY. Digital Twins within eXtended Reality experiences (DT -XRE). 2022 05.

[14] Uzan G. Besoin en informations des voyageurs dans les transports, le modèle SOLID. 2011.

[15] Uzan G, Wagstaff P. In: Pissaloux E, Velazquez R, editors. Solid: A Model to Analyse the Accessibility of Transport Systems for Visually Impaired People. Cham: Springer International Publishing; 2018. p. 353-73. Available from: https://doi.org/10.1007/978-3-319-54446-5_12.

[16] Tijus C, Poitrenaud S, Richard JF. Modélisation Sémantique de l'Utilisateur. In: European Grid Conference; 2005. p. 89-94.

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Accessible Consumer Electronics Are Essential to Closing the Gap in Assistive Technology Provision

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Abstract. According to the Global Report on Assistive Technology (2023) [1] more than 2.5 billion people require one or more assistive products – a number that is expected to grow to over 3.5 billion by 2050 due to the aging of our societies. Over the past decade, the design of products that empower people with a disability has shifted from specialized and dedicated products designed only for those with a disability to features and functions integrated into cost-effective consumer technologies for the benefit of all. The opportunity to expand the availability of such technologies is at risk of being ignored due to models of AT delivery that are founded in medical devices, and which have failed to reflect trends in our understanding of technology and the choices and preferences expressed by persons with a disability. This research suggests that such expansion offers significant benefits to people with a disability and better both economic and social return on investment for authorities.

Keywords. Assistive Technology, accessible technology, consumer technologies, provision, policy, funding

1. Introduction

Mobile technologies have become an integral part of modern societies and, for many people, have become the preferred means of access to employment, education, leisure, travel, and public services. The manufacturers of mobile technology devices, particularly phones and tablets, have increasingly made their products accessible to the broadest possible user base, building in a wide range of accessibility and assistive functionalities.

In 2021, the MWF commissioned a team to conduct an "Analysis of Funding and Provision Models for Mobile Technology for People with a Disability". The study focused on the social return on investment (SRoI) of mainstreaming consumer technology as AT, the Policy environment for AT provision, the user needs sections of standards and guidelines, the eligibility and approval process for public provision of consumer devices, variations in funding and provision due to the context of use, and gaps in current AT provision systems and how consumer products can fill the gaps.

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The study focused on six countries: the US, UK, Norway, Poland, Ireland, and Australia. The findings support the case that accessible consumer electronics are complementary to AT in Technology and Environmental Intervention (TEI) as described by Gitlow and Flecky (2019) [2] and enable people with disabilities beyond the currently limited functional purposes of AT provision, achieving "well-being" as defined in Sen's Capability Approach model [3]. This case challenges funding authorities to consider and provide accessible mobile and consumer technologies as assistive technologies (AT) or environmental interventions (EI) to support people with disabilities to live independently.

2. Methodology

The research undertaken sought to gather data from a range of sources to test and validate the findings. To achieve this, four approaches were combined:

- Initial engagement with subject matter experts.
- Desk research and analysis of source documents, to validate analysis compared to other research undertaken.
- Further engagement with subject matter experts to test assumptions and recommendations.

The documents identified in the desk research were subjected to initial review to review the framework for the provision of AT and associated models of funding associated. Semi-structured interviews were undertaken with stakeholders, including representatives of the AT industry, service providers, and persons with disabilities to understand their experience of accessing the funding models in each of the target countries, and any variations in funding and provision that could be identified by context, including health, education, social welfare (independent living) and workplace.

Having mapped out the funding models the research then considered the alignment between the technical features of mobile phones, tablets, and associated software as listed in GARI with international and national classifications and codes, including user requirements for communications devices. International standards were selected based on the extent of usage and application in both national and international markets and included EN 301 549, Section 508 Guidelines, ISO 9999 and the WHO GATE Priority APL list.

Having identified the parameters for funding of assistive technologies and establishing the extent to which the features of accessible mobile technologies matched the definitions of assistive technologies for the provision we were able to suggest some of the constraints and barriers to incorporating these devices within a framework for provision.

These findings were then reviewed through the lens of underlying trends that will impact the future provision of consumer digital technologies for people with a disability. The analysis of the data from the various sources led to recommendations on expanding the rules and criteria used for the provision of AT to include such devices into funding, and the outline of a potential social return on investment (SRoI).

3. Findings

3.1. There is value in mobile, portable, and consumer technologies in promoting access and inclusion of people with a disability, and this continues to evolve

Mobile technologies have become central to the experience of many. For example, during the Covid19 pandemic, consumer technologies, notably phones and tablets, were critical in allowing public health restrictions to be enforced. In addition, online learning, working from home, and social interaction and contact were all facilitated through such devices. Whilst this has presented challenges, it has been noted that such a "life through a screen" has some benefits to people with a disability that may have longer-lasting consequences.

Mobile technologies, notably smartphones and tablets, dominate the technology marketplace and increasingly offer the basis of digital assistive technology, bringing value for money and a low-cost diversity of applications. Most provide functions to support access, including text-to-speech, voice input, or word prediction. Many devices also offer additional functionality that replaces and disrupts purpose-built devices such as fall detection, AAC (alternative and augmented communication) and sound amplification.

Heller, Jorge and Guedj (2011) found that mobile telephony had opened a vast diversity of new opportunities for older people with different physical restrictions due to aging [6]. In addition, mobile technology allows ubiquitous communications and anytime access to services that they consider vital for older adults' security and autonomy. Other reports echoed such findings, including Harris (2010), who noted, "disabled people are excited by the potential benefits of using advanced technologies at home" [7]. However, they found that many devices may be abandoned early and lie unused. The cost of technologies can be prohibitive, so it is essential that people with a disability can find technology that addresses their needs, is fit for purpose, and is affordable.

G3ICT (2012) noted that wireless technologies provide easy and instantaneous access and that those with disabilities can use them in various ways to live independently and conduct daily activities [8]. The increasing provision of hands-free capability, screen reading and text-to-speech functionality, relay services, internet browsing, home automation, emergency response, and all the assistive features and services promote independent living for persons with disabilities. They note that in addition to enabling them to perform tasks such as paying bills, shopping, booking tickets, reading books, and working, mobile phones also impact the social fabric of the disability community.

The positive impact of accessible technologies appears to be broadly consistent across the spectrum of needs. Muer (2015) noted that: "Overall, information gathered through this study indicated that mobile technology appears to positively impact the quality of life of individuals with developmental or intellectual disabilities by increasing independence, self-determination, and community connectedness." [9]

In interviews undertaken it became clear that in many cases current funding models for assistive technology are not meeting the needs of people with disabilities. Even where funding mechanisms exist, barriers exist in processes. Both the technology distributed, and the procedures were perceived as out of date, often with a list of approved devices available that limit choice and excluded technology that could improve the independent living and quality of life at relatively low cost.

3.2. Current trends in AT design are having an impact on the demand for smartphones and consumer technologies

Technology pervades, and we can observe it impacting all aspects of our lives. In the past, many people with a disability required specialized and often expensive AT solutions. We now find that many of those functions and solutions are now features fully integrated into consumer devices.

Influential emerging technologies include speech Interfaces, Internet of Things (IoT) and Artificial Intelligence, Augmented Reality and wearable technology. Assistive technologies can, in various ways, be high-tech or low-tech, specialist devices or mainstream platforms. They may encompass human augmentation and inclusive design. However, underlying trends have been identified.

Emerging technologies are moving from providing specialist devices designed solely for those with a specific need to an increasing blend with mainstream technology that benefits all users. This reflects the increased implementation of universal design principles and technology's pervasive nature, which often demand access in challenging settings.

In addition, mainstream technologies increasingly embrace the redundancy of inputs, integrating gesture, sound, and vision, giving users greater flexibility to determine how they wish to engage with information and establish control. This further blurs the boundaries between assistive and mainstream technologies. But for people with a disability the interviews made clear that access to mainstream technologies greatly improved the quality of life.

3.3. Definitions of Assistive Technology, and the relationship to consumer technologies

Three categories of technology devices that have value for people with a disability are relevant to this research:

- Mainstream Consumer Technology: These technologies, such as digital television, are designed for the widest population and may include no specific features to facilitate their ease of use by a person with a disability.
- Accessible Technologies: includes products and systems that can be customised providing to ensure access to all services and content.
- Assistive Technologies: refers to products and systems that enhance learning, working, and daily living specifically to address the needs of persons with disabilities.

Definitions of assistive technology products can vary considerably depending on legacy and context, ranging from highly detailed descriptors such as the International Organization for Standardization (ISO) to formal definitions of AT devices and services. Most classifications have been driven by statute and policy to define and often limit the scope of what can be paid. Definitions may discriminate between assistive technology products and the services that support effective implementation and use of products.

These distinctions may have value as they differ by purpose and by the development and implementation process with implications for models of delivery. But, as assistive products may extend beyond any single domain, in practice, such distinctions may be artificial, as products move fluidly between such categories. Products initially described as assistive have transitioned into the mass market. For instance, captions are extensively used to view video in noisy environments, and voice control provides the basis of smart speakers and hands-free operation for much of the population. Understanding the extent to which assistive technology products pervade across categories is essential in reviewing funding models. Anyone using assistive technology products may bring a perspective based on personal experience and as we investigate consumer technologies as enabling technologies, the breadth of potential use must be considered across domains.

If we can successfully define assistive technology to includes consumer technologies, further challenges exist in relating the device to any specific domain. Such devices are pervasive with multiple functions. This seems contrary to traditional domain usage and may be challenging in making a simple case for inclusion. For many interviewed the definition of assistive technology was often too narrow, they recognized that a diverse range of devices and solutions enable those with disabilities to participate in different areas of life. The integration of assistive and accessible technologies was essential to ensure the best use of dedicated technologies and simultaneously to make the most from widely available applications for mobile phones.

3.4. Variations in funding models for assistive technology

The review of funding models suggests that different approaches have emerged and evolved. These can be summarized as Domain-Specific Funding, Direct payments, Public and private insurance schemes, Not-for-profit and charitable funding, Private funding, Refurbishment and reuse. As suggested earlier, barriers exist in the funding processes and regardless of the detail of a specific model of provision, there were limits placed upon individual choice and excluded technology that would improve the independent living of persons with disabilities. In interviews with stakeholders, it was clear that ensuring access to consumer technologies was important and there was widespread support for ensuring access to mainstream technologies for people with disabilities. Change is required in the process of buying and supplying AT devices, software, and equipment.

However, cost was not the only barrier to access to assistive and accessible technology, some of the most referenced barriers to accessing AT were the lack of awareness, training, support, and digital competencies. Such insight strongly supports the need for an ecosystem that builds capacity both within and beyond the community of persons with a disability. It was widely suggested that there is a significant potential impact through widening the scope of assistive devices to include consumer technologies.

Expanding the list of funded AT devices to include mainstream devices would positively impact and increase the quality of life for people with disabilities, including the elderly, for whom it would reduce loneliness.

3.5. Development of a standard set of SRoI metrics and qualifiers for AT would support the integration of any technology into provision

The potential impact of addressing the expansion of funding for consumer technologies for people with a disability can be considered through any social return on investment (SRoI). SRoI provides a sound basis for creating measures to evaluate the non-financial benefits of interventions or policy changes [15]. It allows researchers to consider the social and economic benefits that can provide new opportunities for participation and independent living for persons with disabilities. In considering this approach, we aimed to provide a set of factors that governments may consider when investing in purchasing or providing AT and mainstream technologies to support the independent living of persons with disabilities. The results from this work revealed six key themes. The social benefits of each theme were articulated in a list of questions to provide a clear and measurable standard on which authorities can draw to evaluate the existing AT provision systems and the SRoI of investing in new AT.

While these metrics are meant to provide a broad range of criteria for assessing the provision and impact of AT, they are not comprehensive and require further validation. The first set of metrics focuses on the social impact of providing effective AT to meet users' needs, and the economic and personal benefits. The second set of metrics focuses on evaluating provision to generate the greatest social benefit from the investment.

4. Discussion

As consumer devices become increasingly accessible, more users with disabilities are identifying accessible consumer electronics as an effective way to address their needs. The devices provide a range of accessible and assistive functions rather than only addressing one specific function. For many people with a disability, there is greater enjoyment in using mainstream products that avoid the stigma of using dedicated devices. Investigation of the funding models from domain-specific such as education or employment, direct payments, and private and public insurance schemes, to not-for-profit and charitable funding, private funding, and the use of refurbished and reused models found that mainstream mobile technologies can be a cost-effective way of providing people with disabilities with the technology they want and need. Presently, in many cases, people with disabilities and their families are self-funding these technologies.

As these technologies can provide people with disabilities with a capability set as defined by Sen [3], they offer an enhanced range of options and opportunities. To take advantage of this opportunity, our systems for AT provision need to evolve. Furthermore, we need to reconsider the concept of assistive technology to reflect the trend toward digital solutions. This requires a paradigm shift from a simple functional but blurred definition of assistive technology toward a renewed focus on the impact and purpose of provision upon the lives of people with disabilities. In the review, the most effective approach to meeting users' needs was based on those systems that provide direct funding. In these models, people with disabilities can decide what they need and want for the available money.

The greater value of accessible mobile devices that provide integrated text-to-speech, voice recognition, word prediction, and screen readers alongside other accessibility features lies in being the core for comprehensive and personalised solutions upon which an ecosystem of features and functions can be built. These include fall detection, AAC (alternative and augmented communication), sound amplification, and wayfinding. They offer additional value as the preferred platform of users with disabilities, which is likely to reduce technology abandonment and reach into the widest parts of lives to include social, leisure and entertainment functions. The experience of the pandemic suggests that such devices and functions are central to the emotional well-being of users as an effective means of responding to social isolation and exclusion.

Building on the conclusions of our research undertaken, we believe it is evident that accessible consumer electronics are complementary and expand AT in Technology and Environmental Intervention (TEI) as defined by the American Occupational Therapy Association in 2010 [2]. Their definition of TEI builds on the understanding that environmental interventions (EI) refer to modifications and adaptations of the environment in combination with AT to best serve and enable the person with a disability to live independently. With the emergence of the Internet of Things (IoT), smart home technologies, telecare, and telehealth services, the understanding evolved toward environmental interventions being an integral part of assistive technology.

This trend is reinforced through the continued technological progress towards ambient computing, where a combination of smart devices, data, artificial intelligence, and human activity enable computer actions alongside everyday life, without the need for direct human commands or intervention [16].

5. Conclusions

Given the increasing accessibility and assistive functionality of mainstream mobile technologies, it becomes harder to justify denying access to these technologies and their benefits to people with disabilities especially when considering the number of additional benefits and extended range of functions beyond the central identified and required assistive purpose, often delivered at lower price point than dedicated aids and devices.

Denying such technologies for people with disabilities due to a lack of AT provision can only reinforce social isolation and lack of self-determination. A balanced model of provision will always need to offer some dedicated assistive technologies, but many people with disabilities are well served with accessible technology. When we examine demographics and an aging population, it will become increasingly essential to incorporate accessible mainstream technology into our thinking to enable the community to continue living independently for as long as possible.

Unanticipated benefits and the impact that the joy of using these technologies can have on people's lives require further investigation. Research studies currently being undertaken at University College Cork have begun to consider how people with disabilities derive pleasure from the technology they are using and seek to understand what this would mean for well-being and quality of life. We remain far from fully understanding the true impact of these technologies on a person's opportunities and functioning. However, the technology offers opportunities in keeping with Gaspers (1997) outline of Sen's capabilities approach as a combination of well-being and agency but moreover expands upon that in line with Gaspers' description of Nussbaum's capabilities ethic which stressed the importance of a "good life". This integration of thinking is perfectly in line with the potential of technology, despite being dated just as we were seeing the first shoots of the exponential growth of personal technology.

Ultimately, irrespective of the framework for categorizing technologies as TEI, AT or accessible consumer devices, there is increasing evidence that these devices empower people with disabilities to live independently, gain employment, succeed in education, and facilitate broader participation in social and political life. Increasingly we see new forms of consumer technology for fitness, well-being, and mobility. To continue to reinforce barriers to provision through outdated distinctions, effectively denying access to available products will only serve to maintain the global failure to meet demand.

References

[1] World Health Organization (WHO), UN Children's Fund (UNICEF). The Global Report on Assistive Technology 20202. Available from: https://www.who.int/publications-detail-redirect/9789240049451.

[2] Gitlow L, Flecky K, editors. Assistive Technologies and Environmental Interventions in Healthcare: An Integrated Approach, John Wiley & Sons; 2019.

[3] Gaspers D. Sen's capability approach and Nussbaum's capabilities ethic. Journal of International Development 1997; 9(2), 281-302, doi: 10.1002/(SICI)1099-1328(199703)9:2<281::AID-JID438>3.0.CO;2-K.

[4] Thompson S. Mobile technology and inclusion of persons with disabilities. K4D Emerging Issues Report. Brighton, UK: Institute of Development Studies 2018. Available from: https://www.readkong.com/page/mobile-technology-and-inclusion-of-persons-with-disabilities-7618652

[5] GSMA. The Mobile Economy 2018. Available from: https://manypossibilities.net/report-archives/GSMA_ The_Mobile_Economy_2018.pdf

[6] Heller R, Jorge J, Guedj R. Proceedings of WUAUC EC/NSF Workshop on Universal Accessibility of Ubiquitous Computing: Providing for the Elderly, Portugal, May 22-25, 2011, pp. 90–92.

[7] Harris J. The use, role and application of advanced technology in the lives of disabled people in the UK. Disability & Society, 2010;25(4), 427-439, doi: 10.1080/09687591003755815.

[8] Narasimhan N, Leblois A, Bharthur D, Haridas L, Lal P, Looms P, Sharma M. Making mobile phones and services accessible for persons with disabilities. A joint report of ITU—The International Telecommunication Union and G3ict-the global initiative for inclusive ICTs 2012.

[9] Muer S. Mobile Technology Use and Developmental/Intellectual Disabilities. 2015 Available from: https://sophia.stkate.edu/msw_papers/493.

[10] Morrissey D. Trends In Assistive Technology. 2019. Available from: https://www.eeworldonline.com /trends-in-assistive-technology/.

[11] Litvinov D. How Internet Privacy Is Changing The Online Advertising Market. Forbes. 2021. Available from: https://www.forbes.com/sites/forbestechcouncil/2021/10/28/how-internet-privacy-is-changing-the-online-advertising-market/.

[12] Atzori L, Iera A, Morabito G. The internet of things: A survey. Computer networks 2010;54(15), 2787-2805, doi: 10.1016/j.comnet.2010.05.010.

[13] Lee H. The internet of things and assistive technologies for people with disabilities: Applications, trends, and issues. In Internet of things and advanced application in healthcare. IGI Global 2017; p. 32-65.

[14] Smith R. Technology and Occupation: Past, Present, and the Next 100 Years of Theory and Practice. The American Journal of Occupational Therapy 2017;71(6),7106150010p1–7106150010p15, doi: 10.5014/ajot.2017.716003.

[15] Arvidson M, Lyon F, Mckay S, Moro D. Valuing the Social? The Nature and Controversies of Measuring Social Return on Investment (SROI). Voluntary Sector Review 2013;4(1):3-18, doi: 10.1332/204080513X661554.

[16] Lacoma T. What is ambient computing? Digital Trends. 2021. Available from: https://www.digitaltrends.com/computing/what-is-ambient-computing.

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Japanese Braille Translation Using Deep Learning - Conversion from Phonetic Characters (Kana) to Homonymic Characters (Kanji) -

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Abstract. A blind student writes and submits reports in Braille word processor, which is difficult for teachers to read. This study's purpose is to make a translator from Braille into mixed Kana-Kanji sentences for such teachers. Because Kanji has homonyms, it is not always possible to get correct results when converting. To overcome this difficulty, we used deep learning for translation. We built a training dataset composed from 15,000 pairs of Braille codes and mixed Kana-Kanji sentences, and a validation dataset. In training, we got an accuracy of 0.906 and a good Bleu score of 0.600. In validation, we found 5 mistaken words in selecting homonymous Kanji by examining translation mistakes from 100 pairs of the verification sentences. The choice of homonymous Kanji depends on the context. For decreasing such type of errors, it is necessary to introduce of translation of paragraphs by increasing the scale of the network model in deep learning, and to expand the network structure.

Keywords. Japanese braille, homonym, translation system, deep learning

1. Introduction

It is not uncommon for students with visual impairments to enroll in school. Such students attend lectures and their grades are evaluated by the faculty. Some blind students write and submit reports using a word processor, just as ordinary students do, but there are also many blind students who use braille word processors. At that time, the reports submitted are written in braille, "kana text for braille".

The purpose of this study is to assist faculty members who receive such reports. Faculty members also try their best to read the reports made by blind students. However, it is difficult to read. Therefore, we are building a system in which faculty members will provide Braille translations for reports that are not in "Braille-only Kana text" but in "mixed Kana-Kanji text.

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In the past five years or so, the field of deep learning has made great progress in the field of foreign language translation. Deep learning is one of the machine learning methods that have achieved great success in the field of image identification and recognition [1].

Many applications have emerged for this deep learning-based machine translation ("NMT"). Examples are applications such as "Google Translate" and "Deep L". The accuracy of this translation is high because it is a large-scale network and has been optimized in many cases. Until now, when it comes to Japanese analysis, morphological analysis was important, and "word dictionaries" and "programs" were indispensable.

The objective of this study is to assist teachers in converting Braille reports written by blind students into easily readable reports. Specifically, the aim is to develop a system that can convert Braille reports into Kana-Kanji mixed Japanese. While there are several software packages available that can convert visually impaired individuals' 6-point input into Braille, there is a lack of support software that can convert it into "Kana-Kanji mixed writing". Therefore, our focus is on utilizing TensorFlow and the transformer model included in the Tensor2Tensor libraries within NMT.

TensorFlow is a deep learning software framework developed by Google [2], and the transformer model is a specific type of deep learning architecture introduced in 2017 by Vaswani et al [3]. Transformers have exhibited remarkable success in various NLP tasks such as machine translation, language understanding, sentiment analysis, and text generation. Notably, the Transformer-based model known as GPT (Generative Pre-trained Transformer) has demonstrated impressive capabilities in generating coherent and contextually relevant text based on given prompts.

ChatGPT, one of the latest advancements in deep learning, has recently garnered significant attention due to its performance [4]. It is built upon the Transformer model, which is widely utilized in the fields of natural language processing and computer vision. The Transformer model employs a self-attention mechanism to differentially weigh the significance of each part of the input data.

Hence, our research aims to investigate whether transformers can be effectively employed to interpret "Braille Grammar" and address the aforementioned need for converting Braille reports into Kana-Kanji mixed Japanese.

2. Implementation and experiment

This section describes the system configuration and the data set for translation.

2.1. System construction procedure

Normally, a blind person can type 6 dots into a word processor to create "Braille" or "Braille code". With the Braille code, it is possible to create "Braille-specific kana text" specific to Braille using commercially available software. Therefore, we conducted an investigation to convert "Braille code" and "Braille-specific kana text" as input data into "mixed kana/kanji text".

In previous studies, we have constructed a system to convert "kana-kanji mixed sentences" into "braille data" according to a braille grammar using a morphological analysis tool (MeCab) [5]-[10]. In this report, we describe the conversion from "braille-only kana text" to "kana-kanji mixed text".

2.2. System configuration – Hardware and Software

In this research, deep learning, which has been applied to foreign language translation and whose effectiveness has been recognized, will be applied to translation from Braille to Japanese. The development environment we have prepared is as follows.

- Workstation: Lenovo ThinkStation S30
  Intel® Xeon® Processor E5-1620 v2, 128GB memory
- GPU
  NVIDIA GeForce GTX TITAN (Kepler arch.)
- System
  OS (Windows 10, ver. 1803)
  Visual Studio Community 2017
  Anaconda, Python 3.6.6
- GPU development environment
  CUDA ver. 9.0, CUDA tool kit
  cuDNN ver.7
- Deep learning development environment
  TensorFlow-gpu ver.1.10.0
  Tensor2Tensor ver. 1.9 (including Transformer)

2.3. Training dataset

The training data was more than 100 KB of data extracted from the Aozora Bunko "A" line. Aozora Bunko is a Japanese digital library, encompasses several thousands of works of Japanese-language fiction and non-fiction, and includes out-of-copyright books or works that the authors wish to make freely available.

As input data, 14 books were selected from the Aozora Bunko and converted into "Braille-only Kana characters" using commercially available EXTRA (commercially available high-performance automatic Braille translation software). As preprocessing, text, table of contents, and postscripts were deleted. In addition, line breaks were made where there were full stops in order to make it a single sentence. As output data, the preprocessed original text from the Aozora Bunko was converted into a single sentence by inserting line breaks where there were periods.

As training data for the teacher, 15,000 pairs of sentences containing Kanji characters were prepared. In the training process, 90% of the input was set for training and the remaining 10% for learning evaluation.

As verification data, we extracted some sentences from novels in the Aozora Bunko and investigated whether the data could be restored to kana-kanji mixed sentences.

3. Results and discussions

Supervised deep learning will be performed using a prepared dataset of kana sentences for Braille. Then, the reproducibility of the translation will be investigated using the validation data.

3.1. Training and validation results

In training, we got an accuracy of 0.906 with a calculation of 15 hours and 28 minutes. Since the highest accuracy in this experiment was achieved in the translation from "kana text for Braille" to "mixed kana-kanji text," we quantified the actual translation accuracy, we validated the Bleu score using the Python language processing library "NLTK" [11]. The Bleu score, which was an index often used to validate machine translation, at this time was 0.600. In general, it is said that 0.6 or higher score is meant higher quality than a human translator [12].

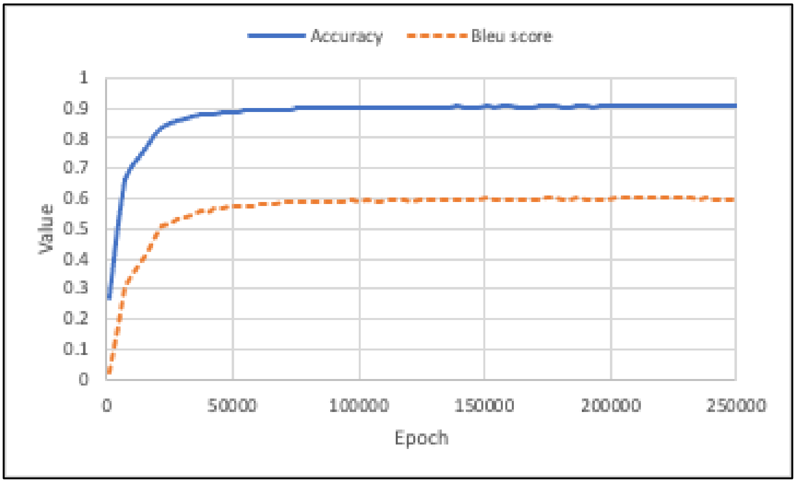

Figure 1. Accuracy and Bleu score

In the validation, significant mistranslations were found even with high training Bleu scores. When 100 pairs of sentences from literatures different from the training data were prepared as validation data and tested to see if they could be restored to kana-kanji mixed sentences, errors were found in 88 locations (not 88 sentences) in the sentences. The errors were divided into several types. There were 5 errors (5.6%) in selecting homonymous Kanji and idioms, 9 errors (10%) that could not be converted to Kanji, and 74 (84%) miscellaneous conversion errors, such as words that should have been expressed in "hiragana" being converted to "kanji". Therefore, 9 errors (10%) are related to kana-kanji conversion, and the other errors are acceptable because they are about the use of kana and kanji.

3.2. Discussion

The Bleu score of 0.60 was achieved in this experiment. In the validation, there were errors in 88 locations out of 100 sentences, but only 10% were essential ones related to homonyms. However, further improvement is needed to convert them into sentences that teachers can read.

Errors that could not be converted to kanji can be reduced by increasing the size of the data set. On the other hand, the selection of homophonic kanji and idioms is context-dependent. Therefore, errors of this type cannot be eliminated by simply increasing the dataset; it may be necessary to extend the attention mechanism underlying the transformer backward as well as forward in sentences. It may also be necessary to translate paragraph by paragraph, rather than sentence by sentence analysis. In order to achieve this, the scale of the network model in deep learning should be increased to the extent that it can handle sentences in paragraphs, and the network structure should be such that sentences after the translation target can also be used as a reference for translation.

4. Concluding remarks

This study reported an attempt to translate Braille into Japanese mixed Kana-Kanji sentences by deep learning using the transformer. Despite a small training set of 15,000 sentences and 16 hours and 56 minutes of training time, the training accuracy was high at 90.6%, and the Bleu score, which represents translation accuracy, was as high as 0.60. Although the translation accuracy was high enough, errors caused by homonyms and idioms of Chinese characters as well as simple conversion errors were found. To overcome these errors, in addition to expanding the type and amount of training data sets, the deep learning network model needs to be expanded to counter the latter. Recently, transformers have been active in extending deep learning network models for images. Incorporating that knowledge should be able to solve the homonym problem. This is an issue for the future.

We are also conducting human verification with the goal of making braille reports as easy to read as possible for teachers in the educational field. I think machine learning will become very useful for braille translation.

Acknowledgements

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References

[1] NTT Media Intelligence Laboratories, Neural Machine Translation for Service Creation. 2018. Available from: https://www.ntt.co.jp/journal/1806/files/JN20180634.pdf
[2] Google. (n.d.). TensorFlow. Retrieved from https://www.tensorflow.org/
[3] Vaswani A., Shazeer N. *et. al*. Attention is all you need. In Advances in Neural Information Processing Systems, 2017. p.5998-6008.
[4] OpenAI. (2021). ChatGPT (Version 3.5) [Computer software]. https://openai.com/
[5] Kawabe H, Seto S, Nambo H, Shimomura Y. Experimental Study on Scanning of Degraded Braille Books for Recognition of Dots by Machine Learning, Proceeding of the 13th International Conference on Management Science and Engineering Management (ICMSEM2019), 2019. p.322-334.
[6] Shimomura Y, Kawabe H, Nambo H, Seto S. Braille Translation System Using Neural Machine Translation Technology I - Code Conversion, Proceeding of the 13th International Conference on Management Science and Engineering Management, (ICMSEM2019). 2019. p.335-345.
[7] Kawabe H, Shimomura Y, Nambo H, Seto S. Application of Deep learning to Classification of Braille Dot for Restoration of Old Braille Books, Proceeding of the 12th International Conference on Management Science and Engineering Management (ICMSEM2018), 2018. p. 913-926.
[8] Shimomura Y, Kawabe H, Nambo H, Seto S. The translation system from Japanese into Braille by using MeCab, Proceeding of the 12th International Conference on Management Science and Engineering Management, (ICMSEM2018). 2018. p. 1125-1134.

[9] Kawabe H, Nambo H, Seto S, Shimomura Y. Detection and classification of cells in old Braille Book by image processing technique, Proceedings of the 18th Asia Pacific Industrial Engineering and Management Systems Conference, (APIEMS2018). 2018.
[10] Shimomura Y, Kawabe H, Seto S, Nambo H. Development of a system that beginner volunteers can translate Japanese into Braille, Proceedings of the 18th Asia Pacific Industrial Engineering and Management Systems Conference, (APIEMS2018). 2018.
[11] Agrawal R nad Jolly SK. Big Data and Machine Learning for Evaluating Machine Translation. In Balas VE, Solanki VK and Kumar R, Editors, "Internet of Things and Big Data Applications", ISRL. Springer. 2020;180: 11-34.
[12] Lavie A, Evaluating the Output of Machine Translation Systems, 13th MT Summit Tutorial Xiamen,8 China, Sep 2011. Available from: https://www.cs.cmu.edu/~alavie/Presentations/MT-Evaluation-MT-Summit-Tutorial-19Sep11.pdf

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Assistive Technology in Low- and Middle-Income Countries (LMICs)

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Unpacking 'What Works': A Commentary of the Key Learnings for ICT from the AT2030 Program

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Abstract. The AT2030 programme was launched in 2018 to test 'what works' in getting assistive technology (AT) to people globally, specifically in low-and middle-income countries (LMIC), where there is often a systematic lack of provision. After four years, this paper reviews the project outcomes, focussing on published material. It provides the backdrop to the AT2030 program, contextualises current developments in global AT global and funding, and unpacks the key learnings of what works to get AT to the people that need it around the world, with a focus on ICT. The paper does this by applying Global Disability Innovation Hub's mission-led and transformative approach, concluding with contemporary actions to improve access to AT to illustrate the value of embracing complexity for AT ecosystem stakeholders, including researchers, practitioners, AT users and policymakers.

Keywords scale, access, assistive technology, innovation, disability, ICT

1. Introduction

Humans have used technologies for millennia, and the role of technology in enabling human outcomes is well established. There is ample evidence that when assistive technology is provided in a timely way, and the assistive products and training are delivered well, there is a positive impact on the AT user. Despite this, a huge global unmet need still exists for millions of people. The impact of fit-for-purpose assistive technology in narrowing the capability gap [1] between person and environment, particularly where environmental barriers and human diversity prevent access, is also becoming progressively clearer as the evidence base improves. Rapid demographic

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changes (such as an ageing population and increases in humanitarian situations), as well as exponential growth in technologies themselves, have led to a 'tipping point' in unmet Assistive Technology (AT) need, that is, products and services which optimise functioning and reduce the experience of disability [2]. So, some key questions arise – What works in getting AT to people?, What systemic barriers must be overcome, and what innovations can help unlock the provisioning potential?

1.1. Contemporary actions to improve access to AT

Global actions, such as the AT2030 programme, are underway to enable access to AT for those who need it. The 71st World Health Assembly (WHA) adopted resolution WHA71.8 on 26 May 2018, which urges all Member States to take action to improve access to assistive technology. The resolution resulted from much hard work by many organisations. The road to this point was well summarised by Layton et al. [3], which establishes the road to the development of coherence across the multiple actors who have helped pave the way for the resolution. Notably, the GATE community, international Assistive Technology Associations (which later became GAATO) (www.gaato.org) and ATscale, Global Partnership for Assistive Technology (www.atscale.com) [3]. Within this global actor-network, Global Disability Innovation Hub (GDI Hub) (www.disabilityinnovation.com) – a research and practice centre – which leads the AT2030 program, takes a disability justice approach to developing a fairer world, asking questions such as assistive technology for what? [4] and ensuring research and practice look at the necessary AT policies and practices, and that the global disability innovation movement focuses simultaneously on removing stigma and discrimination [5].

This paper reports findings from the 'what works' project focusing on Information and Communication Technologies (ICT). For this, we have used the ISO9999 standard [2] (assistive products - classification and terminology) to pull out key learnings from the 'what works' project within the AT2030 programme and use ICT as an exemplary learning area from this corpus of work. First, we explain in more detail the AT2030 program: its purpose, history and framing.

1.2 The AT2030 programme and paradigm shift

In 2018 the UK Foreign, Commonwealth and Development Office (FCDO) awarded a £10m grant from the UK government to run a three-year, multi-partner programme called 'AT:2030 – Life Changing Assistive Technology for All'. AT2030 is designed to trial and test 'what works' to improve access to life-changing AT for all. Due to its success, the UK Government doubled its investment in 2019 to £19.8 million. The partnership has match funded that investment to take the programme to £40m. AT2030 supported the development of the WHO/UNICEF Global Report on AT in 2022 alongside ATscale. The AT2030 programme operates with many partners, including multinational institutions (e.g. WHO, UNICEF, Clinton Health Access Initiative, ATscale), academic partners (e.g. London School of Hygiene and Tropical Medicine, Assisted Living and Learning Institute, University of Maynooth, University of Nairobi) and local partners (Kilimanjaro Blind Trust Association, Sierra Leone Urban Research Centre and Motivation). The insights for AT2030 are being synthesized by the WHO Global Collaborating Centre on Assistive Technology, based in the Academic Research Centre (ARC) arm of GDI Hub at University College London (UCL).

AT2030 comprises four programme clusters – designed to test innovative approaches to AT provision to increase access; which were co-designed between the core partners, the funder and the ATscale forming committee in 2018, following a scoping report [5] setting out the core market failure issues. These are **Data & Evidence** – improving data and evidence to enable better decision-making and to unlock investment into AT, including in humanitarian contexts; **Innovation** – sparking innovation and supporting new products and service delivery models to scale access to AT; **Country Implementation** – laying the foundations for market shaping and systems-level change; driving the availability and affordability of AT; opening up market access and building country capacity; and **Capacity & Participation** – building partnerships, capacity and community solutions, maximizing the power of the Paralympics to overcome stigma and promoting inclusive design. The clusters represent the social justice lens applied by GDI Hub whilst ensuring the necessary systems-thinking and market-shaping pathways are supported and evidenced. Twelve sub-programmes are housed within (and across) these four main clusters.

1.3. The case of information and communication technologies (ICT)

ICT is responsible for a wide range of possible AT – from robots to smart homes and automated captions to synthesised speech [6]. The rehabilitation world has also produced evidence of the efficacy of products such as a switch or voice-operated call systems, telephones, or environmental control units. However, these often focus on the deficit (medical) model of disability rather than enabling the step change possible from current and future ICT and are often reported within small diagnostically based studies. Neither evidence base demonstrated a product ecosystem/supply network view nor a clear line of sight regarding the link between research and development, user testing or evaluation within contexts.

2. Methods

All outputs from the AT2030 programme published between October 2018 and July 2022 were reviewed and systematically clustered under the 'what works' lines of enquiry. which began with the initial research questions contained within the AT2030 bid AT2030 proposal, available here [7]. These research questions then evolved as the outputs were reviewed, and new themes and lines of enquiry were identified by the research team. The data were then synthesized and presented to the AT2030 partnership in a face to face workshop session in november 2022 which resulted in further iterations. The full methodology and results are being written as an open-access publication. Here we summarise the overall 'what works' research questions that have arisen through analysis according to the IMPACT 2 model [8], a widely used framework that is applied to AT interventions in rehabilitation contexts.

Furthermore, we also summarise here the role of ICT for low-and middle-income countries (LMICs) through the lens of the Disability Interaction (DIX) approach [9] which described a new agenda for developing technology for people with disabilities, before applying this model to the relevant AT2030 programme cluster. In the disabiltiy interactions model, disability inclusion is seen as a 'wicked problem' which requires a systematic and whollistic sollution. In thi smodel, effective outcomes for ICT users require a fearless engagement with the complexity of settings and contexts and a commitment to going beyond small-scale studies. Technology (such as AT) is understood to be embedded in multiple ecosystems, which can be unlocked through co-created solutions with all stakeholders, open and scalable innovation practices, effective use of value tools and the application of applied and basic research methods focussing on radically different interaction modalities (see **Figure 1**) [9] We present an example of learning for each AT2030 cluster against the DIX framework.

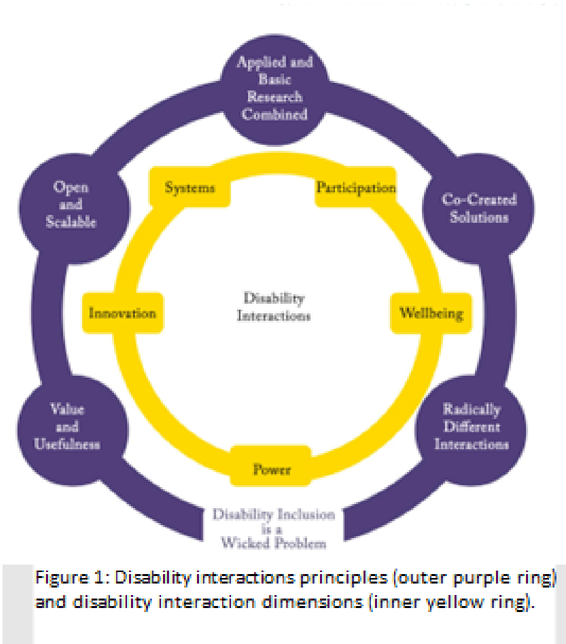

Figure 1. Disability interaction principles (outer purple ring) and disability interaction dimensions (inner yellow ring)

3. Findings

3.1. What Works through the lens of the IMPACT 2 model

Figure 2 below summarises the research questions from the 'what works' analysis. This demonstrates the commitment to Context and Environment. The outcomes demonstrate the breadth and interconnectedness of the clusters of AT2030 work, spanning country-level implementation questions related to priority assisted product lists to the evidence and impact of a single intervention, which would be relevant to both private and public AT investors.

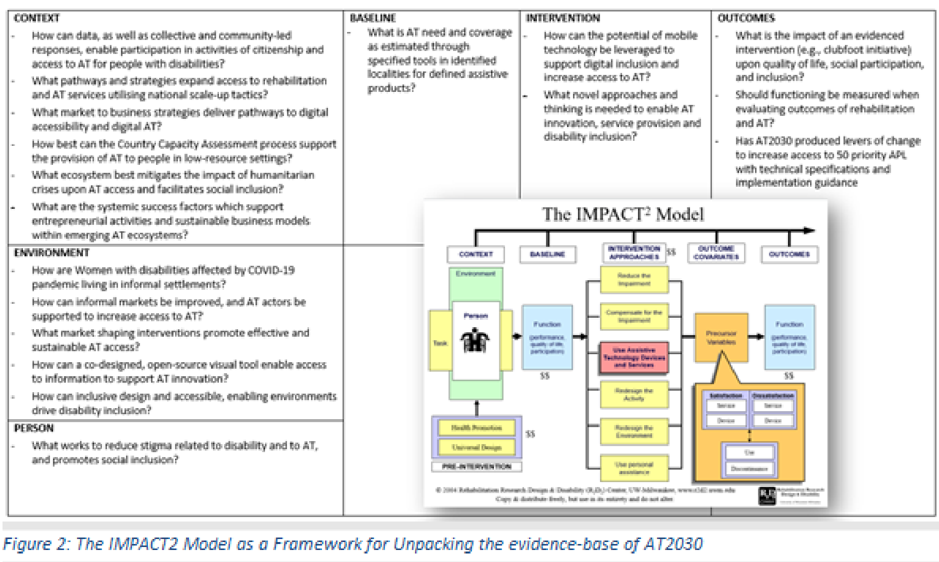

Figure 2. the IMPACT2 Model as a Framework for unpacking the evidence base of AT2030

3.2. Exemplifying access to AT: initial findings from AT2030 (with a focus on ICT)

Within the AT2030 programme, parallel and separate fields of investigation discussed research and the development of digital products or adapting and designing products for the disability sector. Applying this new thinking to ICT, a conceptual reframing is offered by Holloway & Barbareschi in their 2022 text Disability Interactions (DIX): Creating Inclusive Innovations [9].

Data & Evidence: A scoping review of innovation strategies for AT [10] aligned with elements of the DIX framework. Specifically, the findings that open innovation and radical and disruptive innovation strategies were needed to unlock AT innovation pathways in AT provision and supply. Digital transformation was found to be an enabler of both for prosthetic services.

Innovation: An early AT2030 case study demonstrated how people with visual impairment use mobile phones in Kibera, Nairobi (Kenya). Instead of independently using a mobile phone, people used four types of interactions: supported (e.g. asking for help to learn to use the phone or read a text message), direct (e.g. independently making or receiving a call), dependent (e.g. handing over the phone for mobile top-ups with no control on if the action will be completed as requested) and restricted (e.g. unable to access the Internet due to lack of funds) [11]. This new evidence offered by AT2030 research stands with the AT user in considering innovation, utility, and impact. However, we must not consider ICT in isolation from physical AT. Examples such as the study of mobile use in informal settlements explore the reality that digital and physical technologies are used concurrently, opening rich possibilities for integrated and relational design [12].

Country Implementation: The Product Narrative approach [13] was used to create a Digital Product Narrative [14], which describes the ecosystem of Digital AT as four interconnected components : Devices (e.g. mobile phones) and accessories (e.g. braille readers); Platforms or operating systems which enable consumption of what is on the device; Software and applications that fulfil a particular purpose or user activity; Content, such as text, text-to-speech, native language availability and pictograms. The rate of adoption of digital AT is supported by: "1) awareness of digital AT and its accessibility by users, developers, suppliers, providers, and policymakers; 2) availability of mobile network and internet connectivity; 3) the application of universal design and inclusion of accessibility features; and 4) appropriate training in digital AT" [15]. This clearly demonstrates the DIX need for co-created solutions across several actors, along with developing mechanisms to unlock increased value for the procurer to enable access for the end user.

Capacity & Participation: Austin and colleagues foreground the goals of participation and citizenship and the role of AT as mediator, demonstrating the emancipatory power of study designs that step beyond a product focus [16]. We also saw the power of digital communication through the #wethe15 [17] campaign linked to the Paralympics.

4. Discussion and Limitations

Using the IMAPCT2 model, we see multiple variables and engagement with complex systems. This delivers on the promise of the Disability Interaction approach and addresses a longstanding gap acknowledged in the knowledge translation literature concerning the absence of context and real-life applicability in scientific studies. As argued by Dijkers, while using 'best available' evidence to make decisions is important, the best may be the enemy of the good regarding real-world research and practical outcomes [18].

This paper has contextualised current developments in AT global policy and funding, introducing GHI Hub's mission-led approach and transformative model of change. We have illustrated the difference between traditional and new approaches with the example of ICT. However, we only present a snapshot of learnings using limited models. For example, we have not yet applied the SMART (Systems-Market for Assistive and Related Technologies) Thinking Matrix [19] to our data set.

5. Conclusion

AT2030 has purposefully engaged with the major humanitarian and political challenges of current times through a global, mission-led approach with measurable outcomes and clarity of ensuring a return on investment. An underpinning enabler is research and data, proven essential to enable countries to understand the return on investment for AT and the economic choices before them. In terms of products, testing and piloting market shaping are essential steps required before approaches are scaled.

Concurrently, determined work on systemic interventions with national governments is demonstrably essential, as is community participation and capacity building. The exclusion of AT users from programme design, policy and decision-making leads to poorer outcomes, continued power imbalances and political exclusion – these things are all part of the problem and solutions must be designed to counter this.

The AT2030 body of work practically illustrates the value of embracing complexity for AT ecosystem stakeholders including researchers, practitioners, AT users and policymakers.

References

[1] Nussbaum M, Sen A. The Quality of Life. Oxford: Clarendon Press; 1993. p. 1-6.
[2] ISO. ISO 9999 Assistive products for persons with disability — Classification and terminology [Internet]. 2022 [cited 2022 Sep 20]. Available from: https://infostore.saiglobal.com/en-au/Standards/AS-ISO-9999-2018-1128769_SAIG_AS_AS_2618344/
[3] Layton N, MacLachlan M, Smith RO, Scherer M. Towards coherence across global initiatives in assistive technology. Disabil Rehabil Assist Technol. 2020 Oct 2;15(7):728–30.
[4] Austin V, Holloway C. Assistive Technology (AT), for What? Societies. 2022 Dec;12(6):169.
[5] Holloway C, Austin V, Ramos Barajas F, Pannell L, Morgado Ramirez D, McKinnon I, et al. Scoping Research Report on Assistive Technology - On The Road For Universal Assistive Technology Coverage [Internet]. UCLIC - UCL Interaction Centre; 2018 [cited 2022 Dec 28]. Available from: https://uclic.ucl.ac.uk/publications/scoping-research-report-1773176-1
[6] International Electrotechnical Commission (IEC) [Internet]. 2023 [cited 2023 Mar 3]. Available from: https://iec.ch/homepage
[7] FCDO. DevTracker Programme GB-GOV-1-300815 Documents [Internet]. Development Tracker. [cited 2023 Mar 4]. Available from: https://devtracker.fcdo.gov.uk/projects/GB-GOV-1-300815/documents
[8] Smith RO. IMPACT2 Model [Internet]. 2005. Available from: https://uwm.edu/r2d2/methods/impact2-model/
[9] Holloway C, Barbareschi G. Disability Interactions: Creating Inclusive Innovations [Internet]. Cham: Springer International Publishing; 2022 [cited 2023 Feb 16]. (Synthesis Lectures on Human-Centered Informatics). Available from: https://link.springer.com/10.1007/978-3-031-03759-7
[10] Holloway C, Morgado Ramirez DZ, Bhatnagar T, Oldfrey B, Morjaria P, Moulic SG, et al. A review of innovation strategies and processes to improve access to AT: Looking ahead to open innovation ecosystems. Assist Technol. 2021 Dec 1;33(sup1):68–86.
[11] Barbareschi G, Holloway C, Arnold K, Magomere G, Wetende WA, Ngare G, et al. The Social Network: How People with Visual Impairment use Mobile Phones in Kibera, Kenya. 2020; Available from: https://doi.org/10.1145/3313831.3376658
[12] Barbareschi G, Oldfrey B, Xin L, Nyachomba Magomere G, Ambeyi Wetende W, Wanjira C, et al. Bridging the Divide: Exploring the use of digital and physical technology to aid mobility impaired people living in an informal settlement. In: ASSETS 2020 - 22nd International ACM SIGACCESS Conference on Computers and Accessibility. Association for Computing Machinery, Inc; 2020.
[13] Savage M, Tyler N, Seghers F, Afdhila N, Fineberg AE, Frost R, et al. Applying Market Shaping Approaches to Increase Access to Assistive Technology: Summary of the Wheelchair Product Narrative. 2019.

[14] Savage M, Bhatnagar T, Liao C, Chaudron M, Boyar J, Laurentius D, et al. Product Narrative: Digital Assistive Technology. A market landscape and strategic approach to increasing access to digital assistive technology in low- and middle-income countries [Internet]. Loughborough University; 2020 Nov [cited 2022 Dec 21]. Available from: https://repository.lboro.ac.uk/articles/report/Product_Narrative_Digital_Assistive_Technology_A_market_landscape_and_strategic_approach_to_increasing_access_to_digital_assistive_technology_in_low-_and_middle-income_countries/14578815/1
[15] ATscale & AT2030. Product Narrative: Digital [Internet]. 2020 [cited 2020 Sep 14]. Available from: https://at2030.org/product-narrative:-digital-assistive-technology/
[16] Austin V, Holloway C, Vermehren IO, Dumbuya A, Barbareschi G, Walker J. 'Give Us the Chance to Be Part of You, We Want Our Voices to Be Heard': Assistive Technology as a Mediator of Participation in (Formal and Informal) Citizenship Activities for Persons with Disabilities Who Are Slum Dwellers in Freetown, Sierra Leone. 2021; Available from: https://doi.org/10.3390/ijerph18115547
[17] WeThe15 [Internet]. 2021 [cited 2022 Nov 19]. Available from: https://www.youtube.com/watch?v=gHCDvdCaJhI
[18] Dijkers MPJM. When the Best Is the Enemy of the Good: The Nature of Research Evidence Used in Systematic Reviews and Guidelines [Internet]. SEDL. Austin, Texas: TX: NCDDR Task Force on Systematic Review and Guidelines; 2009 [cited 2023 Mar 3]. Available from: https://ktdrr.org/ktlibrary/articles_pubs/ncddrwork/tfsr_best/tfsr_best.pdf
[19] MacLachlan M, McVeigh J, Cooke M, Ferri D, Holloway C, Austin V, et al. Intersections Between Systems Thinking and Market Shaping for Assistive Technology: The SMART (Systems-Market for Assistive and Related Technologies) Thinking Matrix. Int J Environ Res Public Health. Dec;15(12):15.

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Harmonising Assistive Technology Assessment Data: A Case Study in Nepal

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Abstract. There is a practical demand to maximise existing data to understand and meet the assistive technology (AT) needs in dynamic populations. Harmonisation can generate new insight by integrating multiple datasets that were not previously comparable into a single longitudinal dataset. We harmonised AT assessment data from three population-based surveys collected several years apart in Nepal: the Living Conditions of Persons with Disabilities (2014-2015), the Multiple Indicator Cluster Survey (2019), and the rapid Assistive Technology Assessment (2022). The harmonised dataset demonstrates a method that can be used for unifying AT surveys in other settings and conducting trend analyses that are necessary for monitoring a population's dynamic AT needs. We set out to explore AT data's potential for harmonisation, and learned there is indeed value in this approach for situating disparate datasets, though the methodology proposed will need further validation.

Keywords. Survey Data, Harmonisation, Statistical matching

Introduction

Assistive technology (AT) includes products like hearing aids and glasses, and their essential services. AT is critical in supporting independence and wellness for people with disabilities and at older ages.[1–3] Yet access to AT between and within countries is often inadequate and inequitable, with highly fragmented efforts to monitor coverage,[4–6]. Improving data in this sector is a high priority to expand access to AT, which has been greatly advanced by the deployment of population-based surveys that focus all or in part on specific assistive products (APs). As APs gain a presence on national health agendas, many countries have also added functioning and AP need modules to routine data collection efforts.[7,8] However, these are relatively recent additions to the global coherence of AT evidence, which is still characterised by country-level gaps and discordant datasets. A practical, urgent need remains to maximise existing data to inform evidence-based policy. The Global Disability Innovation Hub (GDI Hub) are mapping these and other datasets[4,7] and developing compatible methods to learn more from what is currently available.

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The recent publication of the Global Report on Assistive Technology demonstrated the necessity and power of population-level data.[5] Sparse data inhibit evidence-based decision-making, and while data collection efforts grow globally, many existing datasets are too discordant to link, or go unused altogether.[4,7] Data harmonisation is the process of cleaning and adjusting multiple datasets so they can exist in a single dataset, constituting a method that is growing in importance as the volume and need to share existing data explodes.[9,10] Harmonisation explores how data derived from several different surveys can be integrated and considered together. This method can be especially useful where data collection may have been funded from different sources and for different purposes, which is a common challenge in the AT data space.[11] Overall, the process can even identify opportunities to improve data collection. However, there must be some existing similarity between the datasets so that key variables can be universally defined and applied. To test this method's potential with AT data, GDI Hub sought countries with three or more population-based surveys, conducted several years apart to examine change over time, that each included questions on disability/functioning and assistive products. Currently, three population-based surveys have included similar modules on assistive products (APs) in Nepal: the rapid assistive technology assessment tool (rATA)[12] administered by the WHO, the Living Conditions Studies (LCS)[13] administered by SINTEF, and the Multiple Indicator Cluster Surveys (MICS)[14] by UNICEF. Given GDI Hub's existing work and partnerships in-country, and the availability of multiple population-based surveys, Nepal was therefore chosen for the initial case study.

To provide context for this setting, Nepal introduced a National Policy and Plan of Action (2007) for the provision of access to AT services for people with disabilities. Yet access to AT is still very limited, with the LCS report published in 2016 finding only 1 in 8 people with disabilities having access to AT.[15] Nepal is a multi-lingual, multi-cultural, multi-religious, multi-ethnic country with a diverse geography, consisting of mountains, hills and terai,[16] with most of the population living in rural areas (79.8%), although the urban population is gradually increasing.[17] People with disabilities in Nepal are one of the 'most vulnerable and deprived' sectors of the population.[18,19] The 2011 census conducted by the Government of Nepal reported that 1.94% (513,301) of the total population lives with some kind of disability. This figure is almost certainly underestimated considering the global average estimate from the WHO of around 16%.[20] Indeed, as Karki et al describe: "anecdotal evidence suggests that the Maoist insurgency from 1996 to 2006,[21] the 2015 earthquake,[22] high incidence of natural disasters every year,[23,24] increased traffic accidents,[25] fall injuries,[26] and deafness[27] have contributed to a higher prevalence of disabilities in Nepal compared to some other low/middle-income countries (LMICs)."[21] This strongly suggests a need for more complete datasets on Nepal if the population's AT needs are to be more fully understood.

This case study, therefore, aims to contribute 1) a harmonised dataset for future research seeking to monitor and understand trends in AT outcomes over time and 2) a harmonisation logic for AT assessment questions that can be reused in other settings where AT data exist in previously incompatible forms. These contributions can significantly support dynamic understanding of country-specific AT need.
graph.

1. Methods

An LCS (2015, n = 34,754), MICS (2019, n = 4123), and rATA (2022, n = 11,230) have been carried out in Nepal. Each of these surveys utilise population-based sampling and the Washington Group Short Set[28] of functional assessment questions (or a similar, version), as well as direct questions on AP use. Approval to use each dataset within this paper was sought from the relevant authority.

Based on the assessment strategies used by each dataset, variables for AP outcomes were defined to be applied uniformly. In addition to AP use, two AP outcome variables were defined: total (potential) need and unmet need. Figure 1 uses glasses to illustrate how these definitions were applied across each survey. We considered an individual to potentially have need for the AP if they had any functional difficulty, regardless of any AP use. This estimate of total need can also be calculated by adding met and unmet need, which is necessary in approach 2. Unmet need was considered an individual with potential need that did not use any AP, or used an inadequate AP[2].

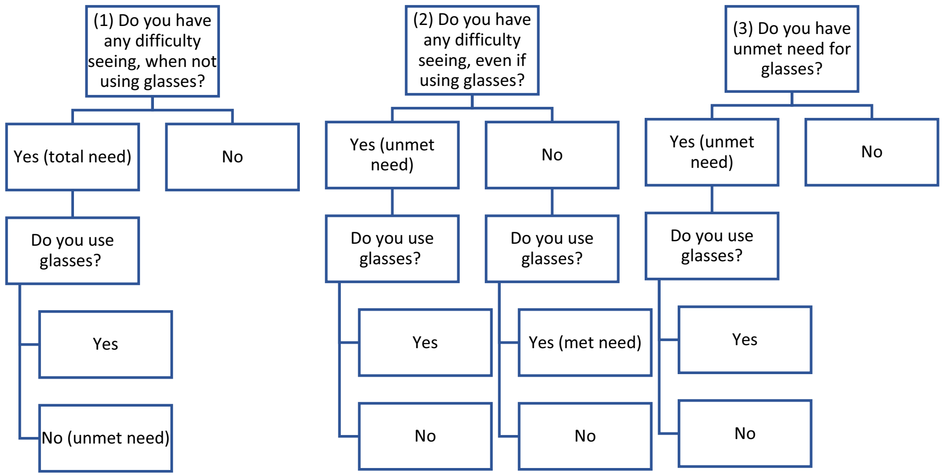

Figure 1: AT outcome variables in survey logic

To explore trends over time, the proportions of respondents using APs and with unmet need for APs were taken out of the total respondents with need, for each wave of the harmonised dataset. These estimates are provided with a 95% confidence interval (CI) based on the harmonised sample size in Figure 2.

Key demographic categories were also aligned during harmonisation, which included some recategorisation with the same value labels and the use of dummy variables as needed. Further adjustments were made to align these variables:

[2] Approach 1 is used in the LCS, rATA, MICS youth (5-17) and child (0-4) questionnaires; approach 2 is used in the LCS and MICS adult (15-49) questionnaires. Approach 3 is included in the rATA questionnaire only, which asks respondents if they have unmet need for any APs and provides glasses as an option.

- The scale used for functional difficulty by LCS and MICS was adjusted for functional difficulty levels, with the 1-5 scale mapped/switched to a 0-3 scale, with 3 and 4 combined into ‘a lot of difficulty’, or ‘2’.
- Respondents aged <3 years or >49 years were removed from each dataset to align with the highest minimum and lowest maximum available across the three.
- For MICS and LCS, a ‘don’t know’ option was included when asking about assistive product use, and those responses were recategorized as no use.
- All responses with missing data for any of the harmonised variables were removed.
- The rATA is the only survey offering gender options outside of male/female, but as no respondents identified with these options during the rATA survey in Nepal, no adjustment was needed based on gender.
- The only assistive products specifically mentioned across all waves were glasses and hearing aids. Questions on other APs or functional domains therefore could not be included.

Results

After harmonising age groups, 39% of LCS, 11% of MICS, and 30% of rATA data were removed. **Table 1** provides demographics and outcome estimates for each wave of the harmonised dataset. **Table 2** stratifies the prevalence of vision and hearing functioning difficulty by level for each wave. **Figure 2** depicts their age distributions.

Table 1: Wave demographics after harmonisation

Survey	Year of data collection completion	Respondents (n)	Female (%)	Vision difficulty (total need) (%)	Hearing difficulty (total need) (%)
LCS	2015	2551	48.8	9.5	17.7
MICS	2019	30993	64.7	10.8	3.5
rATA	2022	7842	53.5	11.7	3.8

The LCS wave identified exceptionally high hearing difficulty compared to the other two waves. The MICS also captured a higher percentage of female respondents. Vision difficulty is consistent across all three waves.

Table 2: Functional difficulty levels across harmonised waves

Survey	No difficulty seeing (%)	Some difficulty seeing (%)	A lot of difficulty seeing (%)	Cannot see (%)
LCS	90.5	6.1	2.5	0.9
MICS	97.2	2.5	0.2	0.1
rATA	88.3	9.9	1.6	0.2

Survey	No difficulty hearing (%)	Some difficulty hearing (%)	A lot of difficulty hearing (%)	Cannot hear (%)
LCS	82.3	10.4	4.5	2.7
MICS	97.6	2.0	0.3	0.1
rATA	96.2	2.4	1.0	0.4

The LCS estimated a higher overall prevalence of hearing difficulty, and therefore potential hearing aid need, particularly with respect to 'some' level of difficulty. However, all waves follow a similar trend of proportional decline in prevalence as severity of difficulty increases, for both vision and hearing.

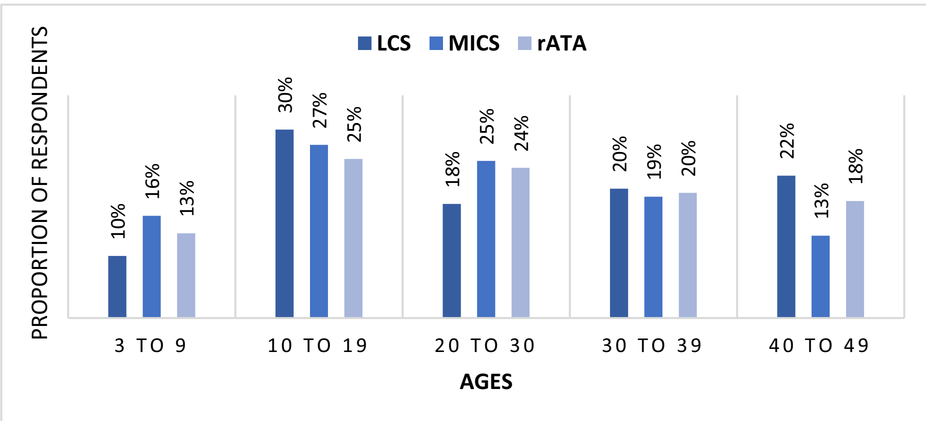

Figure 2: Age distribution of harmonised waves

Trends in AP outcomes were also explored over time. **Figure 3** shows estimates for use and unmet need with 95% CIs for glasses and hearing aids, out of the total with need in the specific functional domain.

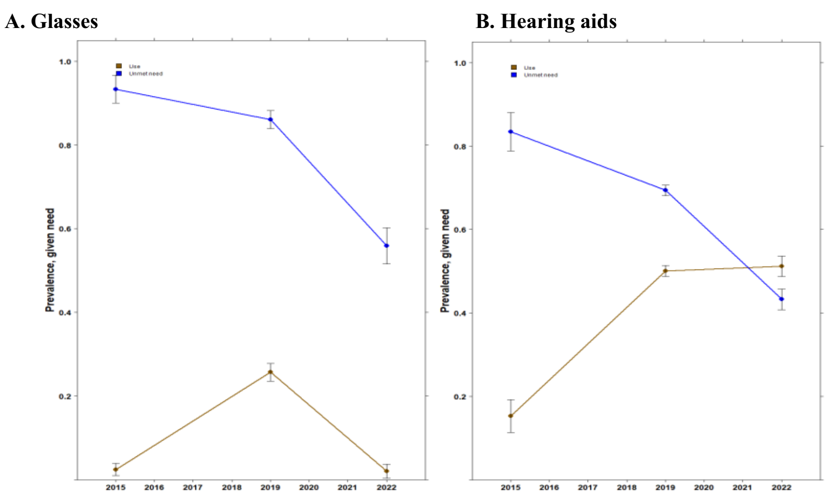

Figure 3: Use and unmet need, among respondents with need for A. Glasses (left) and B. Hearing aids (right).

The LCS is the only survey to include approaches 1 and 2 (Figure 1) as separate questions used to assess total need: 'Do you have any difficulty, without using the AP?' and 'Do you have any difficulty, even when using the AP?' (in combination with 'Do you use the AP?'). Using each approach, unmet need is estimated at 206 and 202 for vision, and 440 and 421 for hearing, out of the total with functional difficulty in each domain. Further, based on the unmet need question specified in the rATA, unmet need for glasses and hearing aids is estimated at 60% and 90% of those with vision and hearing functioning difficulty, respectively. Unmet need was also defined in this analysis as having functional difficulty, but not using the AP. By this definition, unmet need in the harmonised rATA wave is 52% for glasses and 98% for hearing aids, of the total with any functional difficulty for each. In each case, the variation is <10%.

Discussion

The harmonised dataset indicated emerging trends for vision and hearing difficulty as well as AT outcomes. Glasses use increased over time, but hearing aid use was far more limited. The surveys also found considerably high rates of disability, particularly hearing difficulty, given the harmonised population are under 50 years old; hearing impairment have been estimated globally at 1.4% for children aged 5-14, and 9.8% and 12.2% for women and men respectively, aged >15.[29] Though the LCS identified a high prevalence of hearing difficulty (described in the organisation's report[15]), all waves produced the same overall trends when stratifying vision and hearing difficulty by level and age group.

Surveys with multiple questions on AT allow for some internal validation for AT outcome definitions. Our validation tests indicate approaches 1 and 2 can reliably estimate unmet need, demonstrating their utility for further harmonisation work. Applying different definitions within the same dataset also indicates where variation may be related to the specific AP or functional domain if a definition is not consistently producing over/underestimates. Including more comprehensive modules on AT will support harmonisation with earlier datasets that may be more limited.

Though our study has limitations, it can contribute to many avenues of future work. We equate any functional difficulty with need for the specific AP, which assumes all participants with any difficulty would benefit from or want the AP, likely overestimating true need. However, relying on an estimate of potential need is necessary when more nuanced data are not available, and this definition is based on the most inclusive WHO definition of need included in the rATA survey.[12] Working with secondary data, we are also unable to explain anomalies such as the high hearing difficulty prevalence identified in the LCS. This gap highlights a need for a central space for harmonising data and sharing insights, so anomalies can be identified amongst the coherence of AT research, and investigators can further interrogate their data to understand why. Apart from policymakers planning for population health needs, harmonised datasets can be extremely useful to innovators. If e.g. the hearing need is shown to be significant or increasing, there is opportunity for innovators to address the market and demonstrate high potential demand for hearing products to funders.

Conclusion

The AT sector is characterised by disparate, sparse data, with many opportunities for harmonisation. Our investigation tested this potential in Nepal, directly comparing surveys by the same outcomes. More work is necessary to dive deeper into this dataset and test this method in other settings. Yet overall, these efforts contribute to efforts to unify and maximise existing data, to understand population-level needs and gaps, and expand access to AT.

References

[1] Chang AY, Skirbekk VF, Tyrovolas S, et al. Measuring population ageing: an analysis of the Global Burden of Disease Study 2017. Lancet Public Health. 2019;4:e159–e167.

[2] Marasinghe KM, Lapitan JM, Ross A. Assistive technologies for ageing populations in six low-income and middle-income countries: a systematic review. BMJ Innov. 2015;1:182–195.

[3] Michel J-P, Leonardi M, Martin M, et al. WHO's report for the decade of healthy ageing 2021–30 sets the stage for globally comparable data on healthy ageing. The Lancet Healthy Longevity. 2021;2:e121–e122.

[4] Danemayer J, Boggs D, Ramos VD, et al. Estimating need and coverage for five priority assistive products: a systematic review of global population-based research. BMJ Global Health. 2022;7:e007662.

[5] World Health Organization, United Nations Children's Fund, editors. Global Report on Assistive Technology [Internet]. Geneva, Switzerland; 2022 [cited 2022 May 30]. Available from: https://www.who.int/publications-detail-redirect/9789240049451.

[6] Matter R, Harniss M, Oderud T, et al. Assistive technology in resource-limited environments: a scoping review. Disability and rehabilitation Assistive technology. 2017;12:105–114.

[7] Danemayer J, Mitra S, Holloway C, et al. Assistive Technology Access in Longitudinal Datasets: A Global Review. International Journal of Population Data Science. 2023;

[8] Disability Data Report 2022 [Internet]. Disability Data Initiative. [cited 2022 Jun 23]. Available from: https://disabilitydata.ace.fordham.edu/twentyreport/disability-data-initiative-2022-report/.

[9] Granda P, Wolf C, Hadorn R. Harmonizing Survey Data. In: Harkness JA, Braun M, Edwards B, et al., editors. Survey Methods in Multinational, Multiregional, and Multicultural Contexts [Internet]. Hoboken, NJ, USA: John Wiley & Sons, Inc.; 2010 [cited 2023 Jun 12]. p. 315–332. Available from: https://onlinelibrary.wiley.com/doi/10.1002/9780470609927.ch17.

[10] Gateway to Global Aging Data | Blogs: The Harmonized Longitudinal Aging Study in India (LASI) Public Data Release [Internet]. [cited 2023 May 18]. Available from: https://g2aging.org/blogs?title=lasi-data-release.

[11] Jamali-Phiri M, Kafumba JA, MacLachlan M, et al. Addressing data deficiencies in assistive technology by using statistical matching methodology: a case study from Malawi. Disability and Rehabilitation: Assistive Technology. 2020;0:1–15.

[12] rapid Assistive Technology Assessment tool (rATA) [Internet]. [cited 2022 May 18]. Available from: https://www.who.int/publications-detail-redirect/WHO-MHP-HPS-ATM-2021.1.

[13] Studies on living conditions - SINTEF [Internet]. [cited 2022 Nov 13]. Available from: https://www.sintef.no/en/projects/2000/studies-on-living-conditions/.

[14] Surveys - UNICEF MICS [Internet]. [cited 2022 Nov 13]. Available from: https://mics.unicef.org/surveys.

[15] Living conditions among people with disability in Nepal [Internet]. SINTEF. [cited 2023 Jun 7]. Available from: https://www.sintef.no/en/publications/publication/1431820/.

[16] Nepal Indigenous Disabled Association (NIDA), National Indigenous Disabled Women Association Nepal (NIDWAN, Asia Indigenous Peoples Pact (AIPP). Reply from Indigenous Persons with Disabilities Organizations to the List of Issues in relation to the initial Report of Nepal [Internet]. 19th Session of CRPD Committee; 2018. Available from: https://www.indigenouspeoples-sdg.org/index.php/english/all-resources/resource-materials2/reports-and-publications/75-indigenous-peoples-organizations-submit-reply-to-list-of-issues-for-review-of-nepal-under-convention-on-the-rights-of-persons-with-disabilities/file.

[17] UN Data: Nepal [Internet]. [cited 2023 Jun 7]. Available from: http://data.un.org/en/iso/np.html.

[18] Prasai S, Pant A. Monitoring the Employment Rights of Persons with Disabilities in Kathmandu, Nepal - Asian workplalce approach that respects equality [Internet]. Disability Rights Promotion International (DRPI) & National Federation of Disabled - Nepal; 2018 [cited 2023 Jun 7]. Available from: https://nfdn.org.np/studies-and-surveys/employment-monitoring-eng/.

[19] Poudyal N, Banskota M, Khadka D. Disability in Nepal: Taking stock and forging a way forward [Internet]. UNICEF; p. 33. Available from: https://www.unicef.org/nepal/media/1011/file/Disability%20In%20Nepal.pdf.

[20] World Health Organization. WHO Fact Sheet on Disability and Health [Internet]. [cited 2023 Jun 10]. Available from: https://www.who.int/news-room/fact-sheets/detail/disability-and-health.

[21] Karki J, Rushton S, Bhattarai S, et al. Access to assistive technology for persons with disabilities: a critical review from Nepal, India and Bangladesh. Disability and Rehabilitation: Assistive Technology. 2021;18:8–16.

[22] Groves CC, Poudel MK, Baniya M, et al. Descriptive study of earthquake-related spinal cord injury in Nepal. Spinal Cord. 2017;55:705–710.

[23] Landry MD, Sheppard PS, Leung K, et al. The 2015 Nepal Earthquake(s): Lessons Learned From the Disability and Rehabilitation Sector's Preparation for, and Response to, Natural Disasters. Physical Therapy. 2016;96:1714–1723.

[24] Landry MD, Salvador EC, Sheppard PS, et al. Rehabilitation following natural disasters: Three important lessons from the 2015 earthquake in Nepal. Physiotherapy Practice and Research. 2016;37:69–72.

[25] Mytton JA, Bhatta S, Thorne M, et al. Understanding the burden of injuries in Nepal: A systematic review of published studies. Gao Y, editor. Cogent Medicine. 2019;6:1673654.

[26] Gupta S, Wong EG, Nepal S, et al. Injury prevalence and causality in developing nations: Results from a countrywide population-based survey in Nepal. Surgery. 2015;157:843–849.

[27] Little P, Bridges A, Guragain R, et al. Hearing impairment and ear pathology in Nepal. The Journal of Laryngology & Otology. 1993;107:395–400.

[28] WG Short Set on Functioning (WG-SS) [Internet]. The Washington Group on Disability Statistics. [cited 2023 Jun 7]. Available from: https://www.washingtongroup-disability.com/question-sets/wg-short-set-on-functioning-wg-ss/.

[29] Stevens G, Flaxman S, Brunskill E, et al. Global and regional hearing impairment prevalence: an analysis of 42 studies in 29 countries. European Journal of Public Health. 2013;23:146–152.

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Barriers for Accessing Assistive Products in Low- and Middle-Income Countries (LMICs)

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Abstract. WHO implemented the Rapid Assistive Technology Assessment in 2021. This is a household survey on self-reported use, need and barriers for accessing AT in 35 countries globally. In order to obtain comparable data, all surveys followed guidelines developed by WHO, including national two-stage random sampling of households. The 2021 rATA survey included 32 of a total of 140 LMICs globally. Around 40 % of the total respondents (all countries) estimated travel distance to be <5 km, varying from less than 10 % to almost 60 % among the countries. Around 15 % had to travel more than 50 km, varying from 1.3 % to 37.5 %. More individuals living in rural as compared to urban areas had to travel more than 25 km to get their main assistive product. Gender differences were marginal. By far the most prevalent barrier to access assistive products was "Cannot afford", amounting to 39.9% and varying from 6.7 % to 79.1 % among countries. This was followed by "No support" with 14.3 %, varying from 2.3 % to 36.9 %, and "Not available" with 8.1 %, varying from 1 % to 21.5 %. More barriers were reported in rural than urban areas and women report more barriers than men. Variation between countries in both travel time and barriers is substantial and country-specific service development is needed to guide service development.

Keywords. Assistive products, access, low- and middle-income countries

1. Introduction

Access to Assistive Technology (AT) and relevant services is of great importance for inclusion of persons with functional difficulties in education, employment and social life. The Global Report on Assistive Technology (GReAT), published in 2022 by the World Health Organization (WHO) and United Nations Children's Fund (UNICEF), estimated that 2.5 billion people currently need AT [1]. GReAT further confirmed large unmet needs for AT across the world, and particularly in LMICs. The report presented estimates on access to AT varying from 3% to 90% among individuals who needed AT, with the lowest estimates among the poorest countries. In poor and vulnerable populations, access

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to AT and related services may be a key element in poverty reduction and development of inclusive societies. While a broad systems approach is necessary to ensure access to AT for all, understanding the barriers to accessing AT in LMICs is one important element in systems building.

2. Method: The Rapid Assistive Technology Assessment

WHO implemented the Rapid Assistive Technology Assessment in 2021. This is a household survey on self-reported use, need and barriers for accessing AT in 35 countries globally. To obtain comparable data, all surveys followed guidelines developed by WHO, including national two-stage random sampling of households [3]. While some of the studies were implemented in special populations, most of the studies were representative for the respective countries or in some cases regions within countries. Based on the list of LMICs developed by OECD, the 2021 rATA survey included 31 of a total of 140 LMICs globally[2], including more than 300 000 respondents from all WHO regions. Of these, most were representative studies at national or regional level. The rATA data presented in this paper also includes three high income countries. A few countries' data did not distinguish between urban/rural mainly due to use of telephone for data collection. Because of the dominance and character of spectacles as assistive products, some of the analyses were done with and without spectacles.

3. Method: The Rapid Assistive Technology Assessment

Respondents using assistive products were asked to estimate travel distance to get their main assistive product. While this is not a direct question about barriers, it is used here to represent a potential barrier for people with limited resources. Around 40% of the total respondents (all countries) estimated travel distance to be < 5 km, varying from less than 10% to almost 60% among the countries. Around 15% had to travel more than 50 km. varying from 1.3% to 37.5%. Taking spectacles out of the analyses, the proportion of respondents reporting < 5 km to get their main assistive product increases from 40% to 49%, varying among the countries from 21.6% to 67.1%. A total of 11.5% travel more than 50 km, varying from 2.1% to 39.1%. More individuals living in rural as compared to urban areas travelled less than 5 km (Figure 1).

Gender differences were generally small, although a tendency was found for more males to travel longer than females to get their main assistive product.

[2] Including Upper- and Lower Middle-Income countries and Low-Income Countries according to World Bank classification: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups

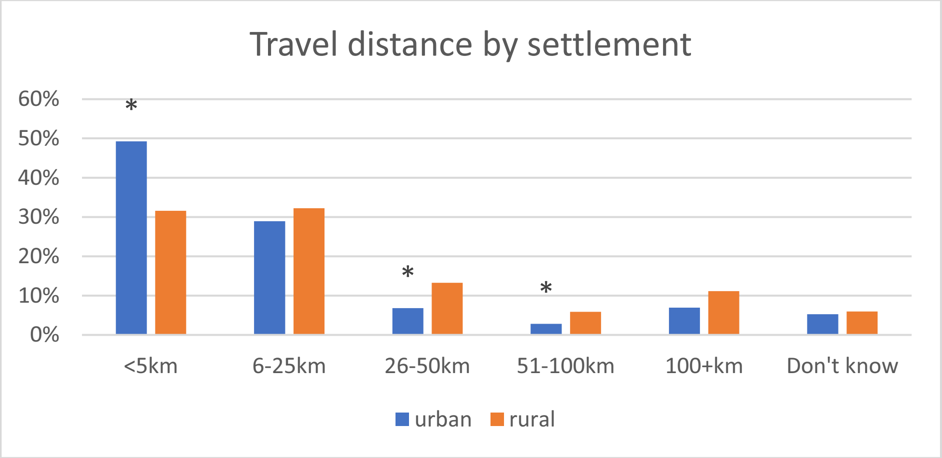

Figure 1. Travel distance to get main assistive product by location (26 countries, N = 49779)

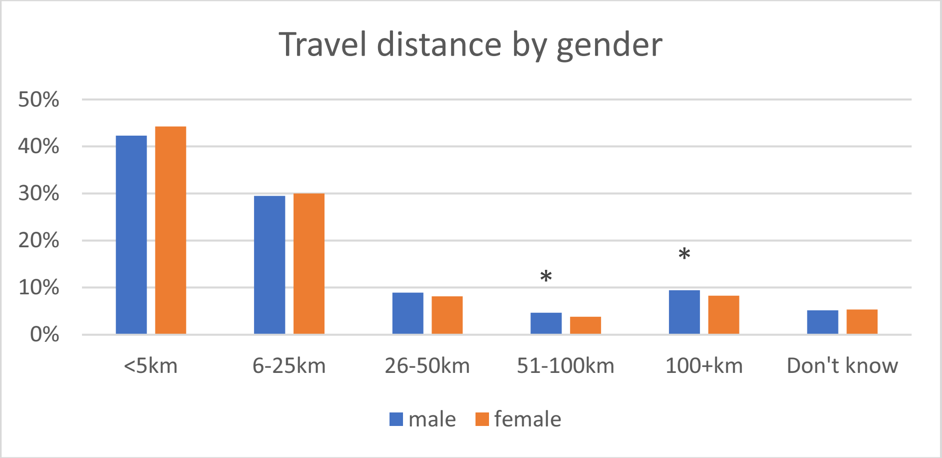

Figure 2. Travel distance to get main assistive product by gender (31 countries, N = 53492)

The survey included the Washington Group Short Set and thus allowed for comparison of travel time between individuals with different levels of functional limitations. Figure 3 compares individuals with "No difficulty" with individuals with at least "Some difficulty". Figure 4 compares individuals with "No difficulty" or "Some difficulty" with individuals with "A lot of difficulty". There is no significant difference when using "Some difficulty" as a threshold, while a weak tendency is present for individuals with severe disability to travel longer than individuals with "No difficulty" or "Some difficulty" (Figure 4), although this was significant only for 100 + km.

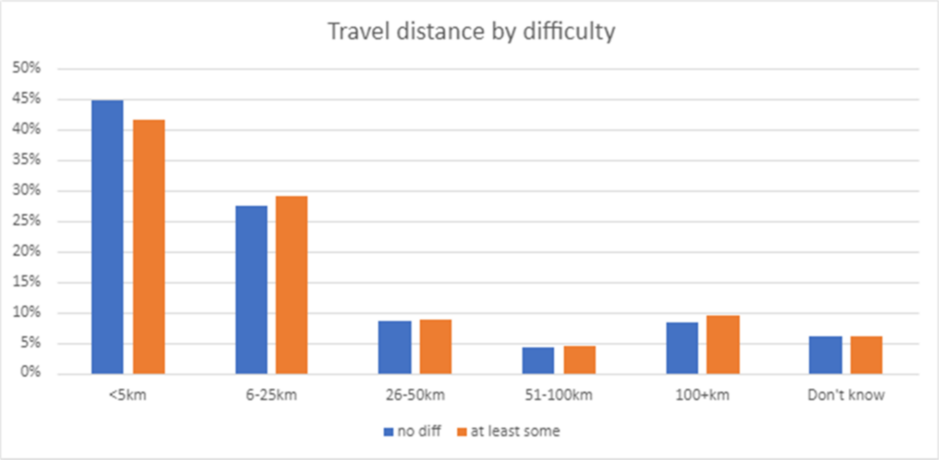

Figure 3. Travel distance by functional difficulty ("No difficulty" compared to "At least some difficulty") (31 countries, N = 53492)

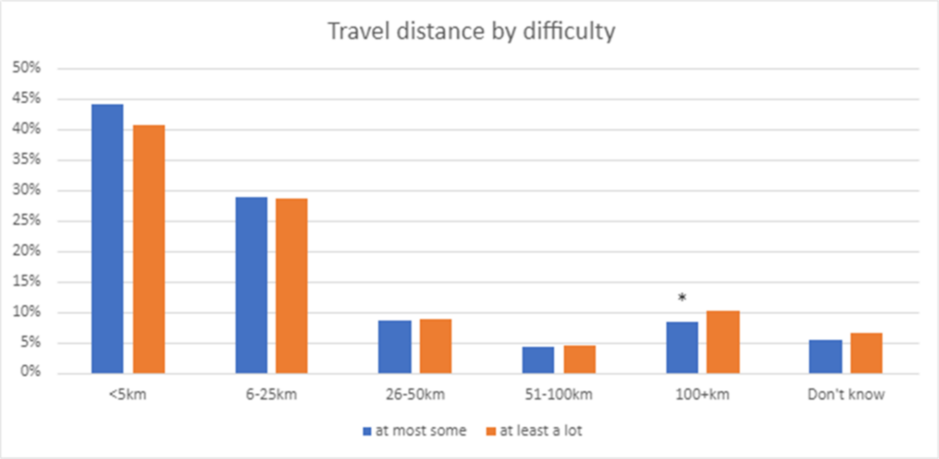

Figure 4. Travel distance by difficulty ("No difficulty" and "At least some difficulty" compared to "At least a lot of difficulty") (31 countries, N = 53492)

The direct question about barriers was "Why don't you have the assistive product that you need?". Responses were restricted to nine answer categories. By far the most prevalent response was "Cannot afford", amounting to 39.9% and varying from 6.7% to 79.1% among countries. This was followed by "No support" with 14.3% and varying from 2.3% to 36.9%, and "Not available" with 8.1% and varying from 1% to 21.5%. When excluding spectacles from the analyses, "Cannot afford" increased to 48%, varying from 11.9% to 85%, followed by "No support" and varying from 4.5% to 41.7%, and "Not available", varying from 1.3% to 40%. Figure 5 shows the overall picture and that the barriers "Not available", "Too far" and "Stigma" scored higher in rural than in urban areas.

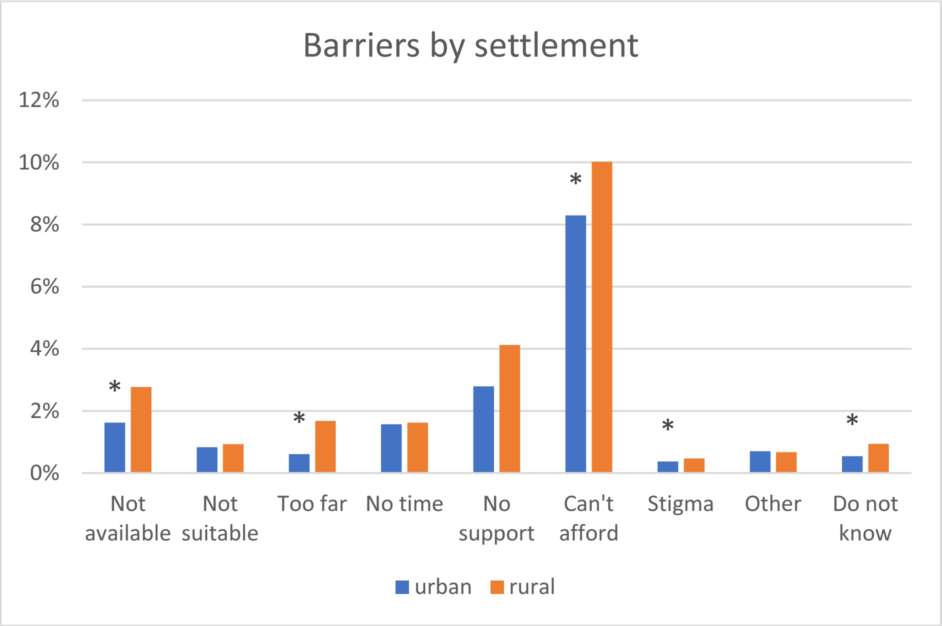

Figure 5. Barriers for accessing a needed assistive product by location (26 countries, N = 49779)

In general, females report more barriers than males. This is particularly the case for the barriers "Cannot afford", "No support", "No time", and "Too far" (Figure 6).

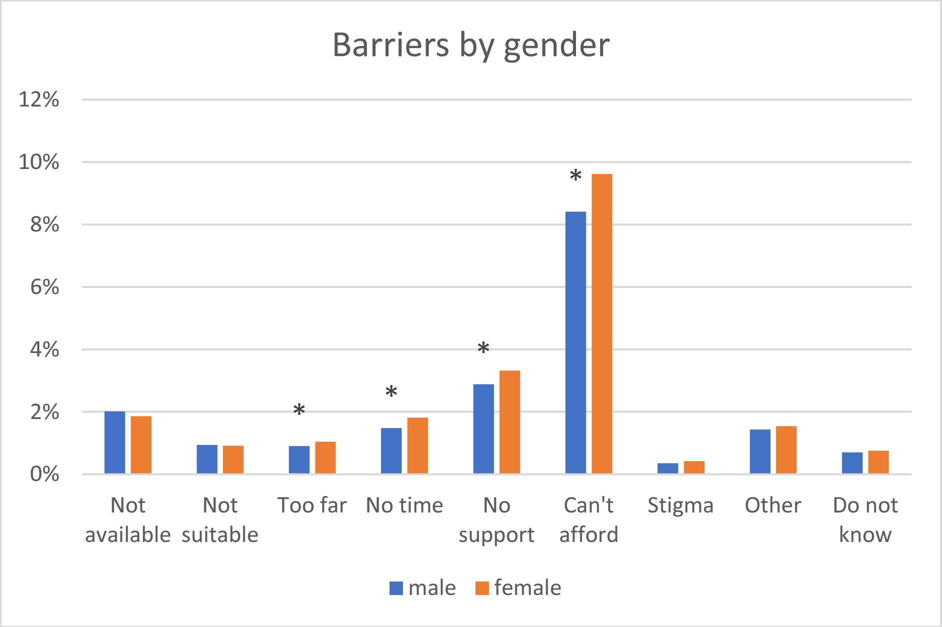

Figure 6. Barriers for accessing a needed assistive product by gender (31 countries, N = 53492)

4. Discussion

The rATA study is unique in being the first global data collection on use and need for AT globally. A thoroughly developed and implemented methodology provides us with a much better picture of the global situation than has been possible with previously limited and not well coordinated research efforts. The self-reported data and unavoidable differences in implementation across countries point to limitations of the study that need to be considered when interpreting results. One aspect worth mentioning here is that awareness about AT will vary between countries, possibly between men and women and between urban and rural locations. This may have some influence on the presented results.

Previous research has shown long travel distance as an important barrier in LMICs for accessing health services, and this applies also to accessing assistive products. As expected, rural populations largely have to travel longer distances, which is often caused by services being located in urban areas. Concerning reasons for not accessing assistive products, the cost is the primary barrier, followed by lack of support and limited availability. More women than men face barriers which is not surprising bearing in mind widespread discriminatory practices against women. Even the tendency for males to travel longer to get the assistive product that they need may be interpreted within the same explanation as women may be restricted from travelling.

The results presented here draw up a global picture. It is important to underline that the variation between countries is substantial and country-specific analyses are needed to guide service development.

References

[1] WHO. Global Report on Assistive Technology. 2022. Geneva: World Health Organization.
[2] Zhang W, Eide AH, Pryor W, Khasnabis C, Borg J. Measuring Self-Reported Access to Assistive Technology Using the WHO Rapid Assistive Technology Assessment (rATA) Questionnaire: Protocol for a Multi-Country Study. *International Journal of Environmental Research and Public Health*; 2021, 182, 3336. https://doi.org/10.3390/ijerph182413336

Advanced Technologies for Inclusion and Participation in Education and Labour

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Exploring Practical Metrics to Support Automatic Speech Recognition Evaluations

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Abstract. Recent studies into the evaluation of automatic speech recognition for its quality of output in the form of text have shown that using word error rate to see how many mistakes exist in English does not necessarily help the developer of automatic transcriptions or captions. Confidence levels as to the type of errors being made remain low because mistranslations from speech to text are not always captured with a note that details the reason for the error. There have been situations in higher education where students requiring captions and transcriptions have found that some academic lecture results are littered with word errors which means that comprehension levels drop and those with cognitive, physical and sensory disabilities are particularly affected. Despite the incredible improvements in general understanding of conversational automatic speech recognition, academic situations tend to include numerous domain specific terms and the lecturers may be non-native speakers, coping with recording technology in noisy situations. This paper aims to discuss the way additional metrics are used to capture issues and feedback into the machine learning process to enable enhanced quality of output and more inclusive practices for those using virtual conferencing systems. The process goes beyond what is expressed and examines paralinguistic aspects such as timing, intonation, voice quality and speech understanding.

Keywords. automatic speech recognition, error correction, word error rate, captions, transcriptions, disability

1. Introduction

During the last few years Higher Educational Institutions (HEIs) across the world increased their use of elearning and video conferencing, in part due to the COVID-19 pandemic [1]. Speaker independent automatic speech recognition (ASR) systems were often used in lecture recording situations for the provision of captions and transcriptions in order to support those students with cognitive, physical and sensory disabilities such as dyslexia, visual and hearing impairments as well as dexterity issues making note taking difficult. Research into presentations in English have also shown that many individuals benefit from these alternative formats such as when the language spoken is not a person's first language and those who may find text-based content easier to work with when concentrating on audio or video output is impossible [2]. However, the audio to text output needs to correctly represent what has been said so users gain maximum benefit and in some countries, such as the United States of America, 99% accuracy rates

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are necessary for captions as a legal requirement [3]. Ideally the output in an academic situation, for example a lecture or seminar, also needs to be transcribed in a timely fashion. This is becoming more achievable with ASR rates of accuracy reaching between 90-95% in ideal classroom settings with native English speakers [4]. But where optimal environments are not possible it is important to discover which aspects are causing an increase in word error rates, whether they are substitutions, insertions or deletions.

In this paper we explore the practical aspects of a series of metrics that are particularly relevant to academic lecture situations with a series of checks that depend on confidence scores as well as values related to comments about the recording situation.

2. Background

Over the years several types of metrics have been used alongside Word Error Rates (WER) such as the Levenshtein distance, Match Error Rates (MER), Word Recognition Rate (WRR), Number of phrase-level insertions, deletions, and mismatches and Concept Error Rates (CER) in order to evaluate the accuracy of ASR[2]. However, none seem to have been used to the same extent as WER despite criticism from many researchers such as those mentioned by Kuhn, Kersken and Zimmermann who add that "ASR output should be validated for real-world use-cases" [5]. So, although WER may provide insights into the accuracy levels of automatic captions and transcriptions [6] there remain other factors that can be explored to provide additional feedback for ASR training models.

Ulasik et al in their work on a Corpus for Evaluating the quality of Automatic Speech Recognition (CEASR) highlighted issues that arise from "disfluencies, speaker and non-speaker noise as well as non-native speech" [7] which may well be representative of the type of problems experienced in an academic setting, but automatically calculated error rates do not necessarily provide reasons why these errors occur [8]. That is why it is important to ensure more information about the speech recordings can be provided to enhance training data.

3. Methodology

As a pilot project 30-minute recordings were taken from four lectures on anatomy, accounting, statistics and counselling, each given by 4 college tutors, two Canadian females and two males, one Chinese and one Canadian in three different lecture theatre settings. The language was English and the automated captions were developed using YouTube[3] with the transcription being copied into a text file. This was compared to the 'ground truth' provided by Otter.ai[4] in the form of speaker notes in order to find the Word Error Rate. Otter.ai was used as it proved remarkably accurate despite the complexity of the content and could easily be manually corrected in situ with the recording running. It also allowed the researchers to clearly see the type of errors that were developing. There followed a review using additional metrics under the main headings of Speaker, Environment, Content and Technology (Table 1). These were listed in an Excel spreadsheet against a 1-3 series where 1 = not confident, 2 = neutral and 3 = confident.

[2] https://symbl.ai/blog/key-metrics-and-data-for-evaluating-speech-recognition-software/

[3] https://www.youtube.com/

[4] https://otter.ai/home

The idea of using confidence levels was based on the need to understand how three evaluators, who were experienced in working with disabled students and creating alternative formats, marked the various metrics as to why each one affected certain types of word error.

Table 1. Additional practical metrics to support the evaluation of ASR outcomes

Speaker	Environment	Content	Technology	Technology
Speech	**Noise**	Complexity	**Hardware**	**Recording**
Pronunciation	Ambient	Unusual	Smart phone	Direct audio
Clarity	noise/continuous	names,	Tablet	recording
Speed	Reverberation	locations, and	Laptop	Synthetic speech
Loudness	Sudden noise	other proper	Desktop	recording
Pitch	Online/Offline	nouns	**Microphone**	Noise-network
Intonation	User device	Technical or	Array	distorted speech
Inflection	Room system	industry-	Headset	**Connectivity**
Accent	Conversation	specific terms	Built-in	Live / Real-Time
Age	Presentation	Out of	Hand held	Recorded
Gender	Single speaker	Vocabulary /	**Camera**	
Use of Technology	Overlapping speakers	not in the	Specialist /Smart	
Too far away /	Multi-speakers	dictionary	Computer	
Near the		Homonyms	Mobile	
microphone			Cont..	

The evaluators, whilst listening to the recording, scored their feelings of confidence against the various metrics, for example if they were confident that the speech was clear or sufficiently loud to be heard by students the score would be 3. A secondary value was added in the form of a comment to clarify the scores given, such as the reason pronunciation may be scored as neutral because the evaluator felt unsure about whether a few sounds were inaudible or mistranslated because English was not the speaker's first language.

4. Findings and Discussion

A review of the findings has yet to be fully undertaken or checked against the developer's decisions as to how many adaptations to the ASR are possible based on the comments. To date, the team have begun to label elements perceived as being the cause of bias based on the matrix and to categorize the training data. This has the potential to highlight the most frequent categories that cause a lack of confidence in the system. Under the speech category pronunciation, clarity and speed received neutral confidence levels for the accounting and counselling lectures and levels of confidence for inflection were neutral across all lectures. This could have been due to the way the evaluators understood this term, namely thinking about the sound of the voice as opposed to questionable changes to word forms[5]. There were differences related to both meanings, so this needs to be clarified in the next iteration of the matrix (Table 2).

One reason that became clear when reviewing the comments was that pronunciation with the aforementioned inflection and accent had an impact. However, developers may be able to preempt likely articulation errors that are typical for those speaking English as a foreign language. There may be specific errors related to some words for instance those that have “th”, “v” and “rl” sounds that do not appear in some Chinese dialects.

5 https://www.oxfordreference.com/search?q=inflection&searchBtn=Search&isQuickSearch=true

Clarity of consonant cluster pronunciation, may also be affected by age which in turn has an impact on WER. The evaluation data highlighted tentative guesses at the age of the presenters and all four lectures received neutral scores for this category although one evaluator was more confident that they could judge the age of two presenters as being between 40-50 years old. Research into the effect of age on the voice tends to have been linked to an older population as described by Kim et al [9]. The authors discuss the concept of a voice conversion framework coupled with linguistic information that may help to reduce issues of bias where the voice files used to generate data sets are mainly from younger adults. It is felt that this framework might improve outcomes where there are multilingual speakers as well as older lecturers.

Table 2. Sample 10 categories with scores based on three evaluators using the 1-3 scale for confidence levels and percentages where all categories were completed.

	Total Scores	**Total Scores**	**Total Scores**			
Category	**1 Not Confident**	**2 Neutral**	**3 Confident**	**%Not Confident**	**% Neutral**	**% Confident**
Pronunciation		6	27		25%	75%
Clarity		4	30		17%	83%
Speed		2	33		8%	92%
Loudness			36			100%
Pitch			36			100%
Intonation			36			100%
Inflection	1	8	21	8%	33%	59%
accent		4	30		17%	83%
age		20	6		83%	17%
gender						100%

Not surprisingly sudden noises and overlapping speakers or multiple speakers affected transcription and caption accuracy and when reviewing the Word Error Rates (WER) these correlated with the 100% confidence levels that these problems affected outcomes. The WER scores for the four lectures were Anatomy WER 6.5%, Accounting WER 14.4%, Statistics WER 9.0% and Counselling WER 18.2%. The higher WERs were matched by lower confidence levels in the completed 10 categories for instance the Accounting lecture had a confidence score of 69 and Counselling 60 compared to 78 and 84 for Anatomy and Statistics consecutively.

This manual process of checking all 48 categories in the matrix would eventually need to be set against a series of automated processes although in some cases, such as the way technology is used, this may not be possible. To date a limitation of the technology checks included the fact that data was collected from live and recorded audio or video output remotely, rather than during face to face lectures. Judgements about use of the microphone came from the sound of the voice and virtual views. For example, in one lecture, as the lecturer moved across the room the voice faded away or in another case the lecturer was wearing a headset and this could be seen on the video so the voice was judged to be very clear with full confidence.

The complexity of terms used in all the lectures was confidently noted with medical terms appearing in the anatomy lecture, but it was the business names and statistical terms that seemed to cause more accuracy problems, although those evaluators, who admitted they knew the terms, felt they would be transcribed accurately when clearly spoken as most were known in English at an academic level. The longer complex words were transcribed accurately in both the YouTube captions and the Otter.ai transcription. The Anatomy lecture having particularly low WER scores of around 6.5% despite the lengthy medical terminology.

The limited evaluation data, collected at the time of writing, highlighted potential matrix changes that would reduce the time taken to complete the checks. These changes would mainly happen in the technology hardware section which was relatively incomplete, with the type of computer used and recording techniques remaining blank. As there were many categories and some were not necessary in certain situations or evaluators did not feel they could fill in the scores, it may be necessary to make public more information surrounding the lecture settings and the way academics use systems.

5. Conclusion

The use of a wider range of practical metrics evaluated by a series of scores and value-added comments has the potential to improve rates of accuracy and tailor ASR for specific requirements. Further information gathered from the data collected will be presented at the conference. In particular it is hoped that the issue of selection bias in ASR [10], that in this case has meant that errors have occurred due to pronunciation differences affected by age, accents and English as a foreign language, can be addressed. ASR providers need to improve accuracy levels by using differently biased input data that is customized, instead of using one single accuracy percentage to denote the performance of the ASR services. External evaluators should be aware of these issues and suggest the need for more inclusive training data to enable corrections to automatically occur in a proactive manner. It is also important to keep raising awareness about best practices for recording settings and to improve the way technology is used by presenters to further enhance ASR caption and transcription outcomes.

Conflicts of Interest

Author Yunjia Li is employed by Habitat Learn UK. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

[1] García-Morales VJ, Garrido-Moreno A, Martín-Rojas R. The Transformation of Higher Education After the COVID Disruption: Emerging Challenges in an Online Learning Scenario. Front Psychol. 2021 Feb 11;12:616059.
[2] Wilson L. Making Online Conferencing Accessible: Platforms, Captions and Transcripts. The Journal of Inclusive Practice in Further and Higher Education. 12.1, 106 Available at: https://nadp-uk.org/wp-content/uploads/2020/12/JIPFHE.ISSUE-12.1-Winter-2020.docx (2020) (Accessed 27 April 2023)
[3] Klein R. U.S. Laws for Video Accessibility: ADA, Section 508, CVAA, and FCC Mandates 3PlayMedia website https://www.3playmedia.com/blog/us-laws-video-accessibility/ (2021) (Accessed 05 March, 2023)
[4] Millett P. Accuracy of Speech-to-Text Captioning for Students Who are Deaf or Hard of Hearing. Journal of Educational, Pediatric & (Re) Habilitative Audiology, 2021;25.
[5] Kuhn K, Kersken V, Zimmermann G. Accuracy of AI-generated Captions With Collaborative Manual Corrections in Real-Time. In Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems. 2023. p. 1-7.
[6] Favre B, Cheung K, Kazemian S, Lee A, Liu Y, Munteanu C, Nenkova A, Ochei D, Penn G, Tratz S, Voss CR. Automatic human utility evaluation of ASR systems: Does WER really predict performance? In INTERSPEECH. 2013. p. 3463-3467.
[7] Ulasik MA, Hürlimann M, Germann F, Gedik E, Benites F, Cieliebak M. CEASR: a corpus for evaluating automatic speech recognition. In Proceedings of the Twelfth Language Resources and Evaluation Conference. 2020. p. 6477-6485.
[8] Wald M. Creating accessible educational multimedia through editing automatic speech recognition captioning in real time. Interactive Technology and Smart Education. 2006.
[9] Kim JW, Yoon H, Jung HY. Linguistic-coupled age-to-age voice translation to improve speech recognition performance in real environments. IEEE Access, 9. 2021. p.136476-136486.
[10] Feng S, Kudina O, Halpern BM, Scharenborg O. Quantifying bias in automatic speech recognition. arXiv preprint arXiv:2103.15122. 2021.

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Intersectoral Development of an Evaluation Tool for the Socio-Professional Rehabilitation Process Adapted to People with Autism

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Abstract. Since there was no French tool adapted to the reality of people with autism enrolled in a work integration program in Quebec, we have modified the Profile of Rehabilitation and Adaptation in a Work Context for People with Intellectual Disabilities according to the scientific literature on autism. Content validity (n=17) and applicability (n=5) were done with success. Result is an Excel compiler containing 3 informative tabs, 10 tabs on the dimensions of work rehabilitation (59 items) and 4 tabs used to compile the results. Socio-professional practicians are welcomed to use this new tool to pursue construct and internal validity.

Keywords. autism, evaluation tool, work integration program, content validity, socio-professional competencies

1. Introduction

Six standardized tools assessing work-related dimensions of individuals with autism have been identified in the scientific literature: the Autism Work Skills Questionnaire

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(AWSQ) [1], the Basic Skill Assessment Tool for Adolescents with Autism Spectrum Disorder" (BSATA-ASD) [2], the Job Readiness Assessment Tool (JRAT) [3], the Maastricht Work Capacity Monitor (MW©M) [4], the Vocational Pre-Requisite Skills Assessment Tool (VOSAT) [5], and the Work Readiness Inventory (WRI) [6]. The AWSQ, JRAT, VOSAT, and WRI are available in English (with instructions for administering them), whereas none of the assessment tools identified have been translated into French. The tools aim to identify an individual functioning profile in different job-related dimensions. Only the AWSQ and the BSATA-ASD were specifically designed for people with autism, while the WRI has just been adapted for people with autism aged from 17 to 29. The others were not designed or adapted exclusively for people with autism. None of the three tools cover all 10 aspects/domains of work rehabilitation as is the case in the PRACT-PDI [7], a tool adapted for persons with intellectual disability: 1-Motivation, 2- Attendance, 3-Relationship with peers, 4-Communication, 5-Attention and memory, 6-Rules and safety, 7-Autonomy, 8- Physical endurance, 9- Handling of tools and machinery and 10-Productivity and quality.

Several psychometric qualities have been demonstrated for the PRACT-PDI by Tremblay et al. in 2012 [7]. The main objective of the PRACT-PDI (translated to Profile of Rehabilitation and Adaptation in a Work Context for Persons with an Intellectual Disability) is to draw a profile of the person in a socio-professional context, to target his or her priority needs and to observe his or her evolution, at three different times, with respect to the intervention plan established by the teams [7]. This evaluation tool can be completed directly on an Excel file with five main sections subdivided into several tabs (presentation, instructions, questionnaire, results and data compilation). The 57-item observation grid questionnaire is divided into 10 dimensions of the person in a socio-professional learning context. The PRACT-PDI is administered after the person has been integrated into the activity or training environment by a socio-professional agent using a 4-level Likert scale refers to the different levels of support (minimal to very important) deployed in the socio-professional settings (day activity center, work shop with lots of support, work in real environment with less support, internship). In order to complete observations, the evaluator is encouraged to ask questions at the person being evaluated, family and employer, and to record comments under each item.

The most comprehensive tool identified is the Maastricht Work Capacity Monitor (MW©M), but it is only in Dutch, it is not specifically for people with autism, and it addresses only 6 of the 10 dimensions of the PRACT-PDI. It is the one that addresses the most dimensions among the 6 identified tools. None of the 6 tools identified contain any mention of encouraging the evaluator to take into account the environment in which the person is being assessed. The failure to consider the human and physical environment and the tools provided to the person are the main shortcomings of the 6 tools identified.

Following these observations, we have proposed these **specific objectives**: 1) To adapt a francophone evaluation tool (PRACT-PDI) considered reliable and valid to the reality of people with autism enrolled in a work integration program; 2) To carry out the content validity of the tool adapted to the reality of people with autism; 3) To test the applicability of the evaluation tool with people with autism in a community setting.

2. Methods

2.1. Research design and participant selection

This study was conducted using three methodological designs for tool adaptation, content validation, and applicability of the assessment tool. The adaptation was done by the principal investigator. The sample of experts was developed at a research team meeting during which members suggested consulting with 8 practitioners (technicians, professionals, and managers) and 9 researchers from various universities interested in autism or employability of people with disabilities. For applicability, three practitioners from *ASD Integration* were solicited, a non-profit organisation which provides an adapted training environment for young people with autism aged 21. They were asked to assess 5 individuals with autism performing assembly or sorting tasks in a workshop at the organization using the paper-based tool. This project received the ethical approval from the CIUSSS-CN's sectoral research ethics committee on rehabilitation and social integration (project 2022-2378).

2.2. Tool adaptation – 35 hours

After reading the book of Poulin et al, in 2020 [8] dealing with autism and the importance of considering the environment, it took 35 hours of work to upgrade the PRACT to ASD and to incorporate the environment aspect. The principal investigator made modifications to the PRACT-PDI tool [7, see Appendix B, p.54-81] in light of the most recent publication in French. Considering the **social, cognitive and sensory specificities** that can influence the functioning of people with autism, she has, in the 10 sections dealing with the dimensions of the person in socio-professional training, modified and augmented the explanatory wording of the scoring of the items and the suggestions for the evaluator's comments to consider the context. She also drafted and added two new items (Reading and Writing) in the Communication section. In total, 413 explanatory boxes were modified (comments in Excel), both in terms of the titles of the domains assessed, each level of rating, and the addition of comments to document the environment and tools in place for the individual. The Beta version was sent to a group of experts to read and identify all the points to be discussed during the focus groups.

2.3. Content validation and applicability of the assessment tool – 6 months

We have conducted 4 focus groups of 3 hours each recorded via the Zoom platform. The mediator (PI) and the co-mediator (research coordinator) collected the opinion of each expert regarding the relevance of the components of each item and the representativeness of the different dimensions in the constructs measured by the tool. A speech-language pathologist listened to the focus group recordings and incorporated the modifications for which consensus had been reached. She then adjusted the content of the first parts of the tool (welcome page, presentation, and instructions), the item labels for the 10 sections of the observation grid, and explanations of the labels and the comments (rf 413 explanatory boxes adapted before). Changes were highlighted so that experts could easily review them and provide their final comments on the first version of the adapted tool. Finally, the research coordinator incorporated the validated changes into the original tool (Excel software) and a student in psychoeducation revised all explanatory wording.

2.4. Applicability – 3 months

A master student asked 3 socio-professional practicians to provide handwritten comments about the tool and potential difficulties encountered during the administration of 5 PRACT-PTSA (Profile of Rehabilitation and Adaptation in a Work Context for Persons with ASD). They all suggest adding *Non applicable* for all the 59 items, and they pointed out the tools that were in place for young people with autism to work. Completion was done over 2 to 4 weeks (3 to 4 hours). Socio-professional practicians knew their trainees more than 2 years. Trainees were aged between 21 and 27 years old and performed tasks like assembly, classification and packaging. These were external contracts granted to the workshop for socio-professional rehabilitation.

3. Results

The experimental version of PRACT-PTSA in Excel software is available for free in the Cirris research products. https://www.cirris.ulaval.ca/produits/pract-ptsa-%e2%94%80-un-questionnaire-pour-dresser-le-profil-de-readaptation-adaptation-en-contexte-de-travail-pour-les-personnes-autistes/. The titles of domains 5, 7 and 8 have been renamed to be more in line with the items assessed. Communication domain has the items *Writing* and *Reading* added (see Table 1).

Table 1. Outcomes of workers with autism in the 10 PRACT-PTSA domains

	Adults with autism (n=5) [1]	
	Mean	Standard deviation
Domains		
1-Motivation (5 items)	72%	25% *
2-Attendance (3 items)	93%	10%
3-Relationship with peers (8 items)	88%	16%
4-Communication (8 items) [2]	87%	13%
5-Conitive skills (9 items) [3]	93%	10%
6-Rules and safety (3 items)	97%	7%
7-Independance (5 items) [4]	75%	26% *
8- Physical demands /endurance (7 items)	90%	10%
9- Handling of tools and machinery (4 items)	95%	11%
10-Productivity and quality (5 items)	79%	21% *
Global	87%	12%

[1] Four males with a mean age of 27 years old
[2] Item *Reading and comprehension* and item *Writing* have been added in this dimension
[3] The original dimension in PRACT-PDI was "attention and memory". It has been renamed
[4] The original dimension in PRACT-PDI was "Autonomy". It has been renamed
[5] The original score in PRACT-PDI was on a 4-level Likert scale : the candidate demonstrates, succeeds or performs almost always (3), regularly (2), sometimes (1), or never (0) the skill, aptitude, attitude or behaviour evaluated. Currently, this rating refers to the different levels of support (minimal to very important) deployed in the socio-professional setting. Non Applicable with Comments section has been added in PRACT-PTSA.
* Standard deviations >20 indicate that some workers have lower scores on these dimensions in their work tasks.

Table 1 presents the results of the applicability of the tool with 5 young adults with autism. We can say that the 5 participants still have to pursue work rehab for Motivation (72% SD 25%), Independence (75% SD 26%) and Productivity (79% SD21%), considering the lower scores and the tool put in places, but there is variability between the them.

Figure 1 shows an example of the domain 8, items 44 and 45, from this Excel questionnaire. For the title, the idea of 'demands' was added, because of the importance to consider what the environment requires in terms of work. The Not Applicable (NA) score was added as an option and socio-professional practicians were invited to tell us why this could not be observed in the context of work rehabilitation. Also, by hovering the pointer over a cell, a note appears. Another major innovation is to invite the socio-professional practicians to write a comment about all the environmental conditions that are disturbing as well as the accommodations put in place. The comment box for the score level 1 of the item 45 clearly indicates what is measured. These definitions are available for each evaluator, then if it is a new evaluator at time 2 or 3 the person have access to the same information to choose the appropriate score. Also, the evaluator can see exactly the evolution of the person, on the same item, even if it is in a different work task, because the same areas of work rehabilitation are always assessed.

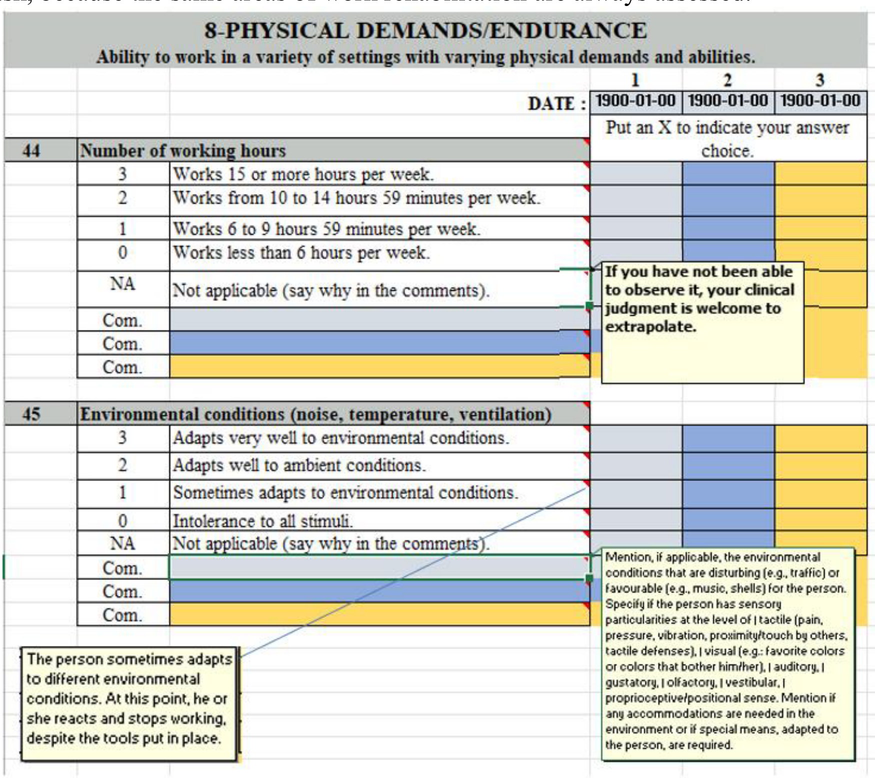

Figure 1. Example of quotation in EXCEL.

4. Discussion and Conclusion

We have met our objectives as we have adapted a francophone evaluation tool considered reliable and valid to the reality of people with autism enrolled in a work integration program; we have carried out the content validity of the tool adapted to the reality of people with autism, and we have proven the applicability of the evaluation tool with people with autism in a community setting. The tool identified with the most comprehensive construct, the MW©M, addresses only six of the 10 PRACT dimensions: attendance/timeliness; peer relationship; communication; memory and attention (cognitive skills in the PRACT-PTSA); autonomy (independence in the PRACT-PTSA); productivity/quality [4]. Regarding the other four dimensions, motivation is assessed only in the VOSAT [5] and behaviors regarding work regulations and safety are addressed only in the WRI [6].

The PRACT-PTSA allows for the assessment of more dimensions of the person's functioning in the learning environment than other tools. It encourages the evaluator to consider all components of a disability situation before assessing the person (e.g., tools in place). The Excel software offers more advantages than other tools.

There are some limits to use the PRACT-PTSA. Several visits to the person with autism being assessed by the clinician are necessary to finalize the assessment (59 items). Completion is done over 2 to 4 weeks (3 to 4 hours). It is not practical with new user or user unknown to the evaluator. It is recommended that the evaluator must have known the client for at least 3 months before completing the evaluation. The PRACT-PTSA does not assess pre-requisites for an internship or work activity.

Future research is needed to demonstrate and, if necessary, improve the construct validity and internal consistency of the PRATC-PTSA. Please, if francophone socio-professional clinicians are willing to participate in the validation until December 2023, just contact the principal investigator to receive the tool and the consent forms. Actually, the tool is in French, but it would be easy to use it for cultural validation in any language, since it is available on the Cirris website.

The collective work of actors from the community, education sector, and health and social services sectors made it possible to validate the content of the PRACT-PTSA, to ensure its applicability in the clinical setting, and then to improve it at every stage of the process. This intersectoral collaboration allowed for the integration of different perspectives and expertise in both the content and form of this innovative tool.

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References

[1] Gal E, Landes E, Katz N. Work performance skills in adults with and without high functioning autism spectrum disorders (HFASD). Research in Autism Spectrum Disorders, 10. 2015.p. 71-77. https://doi.org/10.1016/j.rasd.2014.10.011

[2] Pongsaksri M, Lersilp S, Suchart S. Development and Reliability of the Basic Skill Assessment Tool for Adolescents with Autism Spectrum Disorder. The Scientific World Journal, 2017, ID 2403943. 2017. p. 1-7. https://doi.org/10.1155/2017/2403943

[3] Müller E, VanGilder R. The relationship between participation in Project SEARCH and job readiness and employment for young adults with disabilities. Journal of Vocational Rehabilitation. 2014;40(1):15-26. DOI:10.3233/JVR-130660

[4] Van Ruitenbeek G, Zijlstra FR, Hülsheger UR. . The development of an instrument to measure the work capability of people with Limited Work Capacity (LWC). Journal of Occupational Rehabilitation. 2019;29(1):163-174. https://doi.org/10.1007/s10926-018-9774-x

[5] Jiujias M. Investigating the Development of a Vocational Pre-Requisite Skills Assessment Tool for Adults with Disabilities [mémoire de maîtrise, St. Cloud State University]. St. Cloud, Minnesota.: Culminating Projects in Community Psychology, Counseling and Family Therapy. 2020. https://repository.stcloudstate.edu/cpcf_etds/70

[6] Wittevrongel K, Mitchell W, Hebert ML, Nicholas DB, Zwicker JD. Acceptability of employment readiness measures in youth and young adults on the autism spectrum: a mixed-methods study. Disability and Rehabilitation. 2022;44(16):4319-4331. https://doi.org/10.1080/09638288.2021.1902578

[7] Tremblay G, Paquette G, Desrosiers F. Expérimentation du Profil de réadaptation et d'adaptation en contexte de travail pour les personnes ayant une déficience intellectuelle (PRACT-PDI). 2012. 119 p. https://www.laressource.ca/images/ressources/experimentation_du_profil_de_readaptation_et_dadaptation_en_contexte_de_travail_pour_les_personnes_ayant_une_deficience_intellectuelle_praci-pdi.pdf

[8] Poulin MH, Rousseau M, Bourassa J. L'autisme : comprendre et agir dans une perspective psychoéducative : connaissances et pratiques psychoéducatives. Québec, Québec : Presses de l'Université du Québec. 2020. 255 p.

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Design and Prototyping of a Serious Game on Interactive Tabletop with Tangible Objects for Disability Awareness in Companies

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Abstract. This paper presents elements of user-centered design and prototyping of a serious game. Produced within the framework of the SG-HANDI project, the serious game aims to raise awareness about integration, prevention of professional displacement and job retention of people with disabilities. This serious game is developed on an interactive RFID tabletop with tangible objects. It is intended to be used in a collective context involving one or more facilitators specialized in employment and disability, as well as the company's stakeholders to be made aware of the issue.

Keywords. Serious game, Disability, Accessibility, Employment, Interactive tabletop, User-Centered Design, Tangible interaction, RFID

1. Introduction

Because work and employment are essential for the inclusion of people with disabilities in society, a collective was created in 2021 to launch the SG-HANDI project (Serious

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Game (SG) to raise awareness of integration, prevention of professional disinsertion and retention in employment of people with HANDIcap). Supported by Agefiph, this project is carried out by ARACT Hauts-De-France in partnership with LAMIH-UMR CNRS 8201 laboratory, Serre Numérique (CCI Grand Hainaut), Handyn'Action association, Emploi et Handicap Grand Lille association and HandiExpeRh consulting firm. In order to raise awareness of disability among company's stakeholders (directors, managers and employees, both able-bodied and disabled), this project proposes a user-centered design of a serious game. The serious game is developed on an interactive RFID tabletop associated with tangible objects to encourage company's stakeholders think together about the challenges faced by people with disabilities and find solutions to promote their integration and job retention [1]. A first prototype is realized and will be presented below.

The rest of the paper is structured as follows: Section 2 presents a state of the art on serious games developed for disability awareness. Section 3 describes the methodological approach followed in the project. Section 4 is devoted to the implementation of the SG-HANDI serious game prototype. Finally, this paper is ended by a conclusion and perspectives.

2. State of the art

Serious games have experienced a boom in educational settings and professional training. They have, furthermore, demonstrated their effectiveness as tools that can increase awareness of social and environmental issues [2]. This state of the art presents earlier research in order to portray how serious games can be useful to raise awareness about disabilities.

Search terms selected are: serious game, disability, awareness, management and governance. Papers identified generally cover education sector. Some focus on serious games supporting people with disabilities in their learning [3] [4] [5] [6]. Others cover the topic of protecting people with disabilities from aggression and bullying especially at school. Among these serious games, we describe: Stop bullying now [7], Conectado [8] and The world of Empa [9].

"Stop bullying now" [7] is a serious game designed to help parents, caregivers and teachers to respond in a supportive manner to their children or students to bullying incidents. The game lasts approximately 30 minutes and can be played from any location at any time. It is structured in six levels. Each level presents a character with disability/disabilities in a certain situation where different bullying behaviors take place. The player is required to take the perspective of the character and the carer. Questions are prompted after each situation (short clip). Points are awarded if the player answers correctly. For incorrect answers, points are detracted and feedback is also offered. Authors test and show the effectiveness of the serious game in promoting autonomy-supporting strategies for adults with disabilities at high risk for bullying.

Conectado [8], is a serious game initiated by the e-UCM research group of the Complutense University of Madrid, Spain. The game is designed for youths between the ages of 12 and 17 to raise awareness against bullying and cyberbullying. The player is put in the situation of a student who suffers from bullying and cyberbullying in a daily basis after arriving in a new school. Conectado has been developed to provide a common experience to students, placing them in the role of victims. It is intended to be used in class as a tool for teachers, allowing them to motivate a controlled discussion and make students reflect on the problems of bullying and cyberbullying. Researchers experimented the game with 257 students in three different schools. A previous and a subsequent test composed of 18 questions were proposed to students to measure the impact of the game on their perception of harassment and cyberbullying. Promising results were obtained.

The world of Empa [9] targets students in order to increase their empathy and mitigate prejudices towards people with special needs. First, the player encounters a number of characters, namely a blind boy, a girl with multiple disabilities, a father, a mother, a baby, and a boy without disabilities. Over six levels, questions are asked about the main educational and interactional challenges encountered by the characters in different situations. Several answers are provided. If players answer by choosing an option that reflects an empathic and sensitive attitude, they will be rewarded with points and move on to the next level. Otherwise, they will lose points and have to retry to complete the level. Throughout the game, players can see their score. Once the game is completed, players receive feedback on their measure of sensitivity, empathy, and reactivity.

People's inappropriate behavior and lack of sympathy can have serious consequences on the mental and physical health of people with disabilities, as well as on their ability to participate fully in social, economic and cultural life. Works cited in the state of the art are centered on awareness people about the impact of bullying and the promotion of a tolerance culture to facilitate the social integration of people with disabilities. We think that paying attention to the psychological aspect is extremely important, but not enough for the social and economic integration of people with disability. In this research work we are particularly interested by these two research questions:

QR1: How to use a serious game to promote the integration and the maintain of people with disabilities in companies?

QR2: How a serious game can help company's stakeholders think together about the challenges faced by people with disabilities and find solutions to promote their integration and job retention?

Our contribution consists of proposing a serious game developed on an interactive tabletop associated with tangible objects to let aiming to raise awareness about integration, prevention of professional displacement and job retention of people with disabilities. The rest of the paper is devoted to the description of the tool and its evaluation.

3. Methodology

The SG-HANDI objective is to make employers, employees and company decision-makers aware of the obstacles faced by people with disabilities in the workplace, using a fun and interactive tool: a serious game. The initial thoughts around the SG-HANDI serious game explored various avenues. Initially, a decision-making tool was considered. One possible direction was to allow company's stakeholders to think together about possible solutions and thereby secure the work situation over time by avoiding risks of inaptitude. The partners, then, turned towards creating awareness-raising actions for company's stakeholders. Actions intend to involve them simultaneously around an interactive tabletop with tangible objects. Through this tabletop, pedagogical content is provided. It allows for prior imagining of compensation or accommodation needs in companies, whether they be technical or organizational.

In its current version, the SG-HANDI game is designed to be used in the context of an awareness session involving one or more facilitators and people from the company to be sensitized. The serious game is developed in an interactive RFID tabletop with tangible objects (inspired by previous works [10] [11] [12]). This proposition concerns the first research question (RQ1). It suggests a set of challenges (quiz, drag-and-drop, betting pieces, scenes, etc.) to be solved as a team. These challenges cover several facets of the disability field: basic concepts, legislation, company resources, professional disinsertion, compensation, etc. Members of each team (company's stakeholders) have to discuss, reflect and collaborate together to succeed challenges and get points. A facilitator specialized in employment and disability is present throughout the game to moderate discussions and debrief players.

Referring to ISO 9241-20, a design process centered on facilitators specialized in employment and disability was followed as shown in Figure 1. This process consists of seven phases, beginning with (1) the overall organization of the project and acculturation, followed by (2) defining objectives and (3) collecting requirements for a user experience in the service of the awareness-raising message. Later on, there is the (4) production, scripting, and gamification of awareness-raising content. Then, (5) the evaluation of the prototype is necessary in order to (6) improve it. Finally, (7) the serious game is ready to be deployed and disseminated.

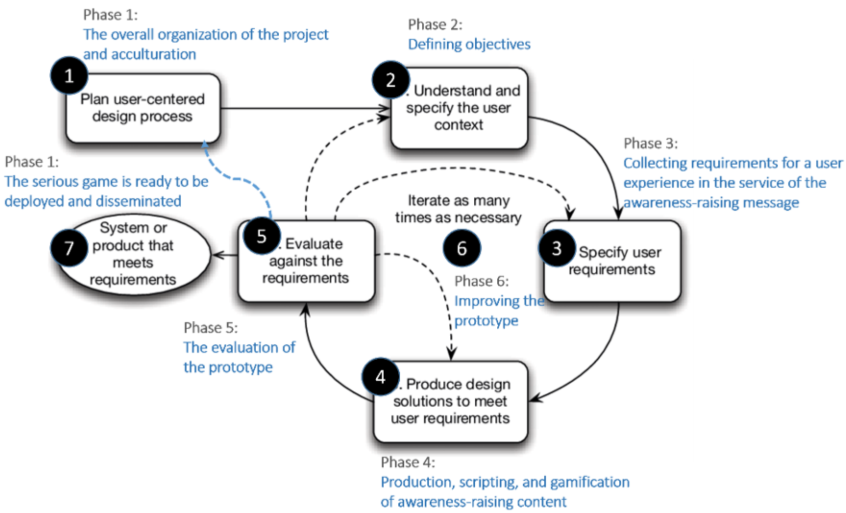

Figure 1. User-centered design approach inspired by the ISO 9241-20 standard for the serious game SG-HANDI.

4. Implementation

In this section, the basic principles of the serious game SG-HANDI are presented. A description of the prototype is also provided.

4.1. Basic principles

The SG-HANDI is designed to be used in disability awareness session in companies. A facilitator (or team of facilitators) presents the serious game, and the game begins as illustrated in Figure 2. Around the TangiSense interactive tabletop (produced by the Rfidees company), two or three teams are formed. Each team chooses its pawn (a tangible object in the form of a 3D-printed character equipped with an RFID tag) [11] [12].

Figure 2. The SG-HANDI basic principles.

In the first phase, teams compete with each other in challenges with countdowns. In the second phase, players get together as one team. They collectively choose a sector of activity (logistics, commerce, or industry) and put themselves in the shoes of a company (human resource manager, service manager, etc.) looking to hire a new employee. To achieve this, the game proposes a set of playful and competitive challenges with disability considerations.

Throughout the game, the facilitator moderates discussions around themes and challenges. At the end, the facilitator proposes a debriefing and concludes the awareness-raising session.

4.2. Description of the prototype

After preparing and evaluating paper and digital mockups, the serious game was developed using (1) a middleware layer in Java to collect data from the interactive tabletop (position and identification of RFID tags on different readers. These tags are stuck on tangible objects handled by the participants) and (2) an application layer developed using a real-time game engine (Unity).

The prototype proposes several challenges that stimulate intellectual cooperation to promote disability awareness in the workplace. These challenges are grouped into five themes: (1) situational disability, (2) disability typologies, (3) disability recognition, (4) compensation and (5) job displacement. For each theme, a set of tangible objects are provided to be used in the resolution of challenges. Figure 3(a) presents examples of SG-HANDI tangible objects: terms related to different types of disability, team pawns (3D-printed characters) and disability logos.

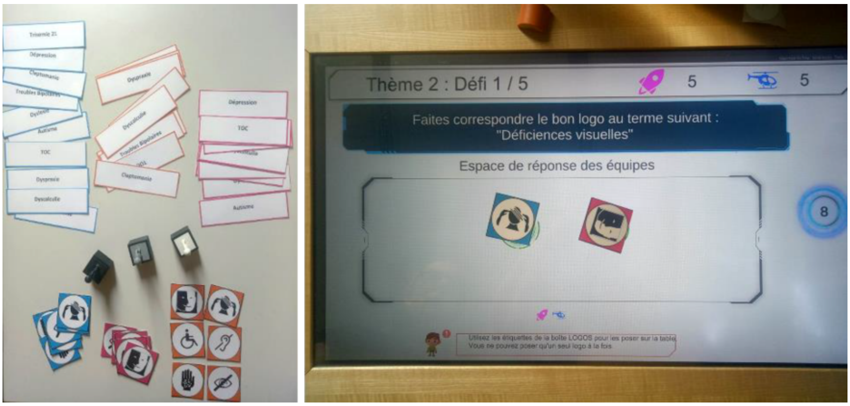

Figure 3. (a) Examples of tangible objects used in the serious game SG-HANDI, (b) example of page-screen. "*Faites correspondre le bon logo au terme suivant : Déficiences visuelles*" translated by: "Match the correct logo to the following term: Visual impairments"

Participants, then, attempt to apply what they have learned the challenges to a real-life scenario, such as hiring a new employee in the logistics, commerce, or industry sector. In order to achieve this goal, they get into one team and must complete six challenges: (1) Job description, (2) Job offer, (3) CV sorting, (4) The interview, (5) Communication and (6) Testimony.

5. SG-HANDI evaluations

The SG-HANDI serious game prototype is nearing completion. It has undergone preliminary evaluations in laboratory and first on-site evaluations.

Preliminary evaluations in laboratory, shown in Figure 4, involved human-computer interaction specialists and business trainers (facilitators) specialized in employment and disability, who themselves are future users of the system. Overall, the prototype was appreciated by the evaluators. They found it fun and easy to use in collective contexts. A set of recommendations were also formulated with the aim of improving it. Among these recommendations can be cited: (1) reformulate certain instructions to remove ambiguity and facilitate the resolution of challenges, (2) provide shorter texts, (3) provide shorter videos, etc.

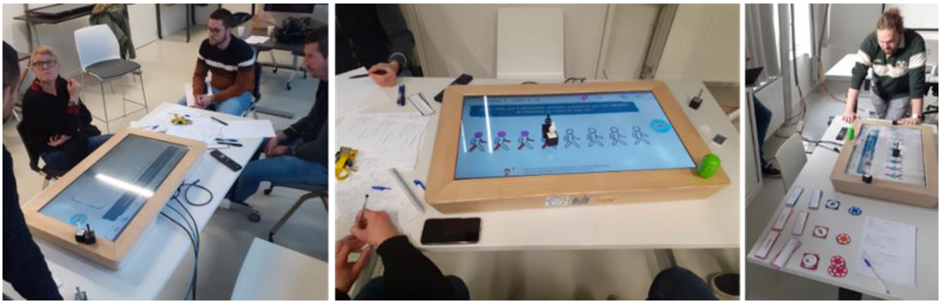

Figure 4. SG-HANDI undergoing preliminary evaluations in laboratory.

First on-site evaluations were made in disability awareness sessions during the annual event "*Printemps du handicap*" (translated by “Spring of disability”) which takes place in the north of France. Each awareness session involved a facilitator and participants from several companies and organizations (Figure 5). Globally, both facilitator and participants feedbacks were very encouraging.

Figure 5. SG-HANDI undergoing on-site evaluations.

6. Conclusion

This paper presented a user-centered design of the SG-HANDI serious game. This one is implemented on an interactive RFID tabletop with tangible objects. The objective of the serious game is to encourage company's stakeholders think together about the challenges faced by people with disabilities and find solutions to promote their integration and job retention. Globally, preliminary evaluations in laboratory and on-site evaluations (in real use) were positive. Actually, we are in the process of analyzing the data collected from the on-site evaluations (linked to the second research question: RQ2). In the future work, details about analysis results will be provided.

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References

[1] Mourali Y, Barathon B, Colin MB, Chaabane S, Fassi R, Guerrier Y, Guilain D, Kolski C, Lebrun Y, Lepreux S, Sauve J. Conception centrée utilisateur d'un jeu sérieux sur table interactive avec objets tangibles: application au handicap en entreprise. In IHM'23-34e Conférence Internationale Francophone sur l'Interaction Humain-Machine. 2023; April, Troyes, France.
[2] Boyle EA, Hainey T, Connolly TM, Gray G, Earp J, Ott M, Lim T, Ninaus M, Ribeirto C, Pereira, J. An Update to the Systematic Literature Review of Empirical Evidence of the Impacts and Outcomes of Computer Games and Serious Games. Computers & Education 2016;94:178–192. Available from: https://doi.org/10.1016/j.compedu.2015.11.003.
[3] Alaribe, I. Design a Serious Game to Teach Teenagers with Intellectual Disabilities How to Use Public Transportation. Procedia - Social and Behavioral Sciences 2015; 176:840–845. Available from: https://doi.org/10.1016/j.sbspro.2015.01.548.
[4] Derks S, Willemen AM, Sterkenburg PS. Improving Adaptive and Cognitive Skills of Children with an Intellectual Disability and/or Autism Spectrum Disorder: Meta-Analysis of Randomised Controlled Trials on the Effects of Serious Games. International Journal of Child-Computer Interaction 2022;33: 100488. Available from: https://doi.org/10.1016/j.ijcci.2022.100488.
[5] García-Redondo P, García T, Areces D, Núñez JC, Rodríguez C. Serious Games and Their Effect Improving Attention in Students with Learning Disabilities. International Journal of Environmental Research and Public Health 2019;16(14):2480. Available from: https://doi.org/10.3390/ijerph16142480.
[6] Papanastasiou G, Drigas A, Skianis C, Lytras MD. Serious Games in K-12 Education: Benefits and Impacts on Students with Attention, Memory and Developmental Disabilities. Program 2017;51:424-440. Available from: https://doi.org/10.1108/PROG-02-2016-0020.
[7] Lievense P, Vacaru VS, Liber J, Bonnet M, Sterkenburg PS. “Stop Bullying Now!” Investigating the Effectiveness of a Serious Game for Teachers in Promoting Autonomy-Supporting Strategies for Disabled Adults: A Randomized Controlled Trial. Disability and Health Journal 2019;12(2):310–317. Available from: https://doi.org/10.1016/j.dhjo.2018.11.013.
[8] Morata AC, Morán MF, Ortiz IM, Manjón BF. Conectado: A Serious Game to Raise Awareness of Bullying and Cyberbullying in High Schools. 2018.
[9] Sterkenburg P, Olivier L, Van Rensburg E. The Effect of a Serious Game on Empathy and Prejudice of Psychology Students towards Persons with Disabilities. African Journal of Disability 2019;8(1):1-10. Available from: https://doi.org/10.4102/ajod.v8i0.328.
[10] Vispi N, Lebrun Y, Lepreux S, Chaabane S, Kolski C. Simulation on RFID Interactive Tabletop of Working Conditions in Industry 4.0. In Service Oriented, Holonic and Multi-Agent Manufacturing Systems for Industry of the Future; Borangiu T, Trentesaux D, Leitão P, Cardin O, Lamouri S, editors; Studies in Computational Intelligence; Springer International Publishing: Cham, 2021; p. 343–354. Available from: https://doi.org/10.1007/978-3-030-69373-2_24.
[11] Kubicki S, Lepreux S, Lebrun S, Dos Santos P, Kolski C, Caelen J. New Human-Computer Interactions Using Tangible Objects: Application on a Digital Tabletop with RFID Technology. In Human-Computer Interaction. Ambient, Ubiquitous and Intelligent Interaction; Jacko JA, editor; Lecture Notes in Computer Science; Springer: Berlin, Heidelberg, 2009; p. 446-455. Available from: https://doi.org/10.1007/978-3-642-02580-8_49.
[12] Lebrun Y, Adam E, Mandiau R, Kolski C. A Model for Managing Interactions between Tangible and Virtual Agents on an RFID Interactive Tabletop: Case Study in Traffic Simulation. Journal of Computer and System Sciences 2015;81(3):585-598. Available from: https://doi.org/10.1016/j.jcss.2014.11.011.

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Using Personas to Raise Acceptance of Digital Tools in Social Organizations – Introducing the Easy Reading Framework

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Abstract. The Easy Reading Framework is a digital tool that can be used to make existing web pages accessible to the individual needs of a wide range of people. The core of this Framework is a toolbar, which currently includes 13 different functions. The potential for multiple applications of the Easy Reading Framework is being investigated and promoted in the recent Easy Reading follow-up project "EVE4all". In this project, Personas play an important role in the first project phase to raise end-user acceptance. Personas represent specific target groups and share the same characteristics, traits, social environments, and circumstances as the intended target group. Working with this method enables developers and project participants to identify with the users of their products and their lifeworld. Our project shows that this method can be used to reflect on and use the introduction of any technology in institutions in a theoretically well-founded way. Thus, this paper aims to illustrate how this method can be successfully transferred into the pedagogical context and show how this method's usage can contribute increasing user acceptance.

Keywords. Technology acceptance, assistive technology, Easy Reading, Digital Media, Persona, inclusive methodology

1. Introduction

Today's society is an always-on-society, meaning there is no place or situation where technologies or digital media are not used [1, 2]. However, despite the increasing Internet usage in Germany and worldwide [3, 4], certain groups of people (e.g., older people, people with disabilities, people with low levels of formal education or financial resources) are still excluded from opportunities of Internet usage [5, 6] and face digital barriers which can result in digital divides [7, 8] and are threatened with exclusion from instruments of participation and empowerment in the digital society and, in turn, reinforce social inequalities [8–10].

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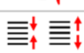
The State Report on the implementation of the UN-CRPD in Germany [11] and the current Participation Report [12] show that the lack of ICT accessibility is still one of many reasons for digital exclusion. To counter the existing lack of ICT accessibility, different measures and strategies can be undertaken. This paper will present the usage of Personas as a method for early identification of opportunities and risks of using digital technology for pedagogical and educational user scenarios [13]. This paper aims to illustrate how this method can be successfully transferred into the pedagogical context and show how this method's usage can contribute to the increase in user acceptance. To reach this aim, the EVE4all project and the Easy Reading Framework are used as an example. In this paper, the conceptual work with Persona Scenarios for use in social contexts will be presented using the example in the EVE4all project. The project and the Easy Reading Framework will be presented first for a better understanding.

2. The Easy Reading Framework

The Easy Reading Framework is a digital tool that can be used to make existing web pages accessible to the individual needs of a wide range of people. The core of the Easy Reading framework is a toolbar, which currently includes 13 different functions and can be divided into four categories (see table 1).

Table 1. Easy Reading Functions (Own Figure)

Category	Symbols	Meaning
Functions for reading a website		Highlights text passages
		Reading aloud function
		Displays web pages centered and without pictures or advertisement
Functions for a better understanding of websites		Adds symbols to a paragraph (ARASAAC)
		Adds an image for a chosen word
		Adds a short explanation for a given word
Functions to customize appearance		Changes font sizes
		Changes contrasts
		Changes line spacing
Others		Translates websites into eight other languages (English, France, German, Spanish, Swedish, Turkish, Russian, Ukrainian)
		Enables own additions to the content (e.g. add questions to a web page, insert your own translation, etc.)

An international, inclusive research team developed the Easy Reading Framework in a research project from 2018-2020, funded by the European Union's Horizon 2020 [14]. The participatory research approach enabled the development of the tools according to the needs of people with disabilities, who were involved in the development process of the Toolbar in all project phases. The Easy Reading Framework aims at a paradigm shift. The accessibility of web pages no longer depends solely on the efforts of website owners. It is more a matter of people with support needs being able to decide which settings they need to understand the content of existing web pages. This paradigm shift increases the potential for minimization of digital divides caused by lack of accessibility, as criticized by the current participation report and the German state report [11].

The potential for multiple applications of the Easy Reading Framework is being investigated and promoted in the recent Easy Reading follow-up project "EVE4all – Einfach Verstehen für Alle" (EVE4all – Easy understanding for all), which is funded by the German Ministry of Education and Research for the funding period of two additional years (August 2022 to July 2024). One of the project´s goals is to develop a sustainability carrier model by exploring strategies to ensure the sustainable perpetuation of Easy Reading. For Easy Reading to be permanently established in practice, technological and financial support must continue to exist after the end of the project. Another project goal is identifying different user groups and exploring application scenarios for Easy Reading.

The range of application scenarios and the potential user groups are diverse. For example, for people with visual impairments, reading difficulties, reading beginners, and people with migration background, Easy Reading can support finding and understanding information on the Internet (for example, when doing homework, looking for new hobbies, or health information). The use of Easy Reading is also conceivable in schools and in formal education context in general. This diversity inspired the project team to use the Personas method in the initial conceptual phase of the project to cluster possible user groups and their respective needs with regard to Easy Reading use and to create potential application scenarios. How and on what basis these Personas were developed is explained below.

3. Personas

Personas are fictional characters or archetypes created as realistically as possible [15]. They are based on relevant information from potential and real users and are often used in marketing or developing software and medical devices [13, 16, 17]. Personas represent specific target groups and share the same characteristics, traits, social environments, and circumstances as the intended target group [15, 17]. To create a Persona, the characteristics and other attributes of the target group must be researched and elaborated.

The Persona description should include information about the following: Profession, Family, Educational background, Sex & Gender, Age, Origin, Place of residence, living conditions, Technical skills, and Aims/Wishes. However, other categories can also be created depending on which characteristics are essential for a specific Persona [17]. In our research, we add the disability of a person to the Persona characteristics, considered in interaction with factors from the environment (e.g., barriers, influence factors).

In software development, Persona scenarios are used to design accessible and user-orientated technologies. Working with this method enables developers and project participants to identify with the users of their products and their lifeworld [13, 18].

In the EVE4all project, 13 Personas were developed, each with fictitious hobbies, family backgrounds, and barriers to Internet use. Overall, the development of the Personas can be divided into three phases, which took a total of about six months of the project duration:

1. Systematic literature research
2. Pre-Test with partners of the project
3. Adaptation of the Personas

The first development phase included systematic literature research about digital barriers among a wide range of people in our society. The guiding research questions were:

- What barriers do predefined groups of people encounter when using the Internet?
- What applications do these groups of people use on the Internet?
- How could Easy Reading support them and reduce existing barriers?

For the systematic research, groups of people were defined who are affected by digital divides [19], including, for example, people with intellectual disabilities, seniors, reading beginners, but also people with a migration background, and many more. Additionally, a first Persona, which can function as a multiplier, was developed.

To check the validity and theoretical foundation of the developed Personas, they were discussed with some practice partners of the project in an online event. This event aimed to determine if the practice partners could find the barriers and characteristics of the theoretical Personas in the behaviors of actual clients in their institutions. After this meeting, Personas were adapted and combined in a published "Personas catalog". To give an example, one Persona is presented in more detail below:

Gerda Vogelweid is one of the 13 developed Personas in the Eve4all Project. The catalog contains a short profile for each persona, including age, hobbies, character, media usage, and life circumstances. Gerda, for example, is a retired senior who lives in an institution for the elderly. She is a person who is open to new things, likes to listen to music, and quickly becomes frantic when she is unsure. Her two children gave Gerda a smartphone, but she rarely uses it. Additionally, she has a computer in her room. Her poor eyesight and short concentration span cause her to have barriers when using her smartphone and her computer. However, she would like to use the smartphone more often to stay in touch with her family. She would also be interested in reading books or magazines on her computer.

Figure 1 Example of a Persona [20]

Based on the development phases described above, the project team assigned this Persona digital barriers, participation desires, and information about current media use. The central question now is how Easy Reading can support Gerda in her participation desires.

The reading aids (for example, the reading ruler) and the contrast settings and font size changes can help compensate for the visual impairment and support concentration. These three tools could help Gerda use her computer more often for the applications she would like. In this way, Personas were developed for very different groups of people to combine the barriers and current media use with the possible life situations of potential users and to derive possible applications for Easy Reading. After this first conceptual project phase, the Eve4all project team starts with the practical phase. This means training sessions on Easy Reading will be offered throughout social institutions to give participants the basic skills to use the software. The project team uses the Personas to be better prepared for the training and to get an idea of how they can meet these people in the training sessions and provide them with concrete support even before their first contact. As a result of this project phase, all developed Personas were summarized in a catalog and published [20].

The purpose of this paper is to show that the application of this method is also possible and usable outside the software development context to determine what needs, opportunities, and barriers may arise when using technologies and digital media in the social context.

4. Transfer into Practice

An essential prerequisite for creating a sustainable transfer into practice is establishing a high level of acceptance in social institutions right from the start. Employees often react to operational changes with fundamental skepticism as existing routines and habits are questioned. Changes are often accompanied by unclear or new work situations that must be mastered. This skepticism is not synonymous with a lack of acceptance but initially expresses ignorance and the resulting uncertainty, which must be considered by the facility management [21]. The development of Personas, which correspond, for example, to the different characters of the employees and those of the people with disabilities in the facilities, can help to understand the different needs already at the first steps of the Easy Reading introduction and to reduce existing barriers of user acceptance.
Thus, this paper will discuss the following research questions.

1. What is necessary to achieve acceptance of users, multipliers and decision-makers throughout the sustainable technology implementation process in social institutions?
2. What application opportunities do Personas scenarios offer in the pedagogical and educational context?

Barriers to the sustainable introduction and use of new technologies can be very diverse. For example, uncertainties regarding data privacy, the integration into existing networks of social institutions, anxiety about leaving familiar routines and unfamiliarity with new technologies. The examples show that promoting acceptance of new technologies can be considered at two levels:

- Stakeholder level: end users, multipliers, decision-makers
- Establishment progress: planning of the introduction (advertising), implementation of the introduction (acceptance), sustainable continuation (transfer concept)

In order to actually and sustainably break down acceptance barriers, the Personas are designed to be used throughout the entire process of introduction and transfer, addressing different target groups as needed. In the following, it is shown which Personas can be used at which stage of establishment progress:

4.1. Stakeholder level

In social institutions, different target groups are directly affected by the establishment of new technologies. The groups differ – among others - in their interest in the technology, their ideas of how to use it, and their barriers to user acceptance.

On the one hand, end users who first need an idea of how they can make a technology usable for them. In order to achieve the highest possible level of identification through the Personas, they represent a profile of the potential users as described above. The connection to Easy Reading is made via suggestions on how and which tools could support the person and remove digital barriers.

On the other hand, during the development process of the Personas and the first transfers into practice, it became obvious that also other Personas with other backgrounds and interests (e.g. facility managers, IT employees in the institution) a different kind of Personas could be useful during the implementation process.

Also, multipliers and decision-makers can be addressed with the Personas. Here, the Personas should give the multipliers an idea of how Easy Reading can support existing routines and habits. Again, the Personas contain a realistic multiplier profile and provide ideas on using Easy Reading in their professional daily live. For example, how a teacher could use Easy Reading to differentiate their lessons according to the needs of their students.

The decision-makers are the last group to address to reduce barriers to acceptance. Decision-makers open the doors in the institutions to ensure that technology can be used sustainably and is financially and technologically secure. For example, they could be IT staff, managing directors, or financial supporters. These Personas also outline a short profile, but also anticipate questions that may become relevant in the implementation process of Easy Reading.

In addition to addressing different groups of people, the establishment progress in which the Personas are used is also crucial for reducing acceptance barriers.

4.2. Establishment progress

Technology acceptance research shows that acceptance must be supported differently (strongly) in different phases [21]. Therefore, the Personas are designed so that they can be used at different stages in the establishment progress as well as in different contexts of the establishment of Easy Reading.

The first phase is perceiving Easy Reading and learning about its potential (see section 3).

In a second phase, the potential of Easy Reading for the own institution is to be perceived in a low-threshold way. The aim is to show how accessibility barriers can be removed and how Easy Reading can be integrated into routines. With the Personas, the potential usefulness of Easy Reading is demonstrated. Caregivers and professionals can get an impression of Easy Reading without testing it in their institution first. In tutorials and courses, Personas are used to get a more hands-on- impression rather than just presenting the tools. Furthermore, through participative research, developing Personas with the staff/Caregivers can also help to work out potential use contexts and scenarios.

A final phase, which the Personas can address, is about the sustainable permanence of a technology. Here, it is particularly important that the people responsible for the successful and long-term establishment of Easy Reading in the social institution are informed transparently about the conditions of long-term implementation, know about potentials and risks, and have solution options ready for expected barriers to implementation. In addition to the Personas, a so-called requirements catalog for sustainable sponsorships was developed here, which, in support of the Personas, should transparently present the strategies and conditions of permanence and provide a good basis for corresponding negotiations.

5. Conclusion

In the context of the EVE4all project, the Personas described above were developed and validated for the introduction and sustainable continuation of Easy Reading. The Personas are intended to sustainably break down barriers to user acceptance in order to make the benefits of Easy Reading accessible to a broad target group.

It is also conceivable to develop them not only for the group of potential end users but also for people who have decision-making power in the facilities or have the task of implementing Easy Reading. These can be people on the management level with different demands and attitudes towards using digital media in their institutions than the end users (e.g., data protection). But they may also be IT staff who have to install the software framework on the institutions' servers and who, in turn, have to consider specific aspects. The developed personas can also serve as an example for other projects to identify different (user) types, e.g., to develop workshops or trainings, or to identify digital barriers in advance, derive strategies for action, and increase the acceptance of all stakeholders from the outset by addressing their needs at an early (project) stage.

Working with personas, especially as they were used in our project, shows that this method can be used to reflect on and use the introduction of any technology in institutions in a theoretically well-founded way. Furthermore, this approach makes it possible to take different diversities into account from the very beginning. The personas catalog is published on an open data repository so that an extension of the catalog is possible anytime.

6. References

[1] Müller T. Habitualisierte Mobilnutzung – Smartphones und Tablets gehören zum Medienalltag: Ergebnisse der ARD-Mobilstudie. Media Perspektiven. 2013;60:410–22.
[2] Keates S, editor. Universal Access: The Challenges Ahead. Cham: SPRINGER; 2019.
[3] Initiative D21 e. V. D21-Digital-Index 2021/2022 – Jährliches Lagebild zur Digitalen Gesellschaft.
[4] Statista. Internetnutzer - Anzahl weltweit 2021. 2021. https://de.statista.com/statistik/daten/studie/805920/umfrage/anzahl-der-internetnutzer-weltweit/. Accessed 6 Jan 2023.
[5] Bengesser C. Digitale Teilhabe. 2015. https://imblickpunkt.grimme-institut.de/digitale-teilhabe/. Accessed 30 Nov 2020.
[6] Haage A, Bosse I. Basisdaten zur Mediennutzung von Menschen mit Behinderungen. In: Bosse I, Schluchter J-R, Zorn I, editors. Handbuch Inklusion und Medienbildung. Weinheim, Basel: Beltz Juventa; 2019. p. 49–64.
[7] Des Power MR, Rehling B. German Deaf People Using Text Communication. American Annals of the Deaf. 2007;152:291–301.
[8] Haage A. Informationsrepertoires von Menschen mit Behinderung – Barrieren und Förderfaktoren für die gleichberechtigte Teilhabe an öffentlicher Kommunikation. Nomos: Baden-Baden; 2022.
[9] Schweiger W, Beck K. Handbuch Online-Kommunikation. Wiesbaden: VS Verlag für Sozialwissenschaften; 2018.

[10] Stubbe J, Schaat S, Ehrenberg-Silies S. Digital souverän?: Kompetenzen für ein selbstbestimmtes Leben im Alter. 2019. https://www.bertelsmann-stiftung.de/de/publikationen/publikation/did/digital-souveraen/.
[11] Bundesministerium für Arbeit und Soziales. Zweiter und dritter Staatenbericht der Bundesregierung zum Übereinkommen der Vereinten Nationen über die Rechte von Menschen mit Behinderungen. 2019.
[12] Bundesministerium für Arbeit und Soziales. Dritter Teilhabebericht der Bundesregierung über die Lebenslagen von Menschen mit Beeinträchtigungen: Teilhabe - Beeinträchtigung - Behinderung. 2021.
[13] Dirks S. Persona Design in Participatory Agile Software Development. In: Stephanidis C, Antona M, Gao Q, Zhou J, editors. HCI International 2020 – Late Breaking Papers: Universal Access and Inclusive Design. Cham: Springer International Publishing; 2020. p. 52–64. doi:10.1007/978-3-030-60149-2_5.
[14] Easy Reading. Easy Reading - Keeping the user at the digital original. o.J. https://www.easyreading.eu/de/uberblick/. Accessed 10.08.22.
[15] Nielsen L. Introduction: Stories About Users. In: Nielsen L, editor. Personas - User Focused Design. London: Springer London; 2019. p. 1–25. doi:10.1007/978-1-4471-7427-1_1.
[16] Chaniaud N, Megalakaki O, Capo S, Loup-Escande E. Effects of User Characteristics on the Usability of a Home-Connected Medical Device (Smart Angel) for Ambulatory Monitoring: Usability Study. JMIR Hum Factors. 2021;8:e24846. doi:10.2196/24846.
[17] Kirchem S, Waack J. Personas entwickeln für Marketing, Vertrieb und Kommunikation. Wiesbaden: Springer Fachmedien Wiesbaden; 2021.
[18] Billestrup J, Stage J, Bruun A, Nielsen L, Nielsen KS. Creating and Using Personas in Software Development: Experiences from Practice. In: Sauer S, Bogdan C, Forbrig P, Bernhaupt R, Winckler M, editors. Human-Centered Software Engineering. Berlin, Heidelberg: Springer Berlin Heidelberg; 2014. p. 251–258. doi:10.1007/978-3-662-44811-3_16.
[19] Dobransky K, Hargittai E. Unrealized potential: Exploring the digital disability divide. Poetics. 2016;58:18–28. doi:10.1016/j.poetic.2016.08.003.
[20] Heitplatz V, Maskut N, Wilkens L, Wüst M, Dirks S. Nutzung von Personas in pädagogischen Handlungsfeldern am Beispiel des EVE4all Projekts. 2023.
[21] Abel J, Hirsch-Kreinsen H, Steglich S, Wienzek T. Akzeptanz von Industrie 4.0. 2019. https://www.plattform-i40.de/PI40/Redaktion/DE/Downloads/Publikation/akzeptanz-industrie40.pdf?__blob=publicationFile&v=6. Accessed 27 Nov 2020.

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Design of Instructional Videos for People with Autism Who Want to Learn About Grocery Store Work: A Community, Business, Educational and Health Partnership

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Abstract. To facilitate the integration of people with autism into the food industry labour market, this cross sectoral project aimed to design, validate and test instructional videos to concretely demonstrate various tasks in the grocery store, and to probe interest and assess knowledge about these tasks. Results are the delivery of 21 instructional videos validated for individuals with autism and 21 for mentors in grocery.

Keywords. autism, employment, grocery, mentorship, coaching, instructional video

1. Introduction

Canadian data on the prevalence of autism among 5-17 years old is less recent, but still comparable: boys were diagnosed with autism spectrum disorder (ASD) four times more

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often than girls. It is 1 in 42 boys (2.39%) who have been diagnosed with ASD and 1 in 165 girls (0.6%), so it is 1 in 66 children (1.5%) who had a diagnosis in 2015 [1]. The employment status of people with autism varies by country but is well below the employment rate of the general population. In Canada, about 14% of people with autism between the ages of 15-64 are employed [2] compared to 62% for the general population at the same time [3]. It is not easy for them to get and keep a job due to difficulties in their social interactions [4]. One strategy to address this issue is to provide support to employers and prospective employees with autism, such as instructional videos.

1.1. Pre-employment instructional videos

From a literature review in six data bases, only 8 of 15 studies identified have used videos as a means of intervention for familiarization with the job for people with autism and have used videos with commentary [5-12]. Two studies involved persons with ASD working in a grocery store (packing groceries for customers or stocking the milk shelves [13-14]. None of the 15 studies took into consideration all the skills needed to perform the job adequately, especially the context and environment that the adult with ASD will have to integrate. Studies have also not leaned towards the use of videos to probe the interest of people with ASD despite the fact that these young people have interests, tastes and desires like each and every one of us. No study reported on videos that are accompanied by questions to be addressed directly to people with ASD [5-12] and none took into consideration videos that were intended to support the mentors of these young adults. Finally, most studies involved only participants with ASD Level 1 or Asperger's Disorder, putting aside people with ASD who need a higher level of support. Since part-time jobs are available at most grocery stores near high schools, a grocery store internship following the viewing of the instructional videos would allow students to access a summer or weekend job during high school.

***1.2.** Aim and objectives*

The aim of the project is to facilitate the integration of people with autism into the job market in the food industry. Objective 1 - To design, validate and test instructional videos to concretely demonstrate various tasks in the grocery store, and to probe interest to the trainee and assess knowledge about these tasks. Objective 2 - Develop educational videos for grocery store mentors to familiarize them with the characteristics of autism.

2. Methods

2.1. Research design and participant selection

Research-development design (4 months), iterative validations (9 months study) and practicability (3 months) were done. Participants were 12 grocery store clerks, 5 researchers, two directors of socio-professional integration programs, 6 individuals with autism, and 3 specialized educators from social and vocational training organizations. The project was approved by the CIUSSS-CN Research and Ethics Committee (#2022-2378).

2.2. Technology development

During the research-development phase, 2 occupational therapy students went to film clerks in a grocery store while they were working, using iPhones 8. The grocery store manager selected seven departments and 12 employees to be filmed in certain tasks. The clerks had to perform the tasks as usual in order to have a global vision of the task and their posture. The OT students edited the videos to make instructional videos with the iMovie application. Text has been added in the videos to draw the listener's attention to important points for people with ASD in a **work environment** (e.g., “the noise of the machine can be loud”; “The texture of the peel is rough and prickly”). There are also embedded images that illustrate the points to allow the listener to better understand the added text. An analysis of the tasks allowed us to highlight noteworthy aspects of the environment and the task itself that could have an impact on a person with ASD. For example, **sensory sensitivities** such as loud, unexpected, and repetitive noises, social interactions, visual and olfactory stimuli and sudden changes in temperature that could cause them anxiety and discomfort. The text on those slides is black and displayed on a white background, with an easy-to-read font type (Helvetica neue), 4 to 6 words per line on the screen and between 1 to 7 lines of text. Three **post-visioning questions** for mentor's were conceived to validate their understanding of what may be disruptive to the trainee with ASD so that they can adapt their environment and approach. On the trainee's side, four questions were formulated to validate their interest in working in the department and performing a task, to draw their attention to the optimal way to perform a task, and to validate their understanding of safety and health rules.

2.3. Data collection and data analysis

The iterative content validation was done in 4 steps including modifications. The videos and questions were submitted first for review to five researchers from the research team; secondly to a foundation with programs welcoming and training of people with ASD to help them integrate the job market; thirdly to 2 persons with ASD, who are participating in a job training program to verify that the videos are easily understandable and thus allow people with autism to understand well (e.g., speech rate, time to read the script, use of certain words, visual; and fourthly to a non-profit organization dedicated to ASD clientele over 21 years old and their family in the transition from school to active adult life social integration. Finally, a master's student in psychoeducation with experience working with people with ASD, viewed all videos and all the questions to ensured that the questions were well suited to the video content. The practicability of the instructional videos was done by the master student where was done the fourth validation step, with 4 young adults with ASD. They were asked to choose the 9 departments that interested them the most, to listen the videos and completing the questionnaires independently. They were free to give comments or ask questions at any time.

3. Results

Results are the delivery of 21 instructional videos for individuals with autism and 21 for mentors, lasting from 2 to 6 minutes. The tasks are in fish (5), cheese and deli (4), bakery and pastry (3), ready-to-eat (3), fruits and vegetables (2), cashier (2) and grocery (2). In Figure 1, there is a screenshot of part of the platform for future workers with ASD.

Figure 1. Instructional videos and quizzes. It is possible to go to this link, which offers the possibility to anyone, to watch a video, and to answer the post-visioning questions in French: https://www.cirris.ulaval.ca/type_produits/outils-devaluation-clinique/

Table 1 shows the results of the practicability phase with future workers with ASD. Participants with ASD identified their "like/neutral/dislike" interest in each task viewed and pointed out disturbing elements (see in yellow). Responses to assess their understanding of the task, safety and health rules are not shown, but they were mostly correct. P3 was the only participant who liked 6 videos (see in red). For the level of discomfort in the videos, it did not bother him 67% of the time. For all participants, including P3, what is bothering are complexity of the task, noise or sound, social contacts and textures.

Table 1. Practicability with young autists (n=4)

	Participants with ASD			
	P1	P2	P3	P4
Number of videos viewed	9	6	9	9
Interest about videos				
☺ Positive	0	0	6	0
😐 Neutral	9	4	0	8
☹ Negative	0	2^{α}	3^{β}	1^{γ}
Level of discomfort in percentage				
It bothers me a lot	5%	13%	20%	17%
It bothers me a little	55%	30%	11%	36%
I don't mind at all	41%	17%	67%	47%
I do not know	0%	40%	2%	0%

It bothers me a little or a lot					
Appearance		3	0	1	0
Complexity of the task	*	3	1	1	5
Estimating quantities		2	0	1	1
Handling sharp tools		2	0	0	3
Having a sense of aesthetics		3	0	0	2
Noise or sounds	*	2	2	1	4
Physical strength needed		0	2	1	0
Repetitions		0	1	0	0
Smell		3	0	2	1
Social contacts	*	7	5	2	4
Temperature variations		2	0	1	1
Texture	*	3	0	3	1
The mess on the shelves		2	0	1	1
Working at heights		1	1	0	0
Working with wet hands		0	1	0	1

α Packing Pineapple and Serving the Customers

β Wrapping cheese, Placement of Products in the charcuterie section and Sous-vide

γ Placement of Products in the charcuterie section

* Frequently reported discomfort

4. Discussion and Conclusion

Interveners in education, in rehabilitation or in community settings should encourage the completion of the post-visioning questions of instructional videos about working in grocery; this would allow to help the person with ASD to target his or her socio-professional interests while providing a space for discussion with them about their future integration into the workplace. High schools or training centers that offer work placements to youth with disabilities should use the instructional videos to introduce the variety of tasks and possibilities of grocery work. In conclusion, this is a first study that focuses on the design of instructional videos by integrating researchers from various disciplines, stakeholders from community organizations for work integration, and people with autism. It is also the first time that instructional videos have been designed for grocery store mentors to review when hosting a trainee.

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References

[1] Public Health Agency of Canada. Autism spectrum disorder among children and youth in Canada 2018: A report of the national autism spectrum disorder surveillance system. 2018. https://www.canada.ca/en/public-health/services/publications/diseases-conditions/autism-spectrum-disorder-children-youth-canada-2018.html (Accessed March 23, 2023)/

[2] Zwicker J, Zaresani A, Herb Emery JC. Describing heterogeneity of unmet needs among adults with a developmental disability: An examination of the 2012 Canadian survey on disability. Research in Developmental Disabilities 65. 2017. p. 1-11. https://doi.org/10.1016/j.ridd.2017.04.003

[3] Government of Canada. 2012. https://www.canada.ca/fr/emploi-developpement-social/programmes/assurance-emploi/ae-liste/rapports/controle2012/Chapitre1.html

[4] Martin V, Flanagan TD, Vogus TJ, Chênevert D. Sustainable employment depends on quality relationships between supervisors and their employees on the autism spectrum. Disabil Rehabil. 2022 May 16:1-12. doi: 10.1080/09638288.2022.2074550

[5] Allen K, Wallace D, Renes D, Bowen S, Burke R. Use of video modeling to teach vocational skills to adolescents and young adults with autism spectrum disorders. Education and Treatment of Children. 2010;33(3):339–349. https://doi.org/10.1353/etc.0.0101

[6] Bross LA, Travers JC, Munandar VD, Morningstar M. Video modeling to improve customer service skills of an employed young adult with autism. Focus on Autism and Other Developmental Disabilities. 2019;34(4):226–235. https://doi.org/10.1177/1088357618805990

[7] Bross LA, Travers JC, Wills HP, Huffman JM, Watson EK, Morningstar ME, Boyd BA. Effects of video modeling for young adults with autism in community employment settings. Career Development and Transition for Exceptional Individuals. 2020;43(4):209–225.

[8] Burke RV, Bowen SL, Allen KD, Howard MR, Downey D, Matz MG. Tablet-based video modeling and prompting in the workplace for individuals with autism. Journal of Vocational Rehabilitation. 2013;38(1):1–14. https://doi.org/10.3233/JVR-120616

[9] Kellems RO, Morningstar M. Using video modeling delivered through iPods to teach vocational young adults with autism spectrum disorders. Career Development for Exceptional Individuals. 2012;35(3):155-167. https://doi.10.1177/0885728812443082

[10] Rausa VC, Moore DW, Anderson A. Use of video modelling to teach complex and meaningful job skills to an adult with autism spectrum disorder. Developmental Neurorehabilitation. 2016;19(4):267–74. https://doi.org/10.3109/17518423.2015.1008150

[11] Schoenherr K. Using video modeling to teach vocational skills to young adults with autism spectrum disorder [Degree of Doctor of Philosophy in Education, University of Missouri-St-. Louis]. Dissertation. 2018. https://irl.umsl.edu/dissertation/723

[12] Bross LA, Travers JC, Munandar VD, Morningstar M. A packaged intervention to improve job performance of a competitively employed young adult with autism spectrum disorder. Journal of Vocational Rehabilitation, 2020;53(2):249–256. https://doi.org/10.3233/JVR-201099

[13] Walsh E, Lydon H, Holloway J. An evaluation of assistive technology in determining job-specific. 2020.

[14] Mazzone L, Vitiello B. Psychiatric symptoms and comorbidities in autism spectrum disorder. Springer. 2016. https://doi.org/10.1007/978-3-319-29695-1

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Rob'Autism Project: Social Learning at the Center of the Therapy

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Abstract. Rob'Autism project was started in 2014, it aims at setting a therapy support for ASD (Autistic Spectrum Disorder) teenagers based on robot, art and culture mediations. The objective of the therapy support is to improve social skills. At its center is the improvement of the capacity to build and destroy affective links with the environment, or generate and drop communication relation with the external world. Three points were addressed to restore social links management: individual, collective and social communication. The experiments were organized in 20 working sessions of 1 hour per week and involved 6 teenagers, 3 robots and 6 accompanying people. During the sessions, a repetitive scenario is performed proposing a fixed frame in which controlled events can occur, in such way that the subjects environment remains simplified. During the 20 sessions, the subjects are supervised to build a show, which is presented to an external public. Up to now, eight groups were studied (48 subjects in total by groups of 6). The results show a redefinition of the subjects' identity and their legitimacy as members of the society.

Keywords. Rob'Autism; Autistic Spectrum Disorder; social learning; robot extension paradigm; robotic mediation

1. Introduction

Two paradigms exist for robotics mediation in therapy support: the companion robot introduced by Dautenhahn *et al.* in 1999 [1], and the extension robot proposed by Sakka *et al.* in 2016 [2]. The companion robot approach considers the robot as a social actor: it is a pre-programmed mechanical interlocutor that solicits an ASD subject to avoid him/her closing in. This approach is used by most researchers [3,4,5,6,7,8,9,10]. The extension robot is used as a prosthesis in communication: the subject programs the robot to act through its mediation. The extension robot was defined in Rob'Autism project initiated in 2014. the project proposes a global, complex and systematic model rebuilding a micro-society in which 6 ASD teenagers are supported to build their social selves and become individuals. To our knowledge, Rob'Autism project is the only one using the extension robot paradigm. In this approach, the operator is not solicited by the robot, but becomes an acting person in the world. This paper addresses the definition of a social individual to explain a possible approach to use robotic mediation in therapy support for ASD teenagers, pointing that the robot allows modifications of an individual but does not

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operate the modifications. Then the therapy must be worked out carefully to accompany the subject to rebuild his identity. Section 2 presents the specific points of an individual definition that are used to design the therapy support, section 3 describe the context of the experiments. Section 4 focuses on the three levels of communication that are worked out during the 21 workshops of the program, sections 5 analyzes the obtain results.

2. Between the self and the world

An individual is defined as "a distinct entity within a group". It is a person separate from other people and possessing his own needs, goals, rights and responsibilities. The frontier between the self, defined according one's frame, and the world (the non-self), results from a complex process which relies on several notions such as envelop, the dynamics of building and destroying links, otherness and selfhood. This frontier is changing, in the sense that it can be affected by external events (the *making*, adaptation to the environment) or by internal events (the *being*, search for balance). It guarantees a subtle and fragile balance of the individual, as it is permanently crossed by a flow of information from outside-in and from inside-out. The frontier leads to the definition of identity, which is studied by many research areas: psychoanalyze, psychology, sociology, anthropology, semiotic, etc. The individual can be separate in two parts: a part that constitutes it, and a part that allows it to (inter)act. Its constitution includes two elements: (1) a fixed, rigid and structured frame leading to a set of unchangeable rules, knowledge and certainties; (2) a strong dynamics built from numerous collisions between realities and imaginary, with a role of balancing regulation (the sensitivity). In this dual situation fixed frame/dynamic motion, the constituted individual evolves in a half-space: mobile and immobile, at the same time. Interaction is based on perception, and involves the notion of managing affective links with others. It is a balance between creating and destroying links. The capability to establish links with the world cannot happen without mediation. The permanent flow of data between the individual and the world is regulated by his/her capability to voluntarily create and destroy links with other social individuals or objects. The rules constituting the frame can evolve with the equilibrium between links creation and destruction: it is the social learning process. This learning is made difficult in case the creation-destruction events are too numerous, in which situation a rigid frame cannot exist; and this too permanent dynamics generates anguish. The notion of temporality is also important here, as the notion of time can only be defined with an adequate identity definition, i.e. in a rigid, existing and identified frame. A robot is defined in a half-space from its design: inanimate and animate, *at the same time*. Real and imaginary, at the same time. A robot is a mediator, it connects to the individual through the capability of creating links. Moreover, the robot offers a simplified, rigid framework in which some actions can be performed, which is reassuring for the user, who feels safe when interacting. The robot is particularly adapted for ASD support. It does not itself operate the change: it takes the operator/interlocutor in its half-space with the feeling of safety that frees the capability of social learning. When the operator/interlocutor is in the half-space, he/she can be reached by a therapy. The work we proposed in the Rob'Autism project, and present thereafter, consists in rebuilding the capability to create links to redefine an individual with ASD, from face-to-face discussions to group and society acknowledgment, as an individual.

3. Rob'Autism Project

Rob'Autism is a multidisciplinary project linking medical, social sciences, arts, robotics and computer sciences. It consists in a therapy support for teenagers with ASD; it lasts 21 weeks and it is based on voluntary interactions between subjects and the world using robots as prostheses in communication (the robot extension paradigm). The subjects program the robots to make them do or say whatever they want, within the technological limits of the machine. The global organization and observed results of the program were described in [11,12,13,2]. In this paper, we will focus on the therapy part of the project: improving social skills by regulating the individual dynamics of creating/destroying links with the non-self.

3.1. The Robot extension paradigm

The ASD participants program the robot and use it as an extension of themselves. Through the robot, they can safely interact with the world. They behave as actors, as the robot will do nothing if they do not program it. They are allowed to transfer their creativity into the world, and their contribution to the world, in return, should be recognized by the world (co-mmunication). This allows them to differentiate what acknowledge (the world) and what generates (the self), identify the parties and have a better view of their frontier. When the companion robot paradigm prevents from closing on oneself, the extension robot paradigm offers an opening to the world, redefining identity and replacing the individual at the center of the action. The robot does not operate the change in its user, it allows it. It places the operator/interlocutor in a half-space in which he/she can be more easily reached by a therapy, it plays the role of a therapy amplifier.

3.2. Subjects, Material and organization

48 subjects, distributed in eight groups of 6 ASD teenagers aged from 11 to 16 years old participated in this experiment (39 boys and 9 girls). All subjects' parents gave written informed consent before entering the study. There was no selection on a specific kind of autism, although the 48 subjects had some ability to read and write, at least identify a few letters. Not all of them were going to school, the groups were very heterogeneous. 34 were familiar with the use of a computer. Almost all of them did not know anyone else in their group before their program started (2 exceptions). One program consists in 20 sessions of 1 hour each, once in a week, and is concluded by a public show where external people are invited. The 20 sessions alternate 10 non-robot programming and 10 robot programming work sessions [2]. Here, a framework was defined and strictly respected during the complete program: A music was played before a session starts (always the same), another at the end of the session. The positions of the tables, chairs and robots were always the same when the teenagers arrived, the working staff was unchanged for the whole program. One room was dedicated to the robotics sessions, another room to the non-programming sessions, a third space for the restitution. The program uses 3 humanoid robots NAO from Softbank Robotics. The robots are programmed by the subjects using the software interface *Choregraph*, which is the classical programming interface sold with the robots (i.e., no specific software was used). The software language is English whereas the participants were not familiar with this language. Except from the

6 participants, 6 people attended the sessions: three nurses who helped the participants focusing on the exercises, finding and/or choosing ideas, and sharing the discovering with them. The nurses had a quick training on using a robot before the programs started. One animator was also present in the room: either a robot specialist for the programming sessions, or a sound specialist for the non programming sessions. One supervisor led the program and attended all the sessions (programming and non programming), dealt with the families, organized the operational part of the whole experimental program.

4. Robot mediation used to improve communication

Communicating is a bilateral notion which supposes to give something (object, feeling, etc.) to someone and accept in return something from this person. It is the first sign of recognition as an individual by the outside world and a classical way of exchanging with others, according to one's definition of others. It cannot be performed when the function allowing to identify the self and the other is damaged, such as in ASD. As a consequence, the capability of communicating can be a way to evaluate the ASD subjects' evolution. In this experiment, communicating is dealt with on three levels: individual, group and social links will be worked out. We will describe in what follows each level of creating links and their respective observed impact on the subjects' behaviors.

4.1. Dual communication

Dual communication takes place with a person, an animated object or an animal. It consists of both giving to and receiving from. The participants worked by binomials, so each can program the robot during a given time (not fixed, according to the needed time to complete the exercise) and have to let their binomial also program the robot until they have finished their exercise. The subjects never exchange anything with the robot itself, as it is not considered as an intentional character. Alternate programming of the robot is at first a difficult exercise. The reactions, not to share, are such as holding firmly the keyboard or the mouse, while screaming or protesting loudly, then become sending disagreeing looks. A first behavior is not to give any interest on what the binomial is programming, trying to get the attention by doing something else that needs attention from the nurse, holding the nurse from helping the binomial to complete his/her programming. Programming the robot is closely linked to catching another attention and focus. Letting the binomial program generates a stress that cannot be controlled by the teenager alone. The exercises were designed short enough to face this situation, and each can performed programming several times per session: when the teenager is allowed to go back to programming quickly enough, the acceptance of individual exchange starts while the stress lowers. The experimentation shows that 10 minutes exercises (each teenager goes back three times to programming the robot during one session) is a good compromise between long enough exercise for elaboration, focus time of the programmer and attention delay of the waiting binomial. An evolution of the behaviors between the binomials is observed, in the case of three programming exercises each per session:

- At first, the other binomial is rejected, nurse's attention is attempted to be monopolized. Observed stress reduction can be seen within the very first robotic session, when the subject is allowed to program again once the binomial has finished.

- Curiosity to what the binomial is programming appears between the second and the fourth robotic sessions, depending on the subject. A progression was observed (same for all the participants) in showing curiosity: first is an attention to what the other has programmed by watching the robot perform only at the end of an exercise; second is to look directly what the other is programming on the computer screen; third is to interact with the binomial and help realizing the performance: give opinion or advice, explain programming, help with insuring robot security, help with holding the robot in a configuration while the binomial is saving it.
- Complete acceptance of relying on the other is observed from the third robotic session for all the subjects (no stress observed).

The progression in dual communication continues over the 20 workshops. The binomials positioning is sitting side by side, the center of attention of the linking process is the computer and the robot. Dual communication impacts two factors: from pleasuring the self to accepting delayed pleasure of the self; and from monopolizing one's attention despite one other to generating an interaction with one other. In the experiment, the framework is insured: when the subjects enter the room, they find the three work stations in the same configuration, the present people are always the same, the manner the exercises are explain do not change. The only changes are the content of the exercises and the working pairs (imposed different binomial at each session). This helps constituting the group as a sort of mini society. Dual communication is the most difficult one, as it needs constant contact and attention in time, which is a demanding exercise for an ASD subject.

4.2. Group communication

At the end of each exercise, the three binomials are asked to stop all activities to show and watch what was performed. Each demonstration is concluded by group applause. Two types of exercises are realized with the robot: 1) tell/show the others about something personal, or 2) address someone with a personal message. Any kind of message is allowed, including "forbidden words" (slang and insults) [2]. Whatever time is needed to conclude the exercise, the groups have to wait until the three are ready to perform. Group communication takes place faster than dual, as the attention is more localized in time. The subject can work a program in a hidden way from the others, and show a demonstration during a short time to the others, still hidden as the group is watching the robot. The effects of group communication can be observed from the very first robotics session:

- First exercise: the subject programs the robot because and how it is asked. (then shows to others, then applause from others, then watch others' programming, then wait for the binomial to do the exercise)
- Second exercise: the subject programs the robot with curiosity. (then shows to others, then applause from others, then watch others' programming, then wait for the binomial to do the exercise)
- Third exercise: the subject programs the robot *for the others* and *expects* a positive reaction from the others.

The positive reactions appear through the applause, which validates the act of creation. This process transforms the subject through the robot mediator from a person to an individual. He is identified by the group as a contributor of the mini-society built in the framework of this therapy. The subjects discover the pride of showing to others and to exist. During the first robotics session, the subjects try the robot. They are still shy, they do not know what will please the others. They can only get their attention using the robotic mediation. From the third robotics session, they know each other and start communicating through the robot actions and personal contribution. Its sayings may mention points that interest another participant (who is in another binomial), or their robot will answer another robot which has previously talked. The positioning for group communication is each binomials facing the two other binomials, the center of attention are the respective robots. The effects of group communication address the notion of intentionality: the subjects learn how to project themselves in time to please other beings in order to be pleased by their reactions. The group is never changed during the complete program. Its constitution is fixed, part of the frame. Some people may be accidentally missing (illness, exams, strikes, etc.), but no new face is included until the social communication.

4.3. Social communication

Social communication is performed only once, at the end of the program: the artistic creation realized during the sessions is publicly shown. The public consists in a maximum of 40 people: family and collaborators. Some may be known by the subjects, but they all represent "the outside world". A scene is set up for the show, on which the programmed robot makes its performance. The 6 subjects sit directly in front of the scene, facing it. The rest of the public sits in their back. It is the first time that the subjects discover their complete show: they had seen only small parts of it while they were creating it. As a consequence, they discover their creation at the same time as the public, which generates a situation of shared experience in this new assembly. Discovering the global result of putting together known small actions led to living an experience that is at the same time known and unknown. The separate small actions are recognized, but take a complete new appearance when all put together. The story shows a new meaning. More than the meaning, the subjects realize the extent of their small contributions. The ascertainment of the greatness of their creation is directly linked to the pride of what they have made. The link leads to realizing how to generate something great step by step, which is equivalent to making a projection in time. Time projection was particularly lacking with the subjects at the beginning of the program. They hardly could focus more than five minutes in the first robot programming session. As a consequence, time projection was not possible. After four robotics sessions, they can focus the complete hour [2]: they can start making time projections. This is fixed by the show restitution. Acknowledgment from the public follows the show, with applause. This acknowledgment validates their being part of the society: they are officially recognized as contributors by unknown people who represent "the outside world"; it is equivalent to an initiatory introduction in the society: recognition by the pairs. From this moment on, they can exist as social individuals, and not only as unidentified persons. Following the show, questions from the public are answered by the accompanying people of the project. During the questions, the participants stay sit and listen. They do not interfere even though there is no doubt they are present in the scene. Social communication is concluded by a drink and cakes served at a table and shared by all: public, subjects and staff. The subjects stay voluntarily in the room, and depending on the group: mix with the society or stick together, reforming the group for talking and laughing.

5. Complementary Analyses

The results are qualitative, based on both interviews with the parents and video observation of the sessions. A few points of the program that are important for obtaining the results are mentioned thereafter:

- Beginning of the sessions: organized so that all the subjects enter the room together. A meeting space is organized, where the subjects arrive one by one until the group is complete. The group can be formed again, and they start communicating. Once they have all arrived, they knock at the working session door, and the animator opens the door. The subjects enter one by one in the room, greeting the animator. The group meeting outside the room allows the subjects to enter the room already in the group mode, so they can focus immediately on the mini society.
- Vocal synthesis: there is a strong temptation to play with the vocal synthesis: putting letters in random order and testing the sounds coming out of the robot, improving the shape of the sound until the subject is satisfied with it. No progress is made with the playing. They enjoy it, it makes them work, they look for the group sharing moment, but they do not improve voluntary communication.
- Training of the staff: during the robotics working session, 3 nurses are dedicated to helping the subjects to focus, one per binomial. The staff was trained to ptogram the robot during 12 hours before the program starts. The training allows two situations: a) autonomy for the simplest requests: where to find the "say" box for example, how to connect the boxes, how to send the signal to the robot. In this situation the link between subjects and staff is based on pedagogy (individual sharing). b) need for help for the more advanced functions, in that case, subjects and staff are in the same situation (group sharing, formulate request to the robot expert).
- The applause stabilizes the working progress of the linking, it generates satisfaction and pleasure that become objectives for the subjects. Applause represents the acknowledgment of the individual's contribution to the group. The contribution is never discussed nor oriented, and will always generate applause.

An appeasement of the subjects' anguish was observed. The consequence was increase of concentration times and voluntary communication. The concentration time evolved from 5 consecutive minutes in the first robotic workshop to the complete hour after 4 robotic workshops. The hard programming time during one robotic workshop was limited to 45 minutes, leaving 15 minutes for playing: make the robot talk. The voluntary communication starts taking place when the group is formed and identified by the subjects: they have been able to observe the others, see their contributions and show their own contribution to them. Not using the robot to give personal impression starts in average at the seventh robotic session. Concerning the anguish, each subject has different symptoms: crises, mutilation, dumbness and other isolation behaviors, screaming, absence, mirror behaviors, search for containment, and so on. Evaluation was performed with the participation of the parents, who observed a reduction in the manifestations of anguish at home or outside the home [2].

6. Conclusion

The robot extension paradigm was addressed in this paper, in a complex experiment involving 8 groups of 6 ASD teenagers. The subjects programmed the robot, using it as a prosthesis in communication, and were accompanied to improve stabilized communication with the world. To do so, they first identified their self and differentiated it from the world (the not self), rebuilding their frontier to the world and redefining their identity. Three levels of communication were worked out: dual communication, dealing directly with another subject over time; group communication that allowed identifying one's contribution to the group and acknowledging recognition of the contribution from the group; and social communication with the restitution of the robot play that was realized during the 20 workshops in front of an external public, and concluded with applause. The qualitative analysis showed longer concentration times, better voluntary communication and appeasement of the anguish (decreased symptoms during sessions and outside sessions). The next step of this study is to analyze the quantitative evaluation of the subjects. It was performed with ADI-R tests before and after the program. Even though the results validate the observations of the qualitative analysis, the heterogeneity of the groups require further statistical understanding.

References

[1] Dautenhahn K. Robots as Social Actors: AURORA and the Case of Autism. In: Third International Cognitive Technology Conference; 1999. .
[2] Sakka S, Gaboriau R, Picard J, Redois E, Parchantour G, Sarfaty L, et al. Rob'Autism: how to change autistic social skills in 20 weeks. In: Int. Workshop on Med and Serv Robots; 2016. .
[3] Robins B, Dickerson P, Stribling P, Dautenhahn K. Robot-mediated joint attention in children with autism: A case study in robot-human interaction. Interaction studies. 2004.
[4] Billard A, Robins B, Nadel J, Dautenhahn K. Building Robota, a Mini-Humanoid Robot for the Rehabilitation of Children with Autism. RESNA Assistive Technology Journal. 2006.
[5] Dickerson P, Robins B, Dautenhahn K. Where the action is: A conversation analytic perspective on interaction. Interaction Studies. 2013;14(2).
[6] Werry I, Dautenhahn K. Human-Robot Interaction as a Model for Autism Therapy: An Experimental Study with Children with Autism. In: Laubichler M, Gerd B Müller MP, editors. Modeling Biology: Structures, Behaviors, Evolution – Vienna Series in Theoretical Biology; 2007. p. 283-99.
[7] Syamimi S, Hanafiah Y, Luthffi I, Fazah Akhtar H, Salina M, Hanizah A, et al. Initial response of autistic children in human-robot interaction therapy with humanoid robot NAO. In: International Colloquium on Signal Processing and its Applications; 2012. .
[8] Tapus A, Peca A, Aly A, Pop C, Jisa L, Pintea S, et al. Children with autism social engagement in interaction with Nao, an imitative robot: A series of single case experiments. Interaction Studies. 2012;13(2).
[9] Bekele E, Lahiri U, Swanson A, Crittendon J, Warren Z, Sarkar N. A step towards developing adaptive robot-mediated intervention architecture (ARIA) for children with autism. IEEE Transactions on Neural Systems and Rehabilitation Engineering. 2013;21(2).
[10] Cabibihan J, Javed H, Ang Jr M, Aljunied S. Why Robots? A Survey on the Roles and Benefits of Social Robots in the Therapy of Children with Autism. Int J of Social Robotics. 2013;5(4).
[11] Chaltiel T, Gaboriau R, Sakka S, Sarfaty L, Barreau A, Legrand M, et al. Un robot en institution pour adolescents autistes: une aventure collective. Dunod; 2017.
[12] Gaboriau R, Sakka S. Le robot comme médiateur thérapeutique: une expérience auprès de jeunes autistes. Tétralogiques. 2017;22:249-62.
[13] Sakka S, Gaboriau R. A Robotic "Puppet Master" Application to ASD Therapeutic Support. International Journal of Mechanical and Mechatronics Engineering. 2017;11(8):1502-10.

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Digital Inclusion and Competence Development

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Training a Child with Blindness on the Basic Use of Computer with the Aim of Internet Socialization; an Intervention Program

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Abstract: In the present intervention program an eleven-year-old student with visual impairments was introduced in the basic use of a computer for the first time. The key tools for achieving this goal were the screen reading software "NVDA" as well as the development of a well-structured educational program. The purpose of the intervention was to enhance the student's technological skills, to make him familiar with the use of assistive technology and to enable him to exploit these new skills for his internet socialization. The evaluation of the intervention program's results was completed on three stages: a) after testing the student's knowledge and skills in the basic use of a computer (pre- and post-assessment), b) after measuring his social network, his self-esteem and the perceived social support, and c) after analyzing the content of the student's written speech based on a series of criteria. (pre- and post-assessment). The results showed that the basic use of a computer was acquired and internet socialization increased his level of self-esteem, his social network and simultaneously created a sense of belonging. Finally, there was an improvement in his writing.

Keywords: blindness, visual impairments, assistive technology, intervention program, internet socialization

1. Introduction

People with visual impairments present themselves as socially isolated and with limited social skills [1]. First, the development of social skills starting in childhood and adolescence leads to acceptance by peers and thus to the building of interpersonal relationships [18]. In the case of visually impaired people, however, where social skills cannot be learned through observation of human behavior or imitation, other strategies, such as focusing on the tone of voice of the interlocutor or role-playing, are used [12]. In particular, a study showed that people with visual impairments perceived that their sighted peers have a negative opinion of them because of their poor social skills and limited social network [4]. Another study on this topic found that people with visual

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impairments are 78% more likely than sighted peers to have a desire to socialize, which could be ascribed to feelings of loneliness [3].

However, since the 1990s, more and more people are choosing to communicate via computer [8]. This form of communication has been called "Computer Mediated Interpersonal Communication" [5]. In particular, thanks to the development of assistive technology, people with visual impairments have mastered computer interaction, navigating the online environment to collect or publish information, transcribing text from braille to braille without the input of a third person, etc. [15]. Also, people with visual disabilities are now able, thanks to the existence of appropriate assistive technologies, to communicate on equal terms with sighted people [11]. Facebook, YouTube, Messenger and then Twitter and Skype are the most preferred by visually impaired people [2]. Visually impaired people use social media with screen reader software that is compatible with the aforementioned websites [10].

However, the benefits of visually impaired people's participation in social media are seen in the areas of social support, self-esteem and self-confidence [14]. Initially, messaging, information sharing, friends, likes and more generally online socialization and the acquisition of a social identity provides confidence and a sense of social support (perceived support) to the visually impaired person, thus compensating for feelings of anxiety caused by interpersonal communication [16].

In addition, , blind people's sense of belonging is enhanced both because of their participation in a widespread network of millions of users worldwide and because they communicate with a circle of people [14]. In a study, it was recorded that the existence of greeting messages in the personal "chat" or profile of the blind user is a factor in enhancing self-esteem and at the same time removing feelings of loneliness [7]. Also, managing and editing their online profile is a daily activity for people with visual impairment, which also enhances their writing and makes them feel active [6]. Finally, their frequent contact with social media contributes positively to maintaining their social interactions [17].

2. Study

The aim of this research was to enhance the technological skills of an 11-year-old student with total blindness, to familiarize him with the use of assistive technology and to enable him to exploit these new skills for his online socialization. Based on the aim of the research, the questions that arose were the following:

1. Was the intervention program for basic computer education able to enhance a student's technological skills?
2. Were the technological and the internet socialization intervention programs able to change a student’s self-esteem?
3. Was the internet socialization intervention program able to change the perceived social support and social network of a student?
4. Was the internet socialization intervention program able to change a student's written language?

3. Methodology

3.1 Case study

An eleven-year-old boy with total vision loss participated in the intervention program. He was born in Greece to immigrant parents. His mother tongue is Albanian but he speaks and understand the Greek language very well as he went to a Greek kindergarten from the age of 4 and then to a Greek primary school for people with blindness. More specifically, he has total blindness from birth, which was caused by optic nerve atrophy. His verbal and motor development did not deviate from the normal course. As far as the self-service sector is concerned, he is independent. In particular, he has the ability to eat on his own, get dressed and wash himself. The above autonomy in daily-living activities is related, on the one hand, to his spatial skills and, on the other hand, to his body knowledge. His coarse and fine motor skills have been estimated to correspond to his age level.

In broad strokes, he is described as a shy, reserved and well-adjusted child who becomes intimate with those around him over time. It is particularly noted that in the 3 years he has been attending primary school he has only formed two stable friendships with 2 children with total blindness of the same age. However, the student is described as sometimes adopting socially inappropriate stereotypes during the lesson, possibly due to boredom or lack of interest.

As far as reading is concerned, he has been able to read Braille texts since the age of 6. During text reading he places his elbows horizontally on the book and the two reading fingers (indexes) have separate functions. His reading ability is very good, continuous and without syllables. However, it lacks in the semantic coloring of words.

As far as the writing field is concerned, he has been using the Perkins machine since the age of 6. In particular, he writes quickly and has the ability to orientate himself within the page. However, his vocabulary is limited and there was difficulty with the spelling of simple and difficult words.

The student knows how to use a mobile phone but his experience with computers is almost non-existent. In particular, he had only been able to use a computer once before. Only knows the basic parts of a computer system. The student's lack of experience is due to the fact that he didn’t have personal computer at home and that no computer lessons are delivered at the school he attends.

3.2 Instruments

A key tool to achieve the training in the basic use of the computer is the screen reading software NVDA. "NVDA" is screen reader software available for free on the internet and its main role is to read all text formats in the user's computer environment (icons, taskbar, windows bar, lists, etc.).

The evaluation of the results of the first intervention program was carried out through a questionnaire as an evaluation tool, constructed by the researcher, with close- and open-ended questions. The questions related to the simple naming of categories of H/Y and its parts, the knowledge of simple PC functions and the description of the student's experiences related to the use of a PC, in order to test the student’s knowledge and skills in computer use (pre- and post-intervention assessment).This was followed by an intervention program aimed at the online socialization of the student. A key tool for achieving the above objective was the student's participation in the social network "ischool". "Ischool" is a student online community (forum), where its registered members have the opportunity to exchange ideas, opinions and perceptions on various issues that concern them with students all over Greece. The evaluation of the results of the second intervention program was carried out through the measurement of the student's self-esteem, the perceived social support, his social network and the content analysis of the student's writing in terms of social adaptation and based on the following criteria (pre- and post-intervention evaluation).

Specifically, the analysis of the content of the student's writing was based on 4 axes: a) the morphology of the text b) the presentation/analysis of the topic in question c) the author's style d) his language/expressive level. In particular, with regard to the morphology of the text, the following indicators were used: a) spelling mistakes b) typographical errors c) use of punctuation marks. As regards the presentation/analysis of each topic, the following indicators were used as indicators: a) the number of sentences per text b) the number of words per sentence c) the ideas developed by theme d) the degree of analysis of the idea in question. At the same time, the following were used as indicators of the author's style: a) the use of transport b) the use of affective words c) the absolute or conciliatory mode of expression. Finally, as regards the linguistic/expressive level, the following indicators were used: a) the degree of complexity of the proposals b) the use of difficult words (multi-syllabic, less frequently occurring words, terms, place names) c) Grammatical errors d) Syntactical errors e) semantic errors.

The research tools with which the aforementioned assessments were conducted are 3 different data collection instruments. The Rosenberg Self-Esteem Scale [13] consists of 10 sentences of which 5 are reverse scored. This response scale is a 4-point Likert-type scale, from "strongly agree" to "strongly disagree". The total score is calculated by summing up the 10 answers. The Child and Adolescent Social Support Scale [9] consists of 60 questions, 12 in each social support group. These groups were parents, the class teacher, classmates, “close friend” and school staff. After the end of each question there are 2 questions about the frequency and the importance of social support. Specifically, the frequency of social support was rated on a 6-point Likert-type scale from "never" to "always", while the importance of social support was rated on a 3-point Likert-type scale from "not important" to "very important". The "Social Network Description" questionnaire consists of 7 open-ended questions to describe the student's close social network (parents, relatives, close friends, friends, classmates, teachers, other persons). Finally, the Perkins Machine to collect the written word data. The analysis of the data collected from the research tools was quantitative and qualitative

3.3 Procedure

The structured training program took place from September 2019 to June 2020 at the Special Primary School for the Blind in Thessaloniki. The first intervention program lasted 13 weeks. The lessons took place twice a week and each lasted 45 minutes. The targeting was focused on building technological literacy and acquiring basic technological skills.

The school computer is a desktop computer and has the screen reading software "NVDA" installed. For proper guidance and formulation of appropriate objectives, an initial assessment was conducted through an open-ended and closed-ended questionnaire constructed by the researcher. The responses were given verbally by the student and recorded by the researcher. The training of the first intervention program was structured as follows: a) recognition of the basic parts of a computer (e.g. monitor, keyboard), b) use of the keyboard and recognition of the position of the keys, c) use of the computer and its basic operations (e.g. opening and closing the computer and the screen reading software), d) writing texts using the word processing software "Microsoft Word", e) navigation through the general-purpose "Windows" software, which involves understanding pop-up windows, navigating the computing environment and filing and sorting files by type, and f) navigation through the internet to search for and collect information. After the first intervention program was implemented, the questionnaire assessing the student's technology knowledge was addressed again in the same was as in the initial-assessment phase

In the second intervention program, which lasted 8 weeks, the lessons took place three times a week and each lasted 45 minutes. The aim was to familiarize the student with the online means of interaction and to train him in the use of the "ischool" forum. The implementation of the second intervention program also took place in the school, during the daily program.. The initial evaluation was conducted through the measurement of the student's self-esteem, the recording of the perceived social support and the student's social network as well as through the content analysis of the student's writing in terms of social adaptation.

During the second intervention program, the student was taught to use "Google Chrome" browser through "NVDA". Next, he created his own personal email account by going to www.gmail.com. After becoming familiar with the website's interface, he sent 2 e-mails to the researcher's e-mail account. Then, he visited the website www.ischool.gr and created an account to this online community of students. His registration was soon confirmed by the platform administrator and he logged in to www.ischool.gr. Finally, the student was given time to orientate himself in the forum environment starting from the home page. It is worth noting that this forum consists of many subsections and graphics.

Next, the researcher explained the student about the function and the role of all the elements of the forum. At this point, the student was also taught how to log in and log out of his account and then how to write and communicate by listening to other users' messages in threaded discussions. On the next level the student attempted to write and post a message himself. It is worth noting that the researcher was not involved in the drafting of his messages, either intellectually or practically. Finally, the student was taught how to correct the spelling mistakes by himself, to check for existence of notifications and the role of "emoticons" in all social networks. More specifically, the researcher described to the student that "emoticons" are symbols of human non-verbal behaviors used to express the user's emotions virtually.

At the end of this intervention program, the student began to communicate online either by reacting to other users' posts or by writing his own posts. The final assessment of the student was carried out using the same tools as in the initial assessment.

4. Results

4.1 Results of training to enhance the technological skills

In the final evaluation of the student through the questionnaire constructed by the researcher to assess his existing technological knowledge, he managed to score 100/100 as opposed to his initial evaluation with a score of 20/100.

4.2 Results of participation in the online forum www.ischool.gr

His participation in the forum started on 25 February 2020 and ended on 29 May 2020. In total, he made 15 visits to the www.ischool.gr web platform. More specifically, he participated in 25 different thematic discussions, writing a total of 30 posts and receiving a total of 85 replies from other users of the platform. Finally, he received totally 2 "reactions" to one of his personal posts and specifically the 2 "reactions" expressed the feeling of wondering about his message. However, he himself made 4 "reactions" to other participants' posts, wanting all 4 times to express his agreement with the views expressed in their posts.

4.3 Rosenberg self-esteem scale results

The results initially showed that the student scored 14 points on the 5 positive scoring questions, 10 points on the 5 reverse scoring questions and thus a total of 24 points, placing him in the normal levels of self-esteem. However, after the end of the structured educational intervention program, he was re-evaluated on this scale, scoring 15 points on the 5 positive scoring questions, 13 points on the 5 reverse scoring questions. Thus, the total score of 28 points raised him to high levels of self-esteem, according to the scale.

4.4 Results of the "Social Support for Children and Adolescents" (CASSS) questionnaire

Moreover, according to the data collected with the CASSS regarding the frequency of receiving the 4 types of social support (emotional, informational, evaluative, practical) and the 5 sources of social support (parents, teacher, classmates, “close friend”, school staff), a score increase was recorded compared to the score of the initial assessment (before the intervention). Specifically, a worth noting change was detected a) in the category of peers and the type of informational social support where there was an increase of 7 points (Before=5 After=12), as well as b) in the category of close friends and the type of practical social support where an increase of 14 points was recorded (Before=3 After=17).

4.5 "Social Network Description" scale results

According to the data collected with "Social Network Description" scale regarding the describe of his close social network (parents, relatives, close friends, friends, classmates, teachers, other persons), a worth noting change was detected a) in the category of close friends where there was an increase of 2 friends (Before=3 After=5), as well as b) in the category of friends where an increase of 6 friends was recorded (Before=1 After=7).

4.6 Content analysis of written discourse

Regarding content analysis, he was asked to develop 3 written texts of different topics twice, once during the initial assessment and once during the final assessment. More specifically, the main idea of the first text was to send a message to a friend, the second text was to present a social issue in the classroom and the third text was to send a letter to the mayor of his city.

More specifically, his final texts were longer in length (Number of words): (Text 1: before=56 after =108 Text 2: before=62 after=115 Text 3: before=80 after=114), (Words per Proposal (Average): (Text 1: B=4.75 A=6.23 Text 2: B=5 A=6.7 Text 3: B=4.5 A=5) and richer in ideas (Suggestions per Text): (Text 1: B=12 A=17 Text 2: B=12 A=17 Text 3: B=17 A=22), (Proposals per Idea (Average): (Text 1: B=1.6 A=4 Text 2: B=2 A=4 Text 3: B=4 A=5). In addition, the presentation of his ideas followed one another without being confused with each other, as in the initial evaluation (Way of Expression): (Text 1, 2, 3: B=dogmatic A= Conciliatory). The use of argumentation in his final texts contributed to a deeper understanding of his positions by the reader.

5. Discussion

In conclusion, thanks to the creation of the intervention program for training in basic use of computer through screen reader software, the person with blindness was able to acquire the basic knowledge of computer use. The above-mentioned achievement is confirmed as people with visual disabilities now interact with the computer and the online environment thanks to the development of assistive technology [15].

Furthermore, it is thought that learning to use a computer in combination with participation in an internet community may help the person with blindness to increase their self-confidence. The above finding is consistent with the view that interaction with the computer, creates feelings of autonomy to the person with blindness, resulting in increased self-confidence [15]. At the same time, the above finding confirms the theory of Social Media, which supports that through pictures, photos and messaging, users' self-confidence levels increase [16].

It is also observed that online socialization provides a form of social support to the person with blindness and thus contributes to increasing their social circle. The above finding is consistent with the view that participation in a social network enhances the sense of belonging of people with blindness and their internet social identity contributes to a more direct communication and acquaintance with a new circle of people [14].

The frequent postings of the person with blindness may be due to the improvement of his writing. The person's with blindness need to communicate probably led to longer texts enriched with more ideas. This view is supported by the research that communication through text messages is now a daily activity and an opportunity for people with visual impairment to enhances their writing [6].

The findings of these intervention programs reveal how important could be the use of assistive technology and the technology literacy for students with visual impairments. The use of these skills for socialization in the internet when this follows a well-structured program and respects the security rules could improve the self-esteem or even the perceived social support of students with visual impairments. Thus, the findings of these interventions programs could be considered by educators or therapists. Of course, this is just a case study and extended intervention trials would shed more light in this direction.

References

[1] Ajayi D. Social interaction skills of persons with visual impairment (VI). SSRN Electron J [Internet]. 2021; Available from: http://dx.doi.org/10.2139/ssrn.3841574
[2] Asuncion JV, Budd J, Fichten CS, Nguyen MN, Barile M, Amsel R. Social media use by students with disabilities. Academic Exchange Quarterly. 2012;16(1):30–5.
[3] Beaty LA. Psychological and Social Adjustment of Visually Impaired Youth: 1936-1992. Education Resources Information Center. 1992;1–23.
[4] Huurre TM, Aro HM. Psychosocial development among adolescents with visual impairment. Eur Child Adolesc Psychiatry [Internet]. 1998;7(2):73–8. Available from: http://dx.doi.org/10.1007/s007870050050
[5] Herring SC. Computer-mediated communication: Linguistic, social, and cross-cultural perspectives. John Benjamins Publishing; 1996.
[6] Gentile B, Twenge JM, Freeman EC, Campbell WK. The effect of social networking websites on positive self-views: An experimental investigation. Comput Human Behav [Internet]. 2012;28(5):1929–33. Available from: http://dx.doi.org/10.1016/j.chb.2012.05.012
[7] Greitemeyer T, Mügge DO, Bollermann I. Having responsive Facebook friends affects the satisfaction of psychological needs more than having many Facebook friends. Basic Appl Soc Psych [Internet]. 2014;36(3):252–8. Available from: http://dx.doi.org/10.1080/01973533.2014.900619
[8] Li C, Ning G, Xia Y, Guo K, Liu Q. Does the Internet bring people closer together or further apart? The impact of Internet usage on interpersonal communications. Behav Sci (Basel) [Internet]. 2022;12(11):425. Available from: http://dx.doi.org/10.3390/bs12110425
[9] Maleski CK, Demaray MK, Elliott SN, Nolten PW. The child and Adolescent Social Support Scale. Dekalb, IL; 1999.
[10] Morris MR, Zolyomi A, Yao C, Bahram S, Bigham JP, Kane SK. With most of it being pictures now, I rarely use it" Understanding Twitter's Evolving Accessibility to Blind Users. In: Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems. California, USA; 2016. p. 5506–16.
[11] Radesky JS, Weeks HM, Ball R, Schaller A, Yeo S, Durnez J, et al. Young children's use of smartphones and tablets. Pediatrics [Internet]. 2020;146(1):e20193518. Available from: http://dx.doi.org/10.1542/peds.2019-3518
[12] Roe J. Social inclusion: meeting the socio-emotional needs of children with vision needs. Br J Vis Impair [Internet]. 2008;26(2):147–58. Available from: http://dx.doi.org/10.1177/0264619607088277
[13] Rosenberg M. Acceptance and commitment therapy. Measures package. 1965.
[14] Okonji P, Lhussier M, Bailey C, Cattan M. Internet use: Perceptions and experiences of visually impaired older adults. J Soc Incl [Internet]. 2015;6(1):120. Available from: http://dx.doi.org/10.36251/josi.95
[15] Smith DW, Kelly SM. Assistive technology for students with visual impairments: A research agenda. In: International review of research in developmental disabilities. Academic Press; 2014. p. 23–53.
[16] Valkenburg PM, Peter J, Schouten AP. Friend networking sites and their relationship to adolescents' well-being and social self-esteem. Cyberpsychol Behav [Internet]. 2006;9(5):584–90. Available from: http://dx.doi.org/10.1089/cpb.2006.9.584
[17] Voykinska V, Azenkot S, Wu S, Leshed G. How blind people interact with visual content on social networking services. In: Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing. New York, NY, USA: ACM; 2016.
[18] Wang Y, Palonen T, Hurme T-R, Kinos J. Do you want to play with me today? Friendship stability among preschool children. Eur Early Child Educ Res J [Internet]. 2019;27(2):170–84. Available from: http://dx.doi.org/10.1080/1350293x.2019.1579545

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Digital Capabilities of Older People and Uptake of Online Healthy Ageing Interventions: An Australian Study

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Abstract. The promise of digital health interventions is tempered by the realities of digital capabilities and infrastructure, especially for older persons. This paper critically examines learnings from a rapid evidence review of digital information tools along with a study evaluating the uptake of a digitally-based healthy ageing intervention by 53 older Australians. Findings suggest that digital literacy is an important precursor to engagement with digital information tools, and that digital information tools must be designed with digital literacy in mind. To achieve digital health equity and realise the potential outcomes that digital tools offer, it may well be necessary to support consumers with the basics of mastering digital platforms.

Keywords. Digital, technology, older persons, capability

1. Introduction

Governments around the world are moving towards 'digital first' approaches for information and public service provision. This means that access to information and services depends upon consumers understanding of online environments, knowledge of information and communication technologies, and access to suitable hardware and infrastructure. Technology which is pervasive today was barely present three decades ago, leading to a situation of digital natives (people under 40 who have grown up with technology), and digital refugees (those who grew up with print based information)[1].

Digital solutions are proliferating across the marketplace, including health. A range of factors have influenced the demand for digital solutions in healthcare and beyond. 'Push factors' include the digitisation of government services combined with ageing demographics and workforce shortages to deliver face to face interventions. 'Pull factors' include increasing digital literacy in many cohorts, an increased demand for digital pathways, growing access to digital infrastructures, and the rapid proliferation of digital commodities.

However, a 'digital divide' can emerge where a person's capability set is not aligned with the demands of digital engagement [2]. While there is substantial work underway

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to address digital literacy including for older people, global evidence suggests a capability gap for many [3]. This may result in disengagement and a range of negative consequences, particularly where people are unable to engage in health and wellness interventions or activities [4].

Australia's Digital Inclusion Index [5] identifies six key capabilities for accessing digital information and using digital tools, including:

1. Basic operations: including downloading and opening files, connecting to the internet, and setting passwords,
2. Advanced operations: including saving to the cloud, determining what is safe to download, customising devices and connections, and adjusting privacy settings,
3. Information navigation: including searching and navigating, verifying trustworthy information, and managing third party data collection,
4. Social: including deciding what to share, how, and who with, managing and monitoring contacts, and communicating with others,
5. Creative: including editing, producing, and posting content, as well as a broad understanding of the rules that may apply to these activities, and
6. Automation: including connecting, operating, and managing smart devices and Internet of Things (IoT) technologies [5].

Evidence suggests that digital capability differs greatly. In 2021, the Australian digital ability average was 64.4, dropping to 41.8 for 65-74 year olds, and dropping further to 27.2 for Australians over 75 years of age [5]. This suggests that many older Australians seeking to use digital health interventions may not in fact have the foundational digital abilities to do so.

This study sought current evidence regarding digital information tools from a rapid evidence review. In addition, a pre and post study evaluated the uptake of one digitally-based healthy ageing intervention in Australia.

2. Method

Firstly, a rapid evidence review focused on the use of digital information provision for improving health outcomes. A systematic search strategy without date restrictions and in the English language was conducted within the PROSPERO International prospective register of systematic reviews as well as across Google Scholar, Ovid Medline Plus and CINAHL databases, based on the search string [functional decline OR health behaviour OR healthy aging OR behavior change AND aged OR aging OR elderly AND digital intervention OR digital information tools OR digital applications OR digital technology OR digital behaviour change intervention].

Secondly, a Monash and Curtin University Ethics Committee approved research study evaluated the use of the LifeCurve™ digital health tool. Functional performance of 53 community-dwelling older Australians with access to digital devices from Western Australia and Victoria were evaluated on a range of measures, before, and three months after the introduction of the digital tool. A survey one month after introduction of participants to the tool collected qualitative data regarding uptake and usage, as well as health literacy. Findings associated with health literacy are reported in this paper.

3. Results

The rapid evidence review located bodies of literature which could be clustered as 'digital behaviour change interventions'; 'digital health interventions', 'decision support systems' and 'patient decision aids'. Screening of 127 articles resulted in 20 full text reviews, locating evidence that digital tools play a role in enabling informed decisions and may result in improved health outcomes. Study types included conceptual models; systematic reviews and meta-analyses of the deployment of digital health interventions, and qualitative studies exploring user experience and the barriers and enablers to use of digital health interventions.

Digital information tools include internet-based web applications, mobile health (mHealth) applications including digital games; the Internet of Things; and wearables/sensors. Digital information tools enable access to personalised health information [6], enable communication with healthcare providers [7] and can enable a person to collect their own health information to share with health professionals [8] or take action in the absence of professional assistance [9]. There is currently little evidence regarding the use of digital information tools in relation to reablement or assistive technology [10, 11].

Literature concerning the perspective of consumers suggests user experience could be improved and often user readiness is overestimated (for example assumed basic digital capabilities). A range of barriers exist to uptake and utilisation of digital tools such as access to digital devices and reliable internet [8]. Finally, consumer concerns exist in relation to data security [12].

In the study, 53 Australians over a three-month period in 2022 accessed the LifeCurve™ tool hosted on a website called LiveUp[2])™. LiveUp is a free digital-first healthy ageing website designed to provide free, independent, and accessible information, advice, and tools to older consumers to improve their access to assistive products and reablement strategies, better enabling them to maintain or improve their independence at home and in the community. LiveUp hosts the screening tool, LifeCurve™, that maps age related functional decline and provides personalised solutions to help older people navigate their ageing experience.

Sixty percent of participants used laptop or desktop computers, 30% used tablets, and 10% used smartphones to access LiveUp and LifeCurve™. Many participants shared devices with other family members, and some relied on visiting family to help use their digital device and to troubleshoot. Nearly 20% of the sample had challenges managing smart devices including connecting to the internet, setting passwords, navigating, and managing digital content. A standardised electronic health literacy scale completed by 29 participants, indicated that 18% had poor knowledge and confidence about using the internet and accessing health resources. A tool exploring stages of change established that up to 25% of participants were at early stages (precontemplation and contemplation) of readiness to make appropriate health related changes. This finding suggests that these participants will need support to implement relevant health-related behaviours.

[2] https://liveup.org.au/

4. Discussion

Study data suggests the precursor skills for use of information and communication technology should not be assumed. These capabilities map clearly to Australia's Digital Inclusion Index, and include basic operations, such as connecting to the internet and setting passwords; advanced operations, including customising devices and connections, and adjusting privacy settings; information navigation; social capabilities such as setting identities and managing social media profiles; creative capabilities like capturing content; and automation, like the ability to connect, operate, and manage smart devices.

This has implications for the formats in which health interventions are provided. Substantial bodies of knowledge exist regarding digital literacy [13], health literacy and e-health literacy [14]. What is required is a convergence to tackle the foundation precursors to uptake of digital health interventions to ensure none are left behind [15].

5. Conclusion

Drawing together the literature and study data, it is apparent that digital literacy is an important precursor to engagement with digital information tools [2]. Implications are that digital information tools ought be fit for purpose for varying levels of digital literacy, congruent with consumer expectations regarding useability, accessibility and universal design as laid out in relevant guidelines [3]. Further, support to engage with and master digital platforms may be required to achieve digital health equity.

References

[1] Prensky M. Digital Natives Digital Immigrants. On the Horizon. 2001;9(5).
[2] Sachdeva N, Tuikka AM, Kimppa KK, Suomi R. Digital disability divide in information society. Journal of Information, Communication and Ethics in Society. 2015;13(3/4):283-98.
[3] United Nations. The Age of Digital Interdependence: Report of the UN Secretary-General's High-level Panel on Digital Cooperation. 2020.
[4] Orthia L, Maccora J, McCallum J. "I am trying to keep up to date...but it is moving so fast": Older Australians' Digital Engagement in Turbulent Times. Canberra: National Seniors Australia; 2022.
[5] Index AsDI. Australia's Digital Inclusion Index: Measuring Australia's Digital Divide RMIT, Victoria: ARC Centre of Excellence for Automated Decision-Making and Society, ; [Available from: https://digitalinclusionindex.org.au/.
[6] Rainero I, Summers MJ, Monter M, Bazzani M, Giannouli E, Aumayr G, et al. The My Active and Healthy Aging ICT platform prevents quality of life decline in older adults: a randomised controlled study. Age & Ageing. 2021;50(4):1261-7.
[7] Lee DR, Lo JC, Ramalingam N, Gordon NP. Understanding the Uptake of Digital Technologies for Health-Related Purposes in Frail Older Adults: Journal of the American Geriatrics Society. 69(1):269-272, 2021 01.; 2021.
[8] Winberg C, Kylberg M, Pettersson C, Harnett T, Hedvall PO, Mattsson T, et al. Feeling controlled or being in control? Apps for self-management among older people with neurological disability. Disability and Rehabilitation: Assistive Technology. 2021;16(6):603-8.
[9] Perski O, Blandford A, West R, Michie S. Conceptualising engagement with digital behaviour change interventions: a systematic review using principles from critical interpretive synthesis. Translational Behavioral Medicine. 2016;7(2):254-67.
[10] Chenel V, Mortenson W, Guay M, Jutai J, Auger C. Cultural adaptation and validation of patient decision aids: a scoping review. Patient Prefer Adherence. 2018;12:321-32.
[11] Auger C, Mortenson WB, Jutai JW, Seguin-Tremblay N, Chenel V, Guay M. Older adults' use of an online decision support system: Usability and stability of assistive technology recommendations. Assistive Technology. 2022;34(3):316-25.

[12] Australian Human Rights Commission. Human Rights and Technology FINAL REPORT • 2021. In: Commission AHR, editor. 2020.
[13] Digital Literacy Unpacked: Facet; 2018.
[14] Kim H, Xie B. Health literacy in the eHealth era: A systematic review of the literature. Patient Education and Counseling. 2017;100(6):1073-82.
[15] Buchholz BA, DeHart J, Moorman G. Digital Citizenship During a Global Pandemic: Moving Beyond Digital Literacy. J Adolesc Adult Lit. 2020;64(1):11-7.

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Involving, Empowering, and Training End Users with Disabilities to Fully Participate in the Web Accessibility Directive Objectives First Results from the UPowerWAD Project

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Abstract. In this paper, we present the first results from the UPowerWAD Project - a project which aims to raise awareness and to empower and train people with disabilities to take active participation in the implementation of the Web Accessibility Directive (WAD). We give an overview of the results on how to capture and categorize feedback from users in the context of web accessibility and present best practices for structuring and reporting web accessibility issues. The results will be discussed focusing on the relevance and implications for further steps in the project.

Keywords. Web Accessibility Directive, Feedback Mechanism, Digital Participation, Digital Accessibility

1. Introduction

In the context of digital technologies and media people with disabilities are often excluded due to a lack of accessible websites, assistive technologies, and other factors like low media literacy [1-4]. Especially accessibility is often described as a central requirement and fundamental prerequisite for the equal participation of persons with disabilities [5-8]. Accordingly, laws and regulations worldwide underline the importance of accessibility of information and communication technologies and the Internet for independent living and full participation of people with disabilities.

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The Web Accessibility Directive (2016, WAD) is one of the EU laws concerning accessibility. It requires public sector bodies (PSB) websites and mobile apps to be accessible to users, mainly persons with disabilities, and to document their accessibility. In addition to the minimum accessibility requirements, the WAD introduced three mandatory instruments to help document and improve accessibility. First of all, PSBs must publish an accessibility statement for websites and mobile applications that are covered within the scope of the WAD. Secondly, a feedback mechanism must be set up so users can flag accessibility problems or request information published in a non-accessible way. Lastly, member states need to regularly monitor PSBs' websites and applications and report on the results to the European Commission.

Research from the European Disability Forum and the European Commission highlights the absence or insufficient implementation of the feedback mechanism and accessibility statement [9-10]. Additionally, the member states reports from 2021 show that most websites and mobile applications could not meet all of the required demands while simultaneously there is almost no feedback on still existing barriers [11]. Therefore, the European Commission highlights the need to improve the awareness and frequency of the use of the feedback mechanism [12]. In addition, Fuglerud & Halbach (2022) state, that research on the design of accessibility feedback mechanisms remains scarce [13].

This paper introduces the UPowerWAD project and presents the first project results on how to capture and categorize feedback from users in the context of web accessibility and best practices for structuring and reporting web accessibility issues. Furthermore, the results will be discussed focusing on implications for the next steps in the project.

2. The UPowerWAD Project

The UPowerWAD project ("Users Power the Web Accessibility Directive") funded by the Erasmus+ Programme aims to help to bridge that gap by raising awareness and empowering and training people with disabilities to take active participation in the implementation of the WAD. The goal of the project is to leverage the knowledge of people with disabilities, encourage them to be an active and essential part of the community and improve the accessibility of PSBs' websites and mobile applications.

The project is divided into two project phases with a total of four results. First, the project developed a 'methodological toolkit' for how to capture and categorize feedback from users in the context of web accessibility. Following this, the consortium developed an 'interactive repository' of best practices on structuring and reporting web accessibility issues. These selected contents will facilitate the building up of a 'model curriculum' on how to prepare Vocational education and training (VET) and Disabled People Organisations (DPO) courses to train people with disabilities to provide actionable feedback on web accessibility issues. The model curriculum will be translated, localized, and piloted in Germany, France, and Sweden. Lastly, the consortium will produce 'practical guidelines' on how to scale up the curriculum to different contexts and member states across Europe will be developed, facilitating the production of specialized VET and DPO courses in the field.

In the first phase of the project (2022), the main requirements for a better understanding of the existing barriers, the support needs of people with disabilities, and the improvement of the WAD feedback mechanism were identified. As outcomes of this project phase, a 'Methodological toolkit on how to capture and categorize feedback from users in the context of web accessibility' and an 'Interactive repository of best practices on how to provide structured feedback regarding web accessibility issues' were developed.

3. Methodology

The research to develop the toolkit was carried out in cooperation with persons with disabilities and DPOs. The consortium interviewed users with disabilities from 14 EU member states covering a wide range of user needs (n = 37). The interview guideline consists of a mix of closed and open-ended questions. Thematically, the interviews focused on the needs, preferences, and expectations of users regarding feedback mechanisms and their ICT and web accessibility expertise.

Table 1. Demographic Profile

Profile	Frequency
Gender	
Male	21
Female	16
Age group	
18 – 29	5
30 – 49	24
50 – 64	5
65 or older	3
User needs	
Limited vision	20
Limited cognition	11
Limited hearing	7
Limited manipulation	4

The results were tested and validated in an online workshop (n = 75). Here, the consortium presented the results from the interviews conducted. Participants were asked to answer closed and open-ended questions (e.g., “What are the barriers you face most often?”; “How would an ideal feedback mechanism look like?”). The results were shared and discussed during the workshop.

For the repository, the consortium developed and conducted an online survey to investigate examples of good practices known or registered by PSBs, web accessibility monitoring bodies, and Ombudsman’s offices (n = 113). Overall PSBs from 20 countries (mainly member states from the EU) participated. The top four countries are Germany (n = 39), Sweden (n = 27), Finland (n = 8), and Belgium (n = 5). The survey consisted of closed and open-ended questions where survey candidates were asked to provide details on their feedback mechanisms structure, clarity, quality, efficacy, cost-effectiveness, actionability, accessibility, and target group satisfaction. Based on the results, in-depth interviews (n = 22) were carried out with the organizations reporting the selected relevant practices. The interviews focused on the experiences with the feedback mechanism and discussed the decisions and implementation process of the selected best practice.

4. Results

The collected and analysed data was published within the 'methodological toolkit' and the 'interactive repository'. Below we present you a summary of the main results.

4.1. Toolkit

The analysis of the results of the interviews and the workshop with the different target groups of people with disabilities identified five preferred and common channel types for the feedback mechanism: Form, E-Mail, Phone, Live-(Video-)Chat, and Voice or Video Message. Important principal characteristics of the channel type are the structure, the exclusiveness to reporting accessibility issues, the level of guidance, the access possibilities, and the characteristics of the response.

Furthermore, the analysis of the collected data showed six main challenges for people with disabilities to provide feedback. First of all, it is necessary to highlight that some users might not know about the obligation for PSBs to provide a feedback mechanism and the right for users to report barriers to PSBs **(= Awareness)**. This might correlate with the fact that the feedback mechanism is not always easy to find, even if users are aware of the mechanism **(= Findability)**. The feedback form's complexity and size can vary, and some users might be discouraged from completing and submitting feedback to the website owners **(= Usability)**. Additionally, some users might not feel they have the (technical) knowledge to provide feedback **(= Knowledge)** and don't feel confident in trying or are unsure if they should report it because it might not violate a legal accessibility requirement **(= Confidence)**. Furthermore, Motivational aspects seem to play an important role to end users when it comes to giving feedback on accessibility issues. The motivation to report barriers can be influenced by different aspects, like previous negative experiences, being "afraid" of authorities or not considering it important or the user's responsibility to give feedback on such issues, and likely many more **(= Motivation)**.

Finally, the collected data gave a first overview of the relevant aspects important for actionable feedback and different ways of capturing feedback:

- What and when: end users should explain the barrier or problem that occurred and additionally give a technical description of the barrier, preferably with an example (e.g., screenshot)
- Where: end users should provide details on where the barrier was found (on which page of the site, during which action, etc.)
- How: end users should explain how the barrier prevented the use of the website, the aim of the action that was blocked, and whether it was related to the assistive technology used
- Technical environment: end users should provide technical details (e.g., OS, browser used, technical aids, …)

4.2. Repository

The repository considers both the user preferences analysed for the methodological toolkit and the existing PSBs practices. The document lists 29 best practices to help PSBs build feedback mechanisms that consider user preferences and thus help to support people with disabilities to be more independent and provide relevant and actionable feedback on web accessibility issues.

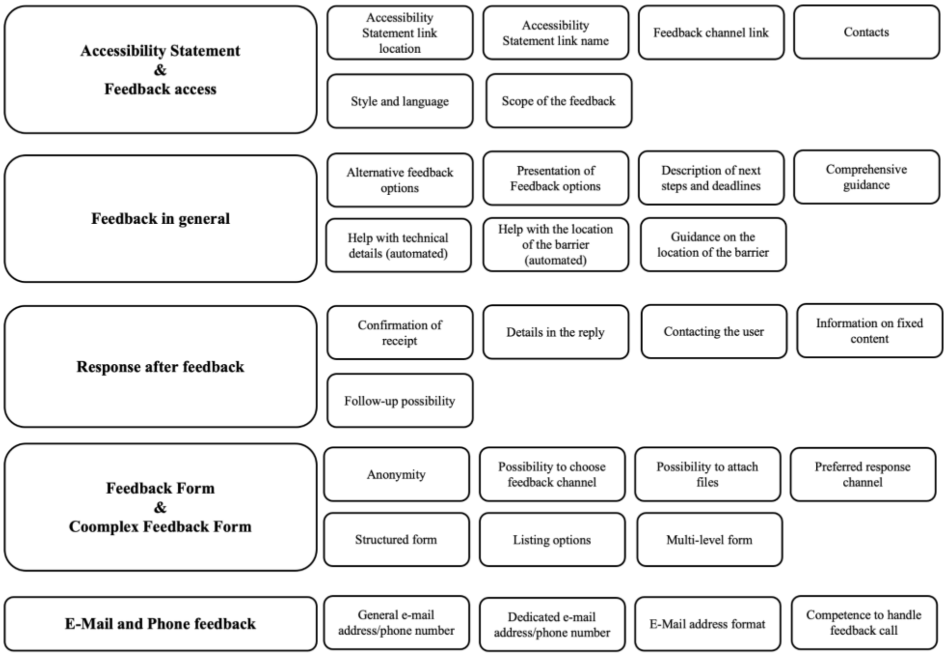

Figure 1. Identified best practices.

The best practices are structured within seven categories, each focuses on different elements of the feedback mechanism. They can be relevant for all mechanisms, for a group of feedback channels, or only for one specific feedback method or channel. The repository presents many real-life examples by providing a screenshot or a link to a webpage.

5. Discussion

Both the developed toolkit and the repository help PSBs improve the existing feedback mechanism and make it easier for people with disabilities to use it. If implemented, this will allow end-users to provide meaningful and actionable feedback on existing barriers on websites and applications of PSBs.

The results of the first phase of the project confirm that an overall requirement is that the accessibility statement and feedback mechanism need to be accessible. Here a combination of the different channel types could facilitate addressing the needs of users with various disabilities. In addition, PSBs might improve the quality and quantity of the feedback by using a coherent set of best practices. It is also essential that the persons handling the feedback need to have the necessary accessibility knowledge, and the competence to communicate with persons with different disabilities. Hence, the repository also lists basic information and guidance because the research cited and conducted implies that many organizations lack the required knowledge and competence.

Moreover, the results of the survey and the interviews with PSBs and the end-users indicate that more information and effort are needed to spread awareness among persons with disabilities to exercise their right to give feedback on PSBs' websites. At the same time, PSBs need to facilitate user feedback and act on it when received, so that end users can understand the value of their contribution. In addition, different stakeholders might need to raise awareness about the WAD, the feedback mechanism, the right to give feedback, and its usefulness for PSBs.

In summary, the results reinforce the need for VET and DPO courses to train people with disabilities to provide actionable feedback on web accessibility issues and provide first indications for its content. For this it is relevant, that the training can be adjusted to a wide range of end users. Regarding the content, the training should provide an overview of the WAD and outline the necessity of web accessibility and such regulations focusing on explaining the feedback mechanism outlined in the directive and how it can be used to report accessibility issues and introduce the concept of actionable feedback and explain its importance in the context of web accessibility in compliance with the WAD.

Limitations in the presented study result mainly from the sample characteristics, which only display specific national conditions and thus only allow for limited comparability and transferability. Therefore, it remains relevant to examine specific national characteristics within this project as well as consider it in future studies.

Considering the results and limitations, the main objectives of the upcoming project phase are the development and evaluation of a modularised model curriculum on actionable web accessibility feedback for VET and DPO courses throughout Europe and the development of corresponding practical guidelines on how to scale up the curriculum to different contexts and member states across Europe.

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References

[1] Dobransky K, Hargittai, E. Unrealized potential: Exploring the digital disability divide. Poetics. 2016; 58:18–28, doi: 10.1016/j.poetic.2016.08.003

[2] Seeman L, Lewis C. Cognitive and Learning Disabilities. In: Yesilada Y, Harper S, editors. Web Accessibility. Human–Computer Interaction Series. London: Springer; 2019. p. 49–58, doi: 10.1007/978-1-4471-7440-0_4

[3] Dirks S, Bühler C, Edler C. Digital Inclusion Through Accessible Technologies. In: Miesenberger K, Kouroupetroglou G, editors. Computers Helping People with Special Needs. ICCHP 2018. Lecture Notes in Computer Science vol 10896. Springer, Cham; 2018. doi: 10.1007/978-3-319-94277-3_67

[4] Rudolph S. Digitale Medien, Partizipation und Ungleichheit: Eine Studie zum sozialen Gebrauch des Internets. Wiesbaden: Springer Fachmedien; 2019, doi: 10.1007/978-3-658-26943-2

[5] Vicente MR, López AJ. A Multidimensional Analysis of the Disability Digital Divide: Some Evidence for Internet Use. The Information Society. 2010; *26*(1): 48–64, doi: 10.1080/01615440903423245

[6] Bühler C. Barrierefreiheit und Assistive Technologie als Voraussetzung und Hilfe zur Inklusion. In: Bernasconi. T, Böing U, editors. IMPuls: Band 2. Schwere Behinderung & Inklusion: Facetten einer nicht ausgrenzenden Pädagogik. ATHENA-Verlag; 2016. p. 155–169.

[7] Bühler C. Accessibility" über Desktopanwendungen hinaus – Barrierefreiheit. Informatik-Spektrum. 2017; 40(6):501–510. doi: 10.1007/s00287-017-1075-9

[8] European Commission, Directorate-General for Employment, Social Affairs, and Inclusion. Union of equality: strategy for the rights of persons with disabilities 2021-2030 [Internet]. March 2021 [cited 2023 May 21]. Available from: https://data.europa.eu/doi/10.2767/31633

[9] European Disability Forum. Web Accessibility Directive: A survey of end users [Internet]. May 2019 [cited 2023 May 21]. Available from: https://ec.europa.eu/newsroom/dae/redirection/document/78800

[10] European Commission. The evaluation of implementation costs and future effects of the Web Accessibility Directive. Final Report [Internet]. June 2020 [cited 2023 May 21]. Available from: https://digital-strategy.ec.europa.eu/en/library/study-implementation-web-accessibility-directive-monitoring-reporting-and-evaluation

[11] European Commission. Web Accessibility Directive - Monitoring reports [Internet]. January 2022 [cited 2023 May 21]. Available from: https://digital-strategy.ec.europa.eu/en/library/web-accessibility-directive-monitoring-reports

[12] European Commission. Study supporting the review of the Web Accessibility Directive [Internet]. December 2022 [cited 2023 May 21]. Available from: https://digital-strategy.ec.europa.eu/en/library/study-supporting-review-web-accessibility-directive

[13] Fuglerud KS, Halbach T. The development of accessibility feedback mechanisms: Related research: The TiTi-Project, Deliverable L2.1.1. August 2022 [cited 2023 May 21]. Available from: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwjl2siW2ob_AhUuQvEDHRulA6EQFnoECAsQAQ&url=https%3A%2F%2Fwww.nav.no%2F_%2Fattachment%2Fdownload%2Fe87f3887-8c2c-4b7c-8f0d-2fdeca9bbae3%3A19fc61ec1e19454c266478e43b4578fc0d98b21f%2FL2.1.1%2520Kunnskapsoversikt%2520Related%2520research.pdf&usg=AOvVaw14egiylLBC7XyzuJcKXdvZ

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Empirical Evaluation of Metaverse Accessibility for People Who Use Alternative Input/Output Methods

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Abstract. This research has analyzed the accessibility of the current metaverse platforms from the perspective of screen reader and switch scanning interface users, using the mixture of quantitative and qualitative assessments. To this end, the two representative metaverse platforms, ZEPETO and Roblox, were targeted. As a result, it was found that the current metaverse platforms are not carefully designed with accessibility in mind. Many content elements and controls in the metaverse environment suffers from the lack of alternative text description and appropriate markups which are essential to make it perceivable and recognizable by assistive technology. People with severe disabilities are very likely to find it difficult or impossible to independently navigate the current metaverse environment, because they do not provide any viable means of orientation and mobility in the 3D virtual space at all. The UI/UX of the current metaverse platforms also do not provide adequate feedback to help people with limited sensory/motor functions to understand the purpose and function of it. Overall, thereby, the current metaverse environment is not robust enough to reliably work with a wide range of assistive technologies.

Keywords. Metaverse, screen reader, switch scanning interface, accessibility

1. Introduction

The metaverse as the next generation of the Web is becoming more prevailing by virtualizing human activities performed in the physical world, using advanced immersive technology such as extended reality (XR). It is also recognized to hold great potential to improve the quality of life for people with disabilities [1], including users of a wide range of alternative input/output methods. Among them, a screen reader and a switch scanning interface have been known as one of the most challenging, respectively [2]. Screen reader is a software program designed to provide auditory feedback by reading aloud the on-screen contents to visually impaired users [3, 4]. Switch scanning interface is a type of assistive technology designed to enable people with limited motor control to interact with digital devices, using a single or multiple switches [2]. It presents the user with a series of options, which are "scanned" or highlighted one by one. When the desired option is highlighted, the user activates the switch [5]. The system then takes the action associated

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with the selected option. As another option, Cartesian scanning is also available, which enables to access every point of the screen coordinates [2].

A wide range of entities have made efforts to support the users of alternative input/output methods for their equal access to digital contents. One of the most well-known is the Web Contents Accessibility Guidelines (WCAG) by World Wide Web Consortium (W3C) as a global accessibility standard and legal benchmark for the Web and new media. It has been developed and updated to reflect changes in technology and new best practices [6, 7]. It is organized based on the four principles: *Perceivable*, *Operable*, *Understandable*, and *Robust*, each of which has specific accessibility guidelines and success criteria. Adapting to the era of metaverse, W3C has proposed and drafted the Extended Reality (XR) Accessibility User Requirements [8]. A number of researchers and research groups, big tech companies and governments have also researched and worked on with the same goals [9, 10]. However, to the best of our knowledge so far, there has been virtually no clear guidelines for the metaverse environment or empirical research on how accessible the current metaverse environments are for users of alternative input/output methods. In this research, we have assessed the accessibility of current metaverse platforms from the perspective of screen reader and switch scanning interface users to provide empirical knowledge and data and viable suggestions for addressing the identified issues.

2. Methods

2.1. Target Platform to be analyzed

Based on the most common metaverse service types (online game and social networking) and the number of monthly active users (MAU) [11], we selected the two target metaverse platforms: ZEPETO (20,000,000 MAU [12] in the social networking type, and Roblox (217,000,000 MAU [13]) in the online game type, respectively.

2.2. Evaluation Criteria

An evaluation criteria (Table 1) was established by combining WCAG (ver. 2.1) [7] and the XR Accessibility User Requirements (Working Draft ver. 2021.08.25) [8]. Total of 27 criteria (20 from WCAG, 7 from XR Accessibility User Requirements) that are considered to be closely relevant to the metaverse environment were selected.

2.3. Assessment Tools, Procedures and Methods

Considering that most of the current metaverse services are targeted on mobile devices, Apple's VoiceOver as a model of mobile screen readers and Switch Control as a model of switch scanning interfaces (both on iOS ver. 16.3) were selected. While no changes were made to the default settings for VoiceOver, the automatic scanning rate was increased to 2 seconds for Switch Control, as the full name of some scanned items may not be read within 1 second. Switch Control has two scanning options: the conventional row/column scanning (*Item Mode*) as default and the Cartesian scanning (*Gliding Cursor*), respectively.

The analysis process followed the six-step common workflow on both platforms, which was divided in two phases: '*preparation*' and '*usage*' phases, respectively. The preparation phase consisted of four primary tasks: Step 1 [Joining the platform], Step 2

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[Interacting with elements on the home screen], Step 3 [Customizing avatars], and Step 4 [Selecting a metaverse content and loading]. On the other hand, the usage phase included two steps: Step 5 [Playing the selected content], Step 6 [Exiting the metaverse content].

Table 1. Evaluation Criteria.

Principle	Accessibility Guideline	Success Criteria	Explanation
Perceivable	1.1 Text Alternatives	1.1.1 Non-text Content	All non-text content has a text alternative that serves the equivalent purpose.
	1.2 Captioning, Subtitling and Text*	1.2.1 Multimedia Content	Captioning and subtitling of multimedia content is provided within the limit of not interrupting the content.
	1.3 Adaptable	1.3.1 Info and Relationships	Information, structure, and relationships conveyed through presentation can be programmatically determined or are available in text.
		1.3.2 Meaningful Sequence	When the sequence in which context is presented affects its meaning, a correct reading sequence can be programmatically determined.
		1.3.3 Sensory Characteristics	Instructions provided for understanding and operating content do not rely solely on sensory characteristics of components such as shape, color, size, visual location, orientation, or sound.
		1.3.4 Identify Input Purpose	The purpose of each input field collecting information about the user can be programmatically determined.
Operable	2.1 Navigable	2.1.1 Page Titled	Web pages have titles that describe the topic or purpose.
		2.1.2 Link Purpose (In Context)	The purpose of each link can be determined from the link text alone or from the link text together with its programmatically determined link context.
		2.1.3 Multiple Ways	More than one way is available to locate a web page.
		2.1.4 Location	Information for the user's location within a set of Web pages available.
	2.2 Gestural interfaces and interactions*	2.2.1 Touch Screen Gestures	Support touch screen accessibility gestures.
		2.2.2 Selective Object Information	Users can make selections about item descriptions.
	2.3 Orientation and navigation*	2.3.1 Orientation /View Change	Users can reset and calibrate their orientation/view in an independent way.
		2.3.2 Landmarks	Clear visual or audio landmarks provided.
Under standable	3.1 Readable	3.1.1 Language of Page	The default human language of each web page can be programmatically determined.
		3.1.2 Unusual Words	A mechanism is available for identifying specific definitions of words or phrases used in an unusual way, including idioms and jargon.
		3.1.3 Pronunciation	A mechanism is available for identifying specific pronunciation of words where meaning of the word, in context, is ambiguous without knowing the pronunciation.
	3.2 Predictable	3.2.1 On Focus	When any user interface component receives focus, it does not initiate a change of context.
		3.2.2 On Input	Changing the setting of any user interface component does not automatically cause a change of context.
		3.2.3 Consistent Navigation	Navigational mechanisms occur in the same relative order.
		3.2.4 Consistent Identification	Components that have the same functionality are identified consistently.
		3.2.5 Change on Request	Changes of context are initiated only by user request or a mechanism is available to turn off such changes.
	3.3 Input Assistance	3.3.1 Error Identification	If an input error is detected, the error is described to the user in text.
		3.3.2 Labels or Instructions	Labels or instructions are provided when content requires user input.
	3.4 Critical messaging and alerts*	3.4.1 No Moving Focus	Critical messages or alerts can be understood without moving focus.
Robust	4.1 Compatible	4.1.1 Parsing	Content implemented using markup languages should be accessible with assistive technology.
	4.2 Immersive semantics and customization*	4.2.1 Assistive Technology	A user of assistive technology can navigate and interact within an immersive environment.

*Selected from XR Accessibility User Requirements

In terms of analysis method, as for screen reader, quantitative assessments were conducted based on the established evaluation criteria. Each criterion was rated as either S(satisfied) or U(unsatisfied). The compliance rates of each workflow step and each phase were calculated by dividing the number of 'S' by the total number of relevant criteria. For the switch scanning interface, qualitative assessments were used to investigate a more realistic user experience. All mobile screen events and activities of the whole process were recorded for more precise analysis.

3. Results

3.1. Results for the Screen Reader

The screen reader accessibility for each target platform is summarized in Table 2 and Table 3, respectively. During the preliminary assessment for the mobile application of Roblox, it was found that all the evaluation criteria were rated as 'U' except for '#2.1.1 Page Titled' for workflow Step 2. Thus, the mobile website of Roblox was assessed via the mobile web browser (Apple Safari).

Table 2. Accessibility Compliance Rate and Unsatisfied Success Criteria ([#]) of ZEPETO.

	Perceivable	Operable	Understandable	Robust	Total
Step 1	40% [#1.1.1;#1.3.1;#1.3.3]	0% [#2.1.1]	71.43% [#3.2.5;#3.3.1]	0% [#4.1.1]	50.0% (7/14)
Step 2	33.33% [#1.1.1;#1.3.1]	0% [#2.1.1-2]	80% [#3.2.1;#3.2.5]	0% [#4.1.1]	54.5% (6/11)
Step 3	0% [#1.1.1;#1.3.1;#1.3.3]	0% [#2.1.1]	75% [#3.2.5]	0% [#4.1.1]	33.3% (3/9)
Step 4	33.33% [#1.1.1;#1.3.1]	75% [#2.1.4]	57.14% [#3.1.2-3;#3.2.5]	0% [#4.1.1]	53.3% (8/15)
Step 5	0% [#1.1.1;#1.2.1;#1.3.1-3]	0% [#2.2.1-2;#2.3.1-2]	0% [#3.1.1-3;#3.2.1-4;#3.2.5;#3.4.1]	0% [#4.1.1;#4.2.1]	0.0% (0/20)
Step 6	33.33% [#1.1.1;#1.3.1]	25% [#2.1.2-4]	0% [#3.1.1;#3.2.1;#3.2.5]	0% [#4.1.1;#4.2.1]	16.7% (2/12)
Overall	22.7% (5/22)	25.0% (4/16)	42.9% (15/35)	0.0% (0/8)	32.1%

Table 3. Accessibility Compliance Rate and Unsatisfied Success Criteria ([#]) of Roblox

	Perceivable	Operable	Understandable	Robust	Total
Step 1	N/A				0.0%
Step 2	66.66% [#1.3.1]	100% -	100% -	100% -	90.9% (10/11)
Step 3	33.33% [#1.1.1;#1.3.1]	0% [#2.1.1]	75% [#3.2.5]	100% -	55.6% (5/9)
Step 4	33.33% [#1.1.1;#1.3.1]	50% [#2.1.2;#2.1.4]	42.86% [#3.1.2-3;#3.2.5]	100% -	53.5% (8/15)
Step 5	N/A				0.0%
Step 6	N/A				0.0%
Overall	19.0% (4/21)	25.0% (4/16)	34.3% (12/35)	37.5% (3/8)	28.8%

The overall accessibility compliance rate was very low on both platforms (32.9% for ZEPETO and 28.8% for Roblox). While the UI/UX of the preparation phase, which was mostly implemented using conventional Web technology, showed relatively higher compliance rate, almost all metaverse content elements in the usage phase failed to communicate with the mobile screen reader. In terms of each principle of the evaluation criteria, a closer look at the results is as follows:

As a main accessibility issue with the principle of 'Perceivable', both ZEPETO and Roblox did not provide adequate alternative text (#1.1.1, #1.2.1, #1.3.1-3) for most of the content elements (e.g., buttons, menu icons on the home screen, images for avatar components, and almost all 3D objects in the usage phase). For instance, while having a text (e.g., 'Cancel', 'Submit') on a button in joining ZEPETO, VoiceOver read the type of the control "Button", not the name of it, which made it impossible to distinguish the difference between the two. As another example, in Roblox, the completed avatar did not have an alternative text while individual components provided alternative texts.

For 'Operable', both ZEPETO and Roblox showed the same compliance rate (25.0%). Neither platform provided any screen reader recognizable page titles or content

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headings (#2.1.1) needed to know the current context and to operate a required action in the situation.

For the principle of 'Understandable', both platforms also showed very low compliance rates (42.9% for ZEPETO and 34.3% for Roblox) As a remarkable specific issue, in many cases, both platforms did not provide the screen reader with the necessary information to notify the context change (#3.2.5). For example, in ZEPETO, the mobile screen reader did not know a pop-up window appeared over the original content and no feedback was given when avatar changed. In Roblox, activating the button to experience the content automatically launched its dedicated mobile application with no audio or haptic feedback.

Regarding the principle of 'Robust', most of the contents in both platforms met little or no success criteria (0% for ZEPETO, 37.5% for Roblox), which means that they were not reliable enough to be interpreted by a variety of assistive technologies, not using valid accessible/semantic markup. For example, in ZEPETO, when trying to interact with menu options on the home screen, it could not be selected individually. The same was true for other container-embedded items (e.g., video thumbnails, metaverse content images). In particular, no content elements passed the success criteria under the principle of 'Robust' in the usage phase. No menus and 3D objects were interactable with the mobile screen reader, resulting in an automatic activation of 'Direct Touch' mode where there is no way for screen reader users to acknowledge the current 3D environment and navigate around the space.

As a complex case caused by more than one unsatisfied success criteria, when customizing avatars, although the number under each component that represented the price of it was recognizable with Voiceover, it did not provide the meaning of the number. For the reasons above, practically no workflow steps could be completed relying on VoiceOver.

3.2. Results for the Switch Scanning Interface

Due to the low accessibility compliance rate as above, both ZEPETO and Roblox did not work well with the conventional scanning option (linear/item scanning). It also made it difficult or impossible to apply any advanced scanning options (e.g., hierarchical/area scanning) that might enhance the efficiency of the scanning interface. Fortunately, however, as Apple's Switch Control provided a good built-in alternative called Gliding Cursor (a.k.a., Cartesian point scanning), in which a vertical bar comes panning left to right and when the user presses a switch and select an area, a horizontal bar comes panning top to bottom to select a point on the screen object. At that point, it works like touching the screen with a finger. In practice, for the mobile application of Roblox, even though Item Mode was set initially, Gliding Cursor had been automatically activated. However, for both ZEPETO and Roblox, although it was possible to access every point on the screen with the Gliding Cursor, they still had crucial accessibility issues as follows.

First of all, it took significantly longer to complete the given tasks, using Switch Control. In ZEPETO, the average completion time of the whole workflow was 524.79 secs, which was about 11 times longer than the average completion time with a normal interface (47.40 secs). The same was true for Roblox. The average completion time (418.8 secs) for the Step 2 to Step 4 was 9 times longer than the completion time (48.51 secs) with a normal interface. In the usage phase, since the objects were only activated through Gliding Cursor and the navigation of the avatar required multi-steps operation, the completion time with Switch Control (1336.47 secs) was about 17.5 times longer than the completion time with the normal interface (76.19 secs).

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Regarding the principle of 'Perceivable', ZEPETO did not appropriately set the hierarchical indexing among elements, which confused users about the relationship between them. It was possible to perceive each element in Roblox, but some elements failed to provide proper voice feedback.

In terms of 'Operable', even though every on-screen target in both platforms could be accessed with the Gliding Cursor, it was very difficult to operate the small targets. In addition, neither provided voice feedback nor information about whether the on-screen target was interactive was provided. Moreover, in the usage phase, which worked fully in the 3D virtual space, both ZEPETO and Roblox were little or no operational. It was not doable to navigate or change the orientation of an avatar at all, while a few menus in the 3D space were operable with Gliding Cursor. It was also not possible to scroll down the list of components with Gliding Cursor. For example, the whole interface menu which had subitems in it could not be selected and activated reliably. A pop-up containing a detailed explanation of a selected content opened from the bottom of the screen could be scrolled down, but there was no way to see if it was scrollable. In addition, it was nearly impossible to complete tasks that requires multi-step interactions such as changing the orientation of the avatar and navigating within the 3D virtual space.

In terms of 'Understandable', ZEPETO included contents which were scrollable but did not provide the relevant information to the assistive technology, which made it difficult or impossible for users to access and understand the entire content. Furthermore, neither platform notified environmental or contextual changes, thereby making it challenging to predict or adapt to the changes.

Since neither platform satisfied the principle of 'Robust' properly, the functions of the switch scanning interface were also negatively affected, as with the screen reader. For example, some elements (e.g., buttons, pop-ups) could not be scanned in the preparation phase of both platforms, and the Roblox even had elements that were scanned but not visually noticeable. Moreover, sometimes, for unknown reasons, the mobile apps for the target metaverse platforms crashed.

4. Discussion

Through the mixture of quantitative and qualitative assessments described above, it was revealed that the current metaverse platforms are not carefully designed with accessibility in mind and are not robust enough to reliably work with a wide range of assistive technologies, making it very challenging for people with disabilities. Below we briefly discuss some suggestions to resolve this issue.

First of all, it is important for developers to adhere to up-to-date digital content accessibility guidelines [7, 8]. If only this is well done, most of the content elements and controls in the metaverse environment would be perceivable and recognizable by screen reader and switch scanning interface.

Second, the current metaverse platforms do not provide any viable means of orientation and mobility in the 3D virtual space at all. This is mainly because that most metaverse 3D spaces were implemented based on a virtual reality of its own or a 3D game engine like Unity®. They should seriously consider relevant accessibility guidelines and APIs [14-16] that most of the base operating systems have already provided under the hood to support a range of assistive technologies. In addition, it is desired to proactively apply the proven knowledge and techniques on adaptive orientation mobility for people with disabilities to the 3D virtual space. Examples includes: allowing for *landmarks* (distinctive reference that the visually impaired can easily identify to utilize for navigation or understand the orientation of a location [17]),

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clues (a unique sensory information that can identify a certain area [18]), and *information points* (an object that shows a feature of the area by relating it with other objects in the area [19]). For instance, in a virtual world (Lotte World) in ZEPETO (Figure 1), if the user remembered and recognized the information learned through exploring of circular sculptures on both sides of the staircase (① in Figure 1(a)) that goes up and turns left is in the right side of MAGIC CASTLE (② in Figure 1(a)), they could know that they were on that location when facing the staircase again. Thus, the staircase could serve as a landmark for MAGIC CASTLE in this case. Furthermore, providing the structural information about 3D objects, the relationship between them and the avatar could enhance the user experience in the metaverse. For instance, the distance and orientation of 3D objects used as landmarks, clues, or information points could be informed through a tree view (Figure 1(c)). Those objects and the corresponding information could also be used to provide a path to a certain location within the 3D space. In addition, a 2D map of the 3D space could be considered to help understand the overall scheme of the environment and allow skip navigation (Figure 1(b)). Besides, for switch scanning interface users, it is important to give adequate amount of tolerance (e.g. extra delay for closing a drop-down menu) for any interface provided [20]. Differentiating audio cues could also be very helpful by informing the users about the distance and orientation. This would also be beneficial to non-assistive technology users by offering them more immersive experience [21].

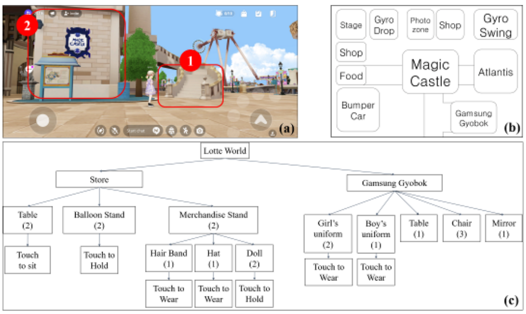

Figure 1. Exemplary alternative map of 3D space.

Last but not least, the UI/UX of the current metaverse platforms do not provide adequate visual/audio feedback to help people with limited sensory/motor functions to understand the purpose and function of it. Specifically, any context with no page/content title makes screen reader users got lost in the metaverse. As a simple yet useful suggestion to address this issue, it should not fail to ensure that each page/context has a proper markup such as <head> tag as recommended by WCAG. However, many newer types of UI elements (e.g., toast messages, animated icons, activity indicators) used in the metaverse might not be in the existing accessibility tree because no static text might be associated with them. As an intervention to overcome this issue, it is advisable to proactively adopt semantic properties [22] that enable fine-tuning of which UI elements should receive accessibility focus and which text should be read aloud to the user. Semantic properties can be attached to any UI element to utilize the underlying platform accessibility APIs. In addition, providing additional haptic feedback and well-designed special sound cues, the users could better understand the surroundings in the current context and how to interact with them.

However, for a successful resolution of the aforementioned challenges, it necessitates an adoption of a more encompassing methodology. This should encompass several intertwined considerations such is disability awareness, technical standardization, compatibility of underlying technologies, and multi-faceted user-centered design approach. This study has limitations. It focused on certain types of metaverse platforms and specific tasks. Investigations on more variety of metaverse types (e.g., education, public service) and a wider range of tasks should be preferred. In addition, follow-up

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studies on adaptive hardware for metaverse contents or compatibility with other assistive technologies should also be considered.

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References

[1] Petrosyan A. Benefits of the metaverse worldwide 2021. Statista 2022 July; Available from: https://www.statista.com/statistics/1285117/metaverse-benefits/.
[2] Simpson RC. Computer Access for People with Disabilities: A Human Factors Approach: CRC Press; 2013.
[3] Lazar J, Allen A, Kleinman J, Malarkey C. What frustrates screen reader users on the web: A study of 100 blind users. International Journal of human-computer interaction 2007;22(3):247-69, doi: 10.1080/10447310709336964.
[4] Momotaz F, Islam MT, Ehtesham-Ul-Haque M, Billah SM. Understanding Screen Readers' Plugins. Proceedings of the 23rd International ACM SIGACCESS Conference on Computers and Accessibility; Virtual Event, USA: Association for Computing Machinery; 2021. p. Article 15, doi: 0 10.1145/3441852.3471205.
[5] Lesher G, Moulton B, Higginbotham DJ. Techniques for augmenting scanning communication. Augmentative and Alternative Communication. 1998;14(2):81-101
[6] Web Content Accessibility Guidelines 1.0 World Wide Web Consortium [Internet]. World Wide Web Consortium; 1999 May 5. Available from: https://www.w3.org/TR/WAI-WEBCONTENT/.
[7] Web Content Accessibility Guidelines (WCAG) 2.1 [Internet]. World Wide Web Consortium; 2018 Jun 5. Available from: https://www.w3.org/TR/WCAG21.
[8] XR Accessibility User Requirements [Internet]. World Wide Web Consortium; 2021 Aug 25. Available from: https://www.w3.org/TR/xaur/.
[9] Google Accessibility Conformance Reports. Google; 2023. Available from: https://about.google/belonging/accessibility-conformance-reports/.
[10] 2021 Survey on Web Accessibility. National Information Society Agency; 2022 March. Available from: https://www.msit.go.kr/bbs/view.do?sCode=user&bbsSeqNo=79&nttSeqNo=3173458
[11] Carla T. Monthly Active Users (MAU): Definition and How the Indicator Is Used. Investopedia; 2022 Jul 20. Available from: https://www.investopedia.com/terms/m/monthly-active-user-mau.asp..
[12] Asia's No.1 Metaverse Platform ZEPETO Reaches 300 Million Global Users. Naver; 2022 March 4. Available from: https://www.navercorp.com/en/promotion/pressReleasesView/30824.
[13] Roblox Live Player Count and Statistics Active Player. Active Player; 2023. Available from: https://activeplayer.io/roblox/.
[14] Karl Bridge M. Microsoft Active Accessibility - Win32 apps. 2023. Available from: https://learn.microsoft.com/en-us/windows/win32/winauto/microsoft-active-accessibility.
[15] P. Kumar, "Accessibility in iOS: Start Off," 2021-06-07, 2021.
[16] Android accessibility overview - Android Accessibility Help. Google 2023 May. Available from: https://support.google.com/accessibility/android/answer/6006564?hl=en.
[17] Belir O, Onder DE. Accessibility in Public Spaces: Spatial legibility for visually impaired people. Proceedings of the Ninth International Space Syntax Symposium Edited by Kim, YO, Park, HT and Seo, KW; 2013
[18] Swobodzinski M, Raubal M. An Indoor Routing Algorithm for the Blind: Development and Comparison to a Routing Algorithm for the Sighted. International Journal of Geographical Information Science 2009; 23(10)1315-1343, doi: 10.1080/13658810802421115.
[19] Long RG, Giudice NA. Establishing and maintaining orientation for mobility. In Blasch BB, Wiener WR, Welch RW (editors) Foundations of orientation and mobility (3rd ed., Vol. 1: History and Theory, pp. 45-62). New York: American Foundation for the Blind, 2010.
[20] Cunningham K. Accessibility Handbook: Making 508 Compliant Websites. O'Reilly Media, Inc. 2012.
[21] Faraboschi P, Frachtenberg E, Laplante P, Milojicic D, Saracco R. Virtual Worlds (Metaverse): From Skepticism, to Fear, to Immersive Opportunities. Computer 2022;55(10)100-106, doi: 10.1109/MC.2022.3192702.
[22] David B. Build accessible apps with semantic properties - .NET MAUI. 2023 May. Available from: https://learn.microsoft.com/en-us/dotnet/maui/fundamentals/accessibility.

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Technologies to Enhance Mobility, Accessibility and Participation

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Measuring Economic Benefits of Built Environment Accessibility Technologies for People with Disabilities

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Abstract. Given the challenges of wayfinding in large indoor built environments, especially for persons with disabilities (PWDs), a new class of accessible technologies called built environment accessible technologies (BEAT) are being developed. Such technologies are envisioned to help achieve product and opportunity parity for PWDs. The impact and adoption of these BEATs depends largely on clear and quantifiable (tangible and intangible) economic benefits accrued to the end-users and stakeholders. This paper describes the results of a survey conducted to measure potential benefits in terms of quality of life and quality of work life (work productivity) by increased accessibility provisions within built environments as it relates to navigation for PWDs and those without disabilities. Results of this work indicate that BEATs have the greatest potential to improve mobility and exploratory activities for people with disabilities, exploratory activities for people without disabilities, and improve job security for everyone.

Keywords. Assistive & Accessible Technology, Built environment, Indoor navigation, Economic Benefits, People with Disabilities

1. Introduction

Technological advances in areas such as, but not limited to, artificial intelligence, digitalization, automation, robotics, biometrics and big data have led to major cultural changes that transformed how people live and work, with impacts on quality of life and labor markets. Benefits accrued to the general population have not necessarily been realized by under-represented populations, which include persons with disabilities (PWDs). One area where PWDs have been historically disadvantaged is efficient access within and around built environments due to fixed and time-varying barriers, improper wayfinding signage, or the inability to access wayfinding information.

The level of accessibility in built environments in most communities meets minimum requirements at best [1]. To enable PWDs to fully participate in society, a holistic change is needed in common-use spaces. These changes will enable people of all ages and abilities to participate equally in social and economic life while creating healthy and socially sustainable communities. Accessible spaces reduce barriers to using

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services and amenities, increase the range of regular activities persons can conduct independently, and enhance user's health and well-being through increased opportunities of physical activity-levels. From a macroeconomic perspective, as of 2021, only 31.4% of working age Americans (aged 16 to 64) with disabilities were employed vs. 72.5% of Americans without disabilities [2]. Enabling environments can be instrumental for the integration of PWDs in workforces and increased productivity. The gross domestic product (GDP) could increase up to $25 billion for each 1% improvement in PWD employment statistics [3]. Globally, in developing countries, 80% to 90% of PWDs of working age are unemployed, whereas in industrialized countries the figure is between 50% and 70%. In most developed countries, the official unemployment rate for persons with disabilities of working age is at least twice that for those who have no disability [4].

To achieve product and opportunity parity for people with disabilities (PWDs) in the context of indoor mapping and navigation, Built Environment Accessibility Technologies (BEATs) are being developed. The impact and adoption of these BEATs depends largely on clear and quantifiable (tangible and intangible) economic benefits accrued to the end-users and stakeholders. *This paper describes and evaluates an economic survey developed to measure potential benefits in terms of quality of life and quality of work life (work productivity) by increased accessibility provisions within built environments as it relates to navigation and wayfinding for PWDs*. Envisioned users of BEATs include those with visual or mobility impairments (blind, low vision, wheelchair users, cane users, etc.), cognitive, hearing impairments, older adults as well as other categories of PWDs including the general population with planning and navigation assistance needs.

2. Built Environment Accessibility Technology (BEAT) System Description

This work is motivated by a specific BEAT system called MABLE (Mapping for Accessible BuiLt Environments) under development by the authors. This BEAT consists of two components: a) digital accessibility maps for indoor environments with an interface for assessing, planning, and navigating within them based on the affordances and capabilities of the user, and b) an indoor navigation system within MABLE called CityGuide that uses information from created digital maps to provide fine-grained, customized, turn-by-turn navigation within or across indoor and outdoor spaces. The various applications of the MABLE BEAT system include emergency management, remote assistance, transit, wayfinding, tourism [5] in large indoor public spaces such as shopping centers, convention centers, stadiums, airports, hospitals and private or access controlled indoor spaces such as company campuses, commercial multi-story buildings. While the creation of the MABLE BEAT system is motivated to benefit PWDs, general population is expected to greatly benefit based on the applications and their needs. An example of the application of the system is illustrated in Fig 1. An objective to reach the destination using the shortest path (dotted lines) may not always be feasible due to temporary obstacles, thus the system provides the safest path (green line) although a longer path, to navigate to the destination.

The intent of developing BEATs is clearly to benefit PWDs in navigating unfamiliar places. However, an important criterion for BEATs to be widely adopted is the consideration of economic benefits, which can be measured as cost-savings or return in investments. This paper sets out to determine the economic value of adopting a potential

BEAT for PWDs and is applicable to the entire class, not limited to just a specific BEAT like MABLE.

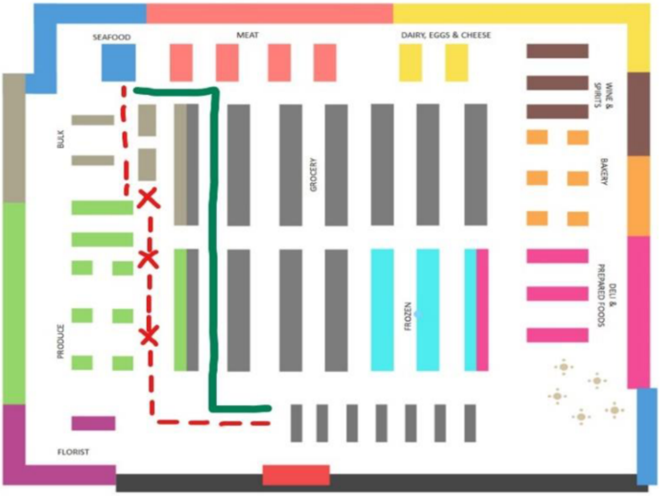

Figure 1. System Application at a supermarket. Photo credit:edrawsoft.com

3. Measuring Economic Benefits

3.1. Objective

The objective of the survey is to evaluate and analyze the economic benefits of adopting accessible and assistive technologies for indoor navigation in built environments in terms of improvements in quality of life and in quality of work.

3.2. Design of Survey

The survey is an adaptation of commonly used survey instruments adopted for measuring health states such as EQ-5D-5L developed by the EuroQoL Group and some others- Health Utilities Index Mark 3 scale (HUI3), SF-6D etc. This questionnaire evaluates not just Quality of Life but also Quality of Work Life, addressing factors that affect productivity at work. It follows the construct to calculate Quality Adjusted Life Years (QALY) which is a well-known measure that attempts to show the extent to which a particular treatment or system extends life and improves the quality of life at the same time [6], [7], [8], [9]. The survey is designed to have two parts, one to measure the *current* health state (quality of life) and work productivity (work life), and two to measure *potential changes* to health states and work life based on adopting BEATs. Both parts of the instrument are constructed with identical 10 questions, where five questions relate to general health and the next five relate to work life. All questions are provided with 5 levels of answer choices, 1 always being the best state and 5 always being the worst state. The structure is similar to that of EQ-5D-5L in which 5 questions focus on quality of life, and the 5 different answer choices mimic the main concepts of the EQ instrument. The flow of the survey is designed to skip work productivity (or work life) questions for respondents who are not working. Fig 2 provides a schema of the questionnaire. As in

[10], the survey instrument is used to generate useful insights into adopting BEATs in improving overall changes in quality of life and work life.

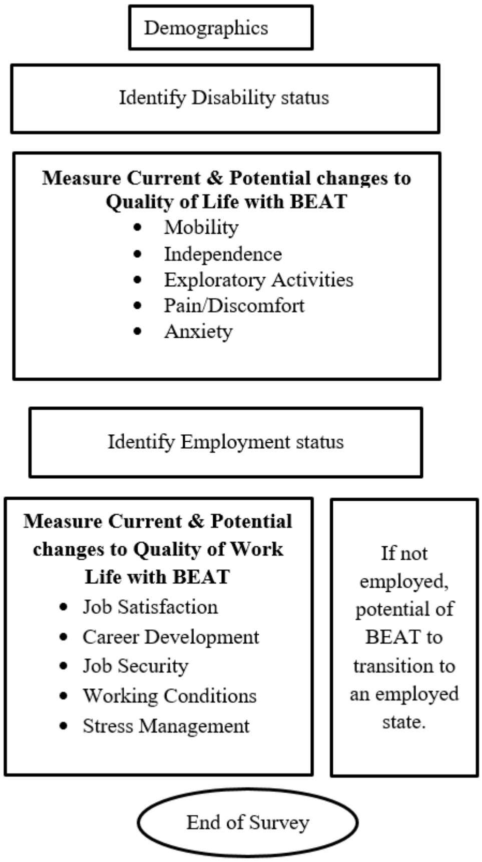

Figure 2. Design of the survey instrument.

3.3. Data Collection

Envisioned users of the system include those with visual or mobility impairments (blind, low vision, wheelchair users, walker users, etc.), cognitive, hearing impairments, older adults as well as other categories of PWDs including the general population with planning and navigation assistance needs.

This study is approved by Kansas State University (KSU) IRB protocol# 10616. Using Qualtrics through KSU, the survey was sent to a) students representing a savvy group comfortable with technology mostly with no disability, and b) individuals known to have a disability (disability types mentioned above) through prior interactions in research studies (who were also encouraged to pass it on to others they know or their care givers). Both groups could have varying employment status, ranging from working full-time, part-time, or not working at all. The survey was sent in May 2023 and participants were given the option of being entered into a drawing to win a gift card. A description of the BEAT system being developed was provided in the survey so that survey takers could make an informed choice. A total of 40 responses were collected and these were split as results for those with a disability and those without a disability.

The 2019 American Community Survey published by the US Census Bureau determined 12.7% of the US population has disabilities. The disability population has 71.2% individuals above the age of 65 years and 25.9% are employed as shown in Table 1. US national statistics for persons with disabilities on age, gender, race, employment provide a benchmark to compare the results of the survey.

People with disabilities constitute 22% of the sample, with types of disabilities identified as vision, mobility and cognitive. Majority of the respondents are below the age of 35 years (68%), male (62%), and represent whites (73%). 78% are employed with almost equal distribution between part-time and full-time employment status. Those who are not employed indicated an even split in the potential of BEATs to be helpful in transitioning to an employed state. Table 1 summarizes the background characteristics of the sample.

Table 1. Demographics

Characteristic	Survey Count (%)	US PWD %
Age		
Less than 21 years	10 (27%)	6.3%
21-35 years	15 (41%)	6.7%
36-45 years	4 (11%)	12.4%
46-55 years	3 (8%)	
56-65 years	3 (8%)	
Above 65 years	2 (5%)	71.2%
Gender		
Male	23 (62%)	12.6%
Female	13 (35%)	12.8%
Non-Binary	1 (3%)	
Race		
Asian	7 (19%)	7.2%
White	27 (73%)	13.2%
Hispanic	3 (8%)	9.1%
Disability		
No	29 (78%)	87.3%
Yes	8 (22%)	12.7%
	Vision-5, Mobility-3, Cognitive-1	Vision-2.3%, Mobility-6.9%, Cognitive-5.2%
Employment		
No	8 (22%)	70.3%
Yes	29 (78%)	25.9%
	Full-time-13, Part-time-16	

3.4. Results

Quality of life is measured using five dimensions: mobility, independence, exploratory activities, pain/discomfort, and anxiety/depression. Quality of work life is defined by job satisfaction, career development, job security, working conditions and stress management at work. The levels range from 1 to 5 where 1 is the best always for any dimension considered. Table 2 provides a comparison of ratings or levels for each dimensions pre and post adoption of a BEAT for people with disabilities and without.

Levels 2 to 5 represent some problems with the dimensions considered such as lower mobility, independence to not mobile or independent at all (rating 5), i.e., not ideal cases. Comparing level 1 (perfect health state and work-life) across dimensions, BEATs are expected to improve both quality of life and work life across all dimensions. For example, row corresponding to level 1 of Table 2 can be interpreted as: the disability community survey takers imply before a BEAT adoption they do not have excellent mobility, are not fully independent, are not able to fully explore activities beyond their routine, are not super comfortable in unknown indoor environments, and two indicated they are never anxious or stressed. After a BEAT adoption, three from the disability group feel mobility is at its best, feel independent, are fully able to explore, are comfortable and two indicate anxiety is removed. Similarly, for the people without disabilities group, 14 indicate their mobility is excellent with a BEAT as opposed to 10 without a BEAT.

Weighted average benefits are determined pre- and post-BEAT for each dimension by multiplying the levels and pre/post values and dividing by sum of all levels. The cardinality of the levels results in a lower post weighted average, which indicates benefits are accrued with a BEAT. Percentage increase in weighted average benefits with BEAT are pronounced in quality of life over quality of work-life. The disability group indicates they benefit the most with mobility using a BEAT (rank #1), the non-disability group benefit the most in exploratory activities, and a BEAT does well in affording job security in the work-life realm.

Table 2: Measuring Weighted Average Benefits: pre- and post-BEAT adoption.

	Quality of Life for People with Disability									
	Mobility		Independence		Exploratory Activities		Pain/Discomfort		Anxiety/Depression	
	pre-	post	pre-	post	pre-	post	pre-	post	pre-	post
1	0	3	0	3	0	2	0	1	2	2
2	1	3	1	3	1	4	2	4	1	4
3	4	1	4	2	4	1	3	1	2	2
4	2	0	1	0	1	0	1	1	1	0
5	1	0	1	0	2	0	1	0	2	0
N/A	0	0	0	0	0	0	1	1	0	0
Total	8	7	7	8	8	7	8	8	8	8
Weighted Average Benefits	1.8	0.8	1.5	1	1.9	0.9	1.5	1.1	1.6	1.1
%increase in Weighted Average Benefits	-56		-35		-54		-27		-33	
Ranking of Weighted Average Benefits	#1		#3		#2		#5		#4	

	Quality of Life for People with No Disability									
	Mobility		Independence		Exploratory Activities		Pain/Discomfort		Anxiety/Depression	
	pre-	post	pre-	post	pre-	post	pre-	post	pre-	post
1	10	14	9	14	10	5	10	12	8	13
2	5	2	7	3	3	6	5	4	8	2
3	9	3	6	2	8	2	5	2	3	3
4	1	3	2	1	3	2	2	2	2	2
5	1	0	1	0	2	0	2	0	4	1
N/A	0	3	0	4	0	4	2	5	1	4
Total	26	25	25	24	26	19	26	25	26	25
Weighted Average Benefits	3.7	2.6	3.6	2	4.1	2.1	3.5	2.3	4.1	2.6
%increase in Weighted Average Benefits	-30		-44		-50		-36		-36	
Ranking of Weighted Average Benefits	#4		#2		#1		#3		#3	

	Quality of Work Life									
	Job Satisfaction		Career Development		Job Security		Working Conditions		Stress Management	
	pre-	post	pre-	post	pre-	post	pre-	post	pre-	post
1	9	11	6	6	7	7	9	12	7	8
2	6	4	9	9	4	5	6	4	6	6
3	8	6	6	3	4	4	7	2	8	6
4	2	1	0	2	2	3	2	2	4	3
5	1	2	2	1	4	0	1	2	1	1
N/A	0	2	3	5	4	7	0	0	0	2
Total	26	26	26	26	25	26	25	22	26	26
Weighted Average Benefits	3.9	3.4	3.5	3.1	3.7	2.7	3.7	2.9	4.3	3.7
%increase in Weighted Average Benefits	-12		-12		-25		-20		-14	
Ranking of Weighted Average Benefits	#4		#4		#1		#2		#3	

4. Discussion

There are many assistive technologies already developed, tested and adopted by people with disabilities. For example, people who are blind can easily navigate using a $35 cane. Familiarity of space and routine activities provide comfort and stability in accomplishing tasks and goals. However, when it comes to navigating unknown large indoor spaces, a system needs to be in place to provide people with disabilities the same access as that of people without disabilities. A BEAT called MABLE is proposed to level the playing field across disabilities for navigational needs and even enhance the quality of life and work-life for people without disabilities. A survey designed to measure economic benefits with a BEAT in terms of certain dimensions of health translating to quality of life and other dimensions related to work, shows that BEATs do have the scope to benefit both people with and without disabilities. Benefits can magnify based on economies of scale and scope, where economies of scale relates to a large user base while scope relates to various uses of the system. BEATs promise to satisfy on both the counts based on the design and its applicability.

The survey results affirm improvements in quality of life and work-life with BEATs for people with and without disabilities. However, results can be more nuanced, intuitive and accurate with a sample more heavily tilted towards people with disabilities. The current results are dominated by people without disabilities. The legitimacy of the results are preserved because a necessary condition of BEAT adoption is increased benefits to people without disabilities while the sufficient condition is benefits to people with disabilities.

Some interesting and perhaps unexpected findings are the ranking of dimensions that affect the groups. For example, it might be expected that a BEAT would alleviate anxiety considerably for people with disabilities. New large indoor spaces can be disorienting, stressful and quite challenging, thereby triggering anxiety. Based on this reasoning, the weighted average benefit of using a BEAT should rank anxiety at the top. However, the results suggest improvements in mobility and exploratory activities with a BEAT are proportionally even greater than other dimensions. The reasoning could be that they believe if technical challenges are solved, the corresponding anxiety afforded by the challenges could be absolved. The other reasoning to explain this result could be that people with disabilities attribute stress and anxiety to multiple factors that transcend navigating an unknown space. In the same vein, employed people with disability or without have an array of challenges related to work-life, that marginal benefits afforded by BEAT can be very low. This would explain the impact of BEATs being more pronounced in improving quality of life over work-life.

Adoption of BEATs requires an analysis of both benefits and costs of establishing the system. This paper focuses on measuring benefits. Costs can be easily determined and will be relegated to future work. There are other directions that can be explored such as calculating Quality Adjusted Life-Years (QALY) based on the foundations of this work. QALY can be further used to determine incremental cost-effectiveness ratio when two different technologies need to be compared and evaluated.

5. Conclusion

The results of this paper show that BEATs will be instrumental in affording people with and without disabilities greater mobility, independence in locating amenities, ability to explore activities in new spaces, relieve discomfort and anxiety to collectively improve their quality of life. In the work-space, BEATs can improve satisfaction with jobs by helping meet some of the demands of mobility, helping with career advancement by enabling new opportunities, improving job security, and providing accessibility to amenities, while alleviating stress related to workplace commute and travel. While benefits are more pronounced with Quality of life over Quality of Work-Life, BEATs have been identified to be helpful in transitioning to an employed state for those who are currently not employed. As the system develops, further iterations of the study will be helpful in attesting to the benefits of BEATs.

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References

[1] Maisel J, Ranahan M. Beyond accessibility to universal design. https://www.wbdg.org/design-objectives/accessible/beyond-accessibility-universal-design
[2] U.S. Bureau of Labor Statistics. Persons with a disability: Labor force characteristics summary. https://www.bls.gov/news.release/disabl.nr0.htm
[3] Getting to equal: the disability inclusion advantage: Accenture 2018. https://www.accenture.com/_acnmedia/pdf-89/accenture-disability-inclusion-research-report.pdf.
[4] United Nations, Department of Economic and Social Affairs Disability. https://www.un.org/development/desa/disabilities/resources/factsheet-on-persons-with-disabilities/disability-and-employment.html
[5] Namboodiri V, Abraham A, Garfias FJR, Joseph S. On the Application of Accessible Wayfinding Systems for Tourism. 2022 IEEE 2nd IoT Vertical and Topical Summit for Tourism (IoTT). Catania, Italy. Sept.
[6] Brandt Å, Alwin J, Persson J, Husberg M. Can we rely on QALYs for assistive technologies? Technology & Disability. 2012; 24 (1):93-100
[7] Weinstein MC, Torrance G, McGuire A. QALYs: the basics, Value in Health 12 (Suppl 1) 2009, S5-S9.
[8] Quality-Adjusted Life Years and the Devaluation of Life with Disability. National Council on Disability. November 6, 2019, https://ncd.gov/sites/default/files/NCD_Quality_Adjusted_Life_Report_508.pdf
[9] Health Related Quality of Life. Centers for Disease Control and Prevention. October 31, 2018, https://www.cdc.gov/hrqol/concept.htm.
[10] Devlin N, Parkin D, Browne J. Using the EQ-5D as a performance measurement tool in the NHS. London, UK: Department of Economics, City University London. Available from: https://openaccess.city.ac.uk/id/eprint/1502/

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Uses of Wayfinding Tools by People Who Are Blind and Low Vision

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Abstract. This paper presents the results of a research study of people who are blind or low vision about their experiences using wayfinding tools. The results present the accessibility issues when using wayfinding tools and assistive technology to learn about new locations. An online survey followed by a series of interviews was conducted with ten people who identify as blind and six with low vision to learn their opinions and concerns about accessibility of three types of wayfinding tools, digital maps, navigation apps and camera apps.

Keywords. accessibility, wayfinding, maps, visual impairment

1. Introduction

Navigating to unfamiliar places presents significant barriers for people with visual impairments. Digital wayfinding tools provide potential solutions for disabled people as they navigate daily through a variety of environments. Navigation and spatial orientation can be challenging for people who are blind or low vision (BLV). People with vision impairments must often rely on their immediate social circles to gain knowledge of an unfamiliar location [1]. This can limit persons who are BLV to independently explore their surroundings and fully participate in society [2]. Recent digital navigation aids present novel opportunities to enhance accessible wayfinding solutions for persons with visual impairments. To our knowledge, there is no comprehensive recent study about how people who are BLV use spatial orientation when wayfinding in unfamiliar places. With the intent of exploring contemporary tools, we conducted an online survey and series of interviews with participants who are BLV to learn their needs and barriers about accessibility of navigational aids.

2. Background

People today are inclined to navigate through surroundings with the aid of navigational aids. When it comes to navigating in unfamiliar areas for the visually impaired, spatial navigation and multisensory information play a significant role [3]. People who are BLV

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who have severe to profound vision loss may use residual eyesight for mobility, despite being legally classified as blind in many countries [1]. A person's capacity to see objects is called visual acuity, which is used for diagnosing a person with visual impairment. The term ”visually impaired” is used if vision acuity is moderate to high (20/70 - 20/200). The word blind is used if there is less than 20/200 of a person's visual acuity or visual field is 20 degrees or less [4].

Wayfinding is a cognitive process that varies based on the person’s navigational skills [3]. Wayfinding employs strategies such as spatial navigation, imagination of the positioning of landmarks and routes (cognitive mapping), and the use of navigational aids. We use prior knowledge from perceived sensory cues of locations to build our position with the location, discover a route, plan a sequential route from significant landmarks, and create a larger network of routes [5]. Landmarks, route instructions, and cognitive maps are all navigation tools that aid in the acquisition of route information [3].

Compared to traditional ways of use navigation, individuals with BLV utilize printed tactile and digital maps, including 3D printed maps, as navigational aids to enhance their navigation and access information about the environment [1]. These maps provide details on environment, signages, surroundings and obstacles as accessible information in unfamiliar areas [6]. But, wayfinding information is not always accurate, and it usually does not include accessible interactions and information [1,7]. The topography of the land provides significant spatial information, emphasizing the importance of considering factors beyond visual elevation cues alone [8].

A survey was conducted to study how individuals with BLV independently plan and navigate trips to unfamiliar buildings [1]. Results show that the majority of individuals with BLV rely on others for instructions. Seventeen out of forty-three participants with low vision (LV) preferred obtaining the route information from personal contacts prior to the journey, while twenty-seven out of sixty-three participants with blindness (BL) expressed a similar preference.

Another survey highlighted the negative consequences when considering the lack of information about environmental changes for individuals with visual impairments who travel alone [7]. The survey revealed that this leads to reduced confidence, limited independence, compromises of safety/injury, and accidental near misses. Furthermore, the participants expressed the need for information about their immediate surroundings to enhance their navigation experience.

In a separate survey of twenty visually impaired individuals navigating in familiar, unfamiliar, and dynamically changing environments, researchers found that participants preferred to rely on personal networks and private transportation services for trip planning, rather than relying on GPS [9]. The study emphasized that participants collected environmental information, such as landmarks and routes, to thoroughly plan their journeys. Additionally, they made more decisions during their trips and relied on memorizing the information they gathered from their close circles. However, the study did not examine the influence of evolving technology, such as assistive technology or digital wayfinding tools, on independent travel. It also did not explore wayfinding strategies involving public transportation or indoor navigation.

Wayfinding tools aid individuals with BLV to learn about indoor and outdoor locations and become less reliant on others [10,11]. In order to learn their surroundings, people who are BLV need a mental map, which they create by using accessible maps and by interacting with digital recreations [4]. Researchers conducted a study with BLV in virtual environments to compare early and late blind participants to asses the transfer of acquired spatial information using a highly interactive immersive exportation of the virtual environment: Results showed that prior visual experience did not have a significant effect on overall navigation performance [12].

It has previously been observed that route descriptions including the surrounding landmarks lower the cognitive load for travellers [13]. Likewise, providing a description of a route and its destination together with other landmarks on the route decreases cognitive load [14]. Previous findings reveal that visually impaired users could use route previews for localization and orientation when given wayfinding instructions with landmarks, rather than orientation and distance-based information given alone [10]. A research study shows that BLV individuals who lost sight after birth have a more difficult task learning how to navigate without sight than individuals who were congenitally blind, who were quicker to remember a previous location learned with navigational aids [15].

3. Methodology

We conducted an online questionnaire and interviews with people who are BLV. We asked participants about their experiences and the ways that they learn about unfamiliar places. We also asked about accessibility, their knowledge of wayfinding tools, whether or not the tools helped them become more independent, and the configurations they use. We then asked them about their experiences exploring places without the aid of technology. The research study goals were to identify issues with the accessibility of digital maps for the use of blind and low vision communities.

3.1. Participants

The study involved a total of sixteen participants, representing a diverse range of demographics. The participants' ages ranged from twenty-one to eighty-two years, with a mean age of forty-three years. Among the participants, ten were blind, and six had low vision with sight less than moderate (20/100, or "legally blind"). Four participants had been blind or visually impaired since birth, three had visual impairment since childhood, while five experienced visual impairment before the age of eighteen. One participant developed visual impairment after the age of thirty-four, and three participants were older than forty-five when their vision impairment occurred. Nine were from North America, three from Europe, two from Asia, one from Oceania, and one from Central America.

3.2. Survey and Interviews

The survey aimed to investigate how individuals with visual impairments discover new locations and use spatial navigation and wayfinding methods, particularly in both familiar and unfamiliar environments, with the aid of modern technology. Our focus was to gain insights into the experiences and concerns of visually impaired individuals when planning and embarking on solo trips to both known and unknown destinations. Survey questions were a combination of multiple choice and open-ended questions. Users were asked their experience, how they learn about locations, and their use of digital maps that are accessible with screen readers. We followed the survey with a series of one-on-one interviews. The interviews gathered qualitative data, which we then subjected to thematic analysis. Interviews covered the additional topics from the survey and allowed participants the opportunity to expand on their thoughts and provide us with more details. Qualitative answers were clustered into themes and features that would help us to design a wayfinding alternative to visuals. Topics that were mentioned more than three times were added to the list of themes.

4. Results

4.1. Survey

Out of sixteen participants, two participant reported travelling alone at least once a day, four several times a week, two once a week, five once a month, and three once a year. Eleven participants used Google Maps, five used Apple Maps, and two used OpenStreet Maps for navigation purposes. Eight participants used digital maps on a monthly basis, while five used them a few times a week, three used on a daily basis. Twelve participants mainly used digital maps on their phones, only a three were using digital maps on their tablets.

Out of the four participants who used digital maps on a computer, two strongly agreed that they were accessible, while the other two remained neutral. However when it came to the accessibility digital maps using mobile phones, opinions were divided, two participants strongly agreed, three agreed that digital maps were accessible with mobile phones. On the other hand, one disagreed or two strongly disagreed, and four remained neutral.

Fourteen participants used phone-based navigation assistants, with varying opinions on accessibility: five disagreed, five agreed, two strongly agreed, and two remained neutral. Among the ten participants who used camera apps to convert visual information into audio for their surroundings, three participants agreed and one strongly agreed that these apps were accessible. However, two participants disagreed and one strongly disagreed with their accessibility, while three participants remained neutral.

The study also explored location preferences, with five participants expressing a greater interest in previewing indoor locations, while six participants were more inclined towards outdoor locations and an equal number for traveling and transportation locations. Furthermore, fifteen out of the sixteen participants demonstrated proficiency in using screen readers, twelve were familiar with voice command usage, twelve used the voice command, and only three used a tactile keyboard.

4.2. Interviews

The interviews were more useful to us than the survey results, as we could delve more deeply into the challenges faced by people who are BLV when using digital maps, and the need for maps to be more accessible for them.

The participants highlighted the limitations of current digital maps, such as the lack of guidance, the heavy reliance on visual content, and the difficulty in tracking streets and locations. Participants highlighted that knowledge and past experience plays an important part in their ability to navigate. Potential solutions to the challenges of planning for navigation and orientation in urban areas were discussed. Two participants gave an example of trying to locate a bus and how having more specific information about the location would make it easier to plan and find it.

Participants addressed not having accessible information when travelling, such as not knowing which side of the street a bus stop or crosswalk is on. Participants suggested using cues such as street names and nearby landmarks and sidewalk accessibility such as tactile guiding system, curbs and location of traffic lights to help orient oneself. Other participants mentioned that in many countries, cities have implemented legislation and measures to ensure the accessibility of crosswalks.

The complexities and challenges involved in orientation when travelling to locations were about following directions, and the importance of having a clear understanding of one's surroundings. The participants mentioned the importance of references, such as street addresses and adjacent shops, to help orient oneself and provide useful reference points. Two participants discussed various ways of understanding and giving directions in a physical environment, such as finding a specific location on a map or navigating a city block. One mentioned more specific and accurate directions, such as knowing exactly how many shops down a particular location might be, and one suggested that sensory cues like sounds and smells might also be useful for navigating. Participants with LV indicated that, despite their reduced visual acuity, some are still able to perceive colors, and specifically mentioned relying on architectural and color cues to remember buildings.

Two participants with BL commented that to find the traffic light button, one should get to the slanted part of the curb. Two participants also mentioned that crosswalks are not as difficult to find as bus stops, but still require orientation and some attention to detail, such as looking for traffic lights, curb cuts, or other landmarks.

Eight participants expressed their interest in using location preview tools such as Google's preview feature to explore restaurants or tourist destinations prior to their trips. Additionally, five participants indicated their preference for having a seating layout map for planes or buses in transportation. Two participants specifically mentioned the value of location previews to assist in selecting and reserving seats at accessible restaurants.

Participants had various challenges with navigation and orientation in environments when using GPS and public transportation. Participants mentioned that while GPS can provide directions, it often doesn't provide enough detail about the exact location, such as which side of the street to stop on. Moreover, GPS was limited or unusable indoors or in adverse weather conditions. Participants addressed their confusion of finding the exact location of an entrance to shop or to a restaurant that is between intersections because of inaccurate GPS-based directions. Participants suggested that having more information about the surrounding environment, such as cross streets and the number of doors to enter, would be helpful.

Participants noted the limitations with regards to indoor wayfinding, and that information such as doors and windows, could be beneficial for both visually impaired individuals and other users, for instance, in blackout situations or fires. For example, When using a map to navigate inside a shopping mall, participants with BLV mentioned that the map did not give information what level the shops were on, and did not provide landmarks or information on what the shops were located next to. Participants suggested that maps could include information about accessible ramps, bathrooms, and elevators.

Participants highlighted the importance of research with the BLV community in addressing accessibility issues, and the need for more inclusive approaches to technology development. Five participants with BL addressed the challenges faced by BL people in using maps, particularly on touch screen mobile phones. Three participants suggested that making maps with listed items that lists each point of interest could help improve the user experience. Participants also suggested using maps to provide detailed information about these locations, including descriptions of door handles, entrances and layout of rooms. Interviews also discussed the potential benefits of such technology, not just for people with disabilities, but for society as a whole. All participants BLV mentioned the need to consider the layout of indoor spaces, such as entrances, exits, and accessibility features, when designing interactive maps.

Participants mentioned the potential of using other sensory or interaction modes, such as haptic or audio, to create maps more inclusive wayfinding tools. Results highlight the importance of tactile information and accessibility in navigating physical environments. Participants commented that the feeling of the ground, particularly the tactile pavement, is important for understanding the environment. Participants suggested that including tactile information on location maps with screen readers could be helpful for accessibility.

Other participants suggested the use of beacons for locating specific areas and having a list of nearby locations. Participants added that sound interaction could be useful when exploring maps, and that different sounds could indicate different locations such as shops. They also discussed the topic of auditory information and how it's not a one-size-fits-all solution for blind individuals, as not everyone is auditory. Users need flexibility in multimodal applications for information be available to be helpful for people who have different learning styles and accessibility needs. Again, these adaptations may be beneficial for non-BLV people as well.

5. Discussion

The study highlights the importance of using technology to make spaces more accessible and navigable when designing and providing information about locations: Three participants said they would not go to places unless they know the accessibility information. Participants addressed the importance of providing more detailed information on location and accessibility in navigation apps. The findings of this study highlight the importance of addressing the accessibility challenges faced by visually impaired individuals in navigating unfamiliar places. The results highlight the need for digital maps to provide more precise information, and multimodal information in the form of auditory or tactile cues.

The interviews provided deeper insights into the challenges faced by visually impaired individuals when using digital maps. By addressing the identified challenges and incorporating user-centric design principles, digital mapping solutions can be made more inclusive and empower visually impaired individuals to navigate and explore unfamiliar locations with greater independence and confidence.

However, it is important to acknowledge that although this study had diverse participants with different ages and backgrounds, the study had a small sample size, limiting the generalizability of the findings. Future research should aim to include a larger sample size to have a comprehensive understanding of the experiences and needs of visually impaired individuals in using wayfinding tools. Additionally, conducting usability tests and user-centered design approaches could provide more detailed insights into the specific requirements and preferences of visually impaired users when interacting with digital maps.

Our aim was to create an analysis of wayfinding from a blind and low vision experience to develop a wayfinding solution for people who depend on the use assistive technology as navigational aids. Participants provided valuable insights into preferences and challenges related to digital maps, navigation assistants, camera apps, sensory information, and the use of traditional wayfinding methods.

We explored the challenges in navigating unfamiliar environments and discussed the potential of digital maps as alternative solutions. The responses gathered from our survey and interviews highlight the importance of creating inclusive and user-centric designs for digital maps. The most significant requirements noted were: incorporating alternative sensory modes like haptic or audio feedback; providing tactile cues and auditory landmarks; and offering reference points with accurate, detailed and clear directions, particularly when it comes to large indoor settings.

Although there are inherent difficulties in achieving complete accessibility for individuals with visual impairments when it comes to digital maps, the need for creating inclusive and accessible digital maps with location previews is significant. By continuing to prioritize accessibility and incorporating user feedback, we gathered requirements to develop accessible digital mapping solutions that address the specific needs for people with vision impairment. Their insights and specific needs have the potential to increase their independence by helping them with mobility. our future work plans to co-design a more accessible application for wayfinding.

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References

[1] Engel C, Müller K, Constantinescu A, Loitsch C, Petrausch V, Weber G, et al. Travelling more independently: a requirements analysis for accessible journeys to unknown buildings for people with visual impairments. In: Proceedings of the 22nd International ACM SIGACCESS Conference on Computers and Accessibility; 2020. p. 1-11.

[2] Goffman E. Stigma: Notes on the Management of Spoiled Identity. 1st ed. New York: Simon & Schuster; 1986.

[3] Golledge R, Jacobson D, Kitchin R, Blades M. Cognitive Maps, Spatial Abilities, and Human Wayfinding. Geographical review of Japan series b. 2000 12;73:93-104.

[4] Almeida V, Tsuji B. Chapter 18 Interactive Mapping for People Who Are Blind or Visually Impaired. In: Taylor DRF, editor. Modern Cartography Series. vol. 4 of Cybercartography. Academic Press; 2005. p. 411-31.

[5] Lithfous S, Dufour A, Després O. Spatial Navigation in Normal Aging and the Prodromal Stage of Alzheimer's Disease: Insights from Imaging and Behavioral Studies. Ageing Research Reviews. 2013 Jan;12(1):201-13.

[6] El-Taher FEZ, Taha A, Courtney J, McKeever S. A systematic review of urban navigation systems for visually impaired people. Sensors. 2021;21(9):3103.
[7] El-Taher FEZ, Miralles-Pechuan L, Courtney J, Millar K, Smith C, McKeever S. A Survey on Outdoor Navigation Applications for People With Visual Impairments. IEEE Access. 2023;11:14647-66.
[8] Previc FH. The Neuropsychology of 3-D Space. Psychological Bulletin. 1988;124(2):123-64.
[9] Quinones PA, Greene T, Yang R, Newman M. Supporting Visually Impaired Navigation: A Needs-Finding Study. In: CHI '11 Extended Abstracts on Human Factors in Computing Systems. CHI EA '11. Association for Computing Machinery; 2011. p. 1645-50.
[10] Upadhyay V, Bhatnagar T, Holloway C, Rao PVM, Balakrishnan M. Can Route Previews Amplify Building Orientation for People with Visual Impairment? In: Miesenberger K, Kouroupetroglou G, Mavrou K, Manduchi R, Covarrubias Rodriguez M, Penáz P, editors. Computers Helping People with Special Needs. Lecture Notes in Computer Science. Springer International Publishing; 2022. p. 187-96.
[11] Bandukda M, Singh A, Berthouze N, Holloway C. Understanding Experiences of Blind Individuals in Outdoor Nature. In: Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems. CHI EA '19. New York, NY, USA: Association for Computing Machinery; 2019. p. 1-6.
[12] Connors EC, Chrastil ER, Sánchez J, Merabet LB. Virtual Environments for the Transfer of Navigation Skills in the Blind: A Comparison of Directed Instruction vs. Video Game Based Learning Approaches. Frontiers in Human Neuroscience. 2014;8:223.
[13] Bradley NA, Dunlop MD. An Experimental Investigation into Wayfinding Directions for Visually Impaired People. Personal and Ubiquitous Computing. 2005;9(6):395-403.
[14] Raubal M, Winter S. Enriching Wayfinding Instructions with Local Landmarks. In: Egenhofer MJ, Mark DM, editors. Geographic Information Science. Lecture Notes in Computer Science. Berlin, Heidelberg: Springer; 2002. p. 243-59.
[15] Cornoldi C, Vecchi T. Visuo-Spatial Working Memory and Individual Differences. Essays in Cognitive Psychology. Hove, East Sussex ; New York: Psychology Press; 2003.

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Social Participation and Physical Activity Incentive at Home in Stroke Survivor: Contribution of Technologies

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Abstract. Increased physical activity has been demonstrated as a relevant treatment after a stroke, with positive effects on impairment recovery, activity limitation, social participation and quality of life. Furthermore, PA is now recommended as part of the stroke recovery pathway, starting during inpatient care and extending through rehabilitation and community integration. The purpose of this presentation is to describe how current technologies may facilitate a continuity of care for stroke survivors. We present a synthesis of 8 studies that we have conducted to date to assess and monitor the activity level of post-stroke patients at home. The results of these studies show that home rehabilitation of post-stroke patients requires the use of individualized monitoring criteria to optimize patient care. To encourage the patient to increase his level of moderate physical activity and reduce his sedentary time, it would be recommended to propose a regularly monitored and structured program.

Keyword: Stroke; Home; Physical activity; Activity tracker.

1. Introduction

Strokes are the leading cause of acquired neurological disability. In France, it is estimated that approximately 750,000 people have survived a stroke, 60% of whom still have associated sequelae (e.g., motor deficit, language disorders, cognitive disorders, sensory or visual disorders). Limited physical mobility is a common consequence of strokes and has been associated with lower participation in physical activity (PA) [1]. Increased physical activity has been demonstrated as a relevant treatment after stroke, with positive effects on impairment recovery, activity limitation, social participation and quality of

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life. Furthermore, PA is now recommended as part of the stroke recovery pathway, starting during inpatient care and extending through rehabilitation and community integration [2]. In France, after hospitalization in an acute unit, 36% of patients receive inpatient rehabilitation (23.4% in general or geriatric rehabilitation center and 10.4% in neurological rehabilitation center) for an average of 46 days [3]. Returning home allows the subject to be reintegrated into their environment in a real-life setting. It is at this moment that the person who had a stroke and their relatives truly become aware of the restrictions in social participation linked to stroke sequelae. Participation restrictions are partly linked to the severity of the stroke and the associated sequelae that limit activities [4], and partly to contextual factors such as adapting to the living environment, and especially social support [4]. Support from relatives is essential when returning home, as social support can facilitate social participation [5]. However, increased reliance on others for support may lead to increased burden and fatigue for family members. After returning home, stroke survivors experience a breakdown in care and follow-up from health care professionals [6]. A systematic review by Chen et al. in 2019 showed that 73% of patients report at least one essential unmet need that would facilitate their daily life at home, and generally reported between two and five unmet needs [7]. These needs are most often related to impairments and activity limitations (59.7% to 83.7%). Stroke survivors also requested assistance with mobility in the community (e.g., transportation, moving around) (5.4% to 53%) and assistance in the home and personal care (4.7% to 39.3%). Finally, they reported a lack of information about stroke and its sequelae (3.1% to 65%). In order to avoid this disruption and ensure continuity of care, rehabilitation programs must continue through community integration when the person returns home, taking into account the complex contextual factors [8]. The purpose of this presentation is to describe how current technologies may facilitate a continuity of care for stroke survivors.

We aim to answer different questions:

- How to maintain long-term benefits, especially for maintaining activity in real-life situations?
- Can current wearable technologies help us to better assess the patient at home? In the context of their physical activity? In the context of daily life?
- How can wearable technology facilitate novel approaches to collect data? Which parameter(s) are most relevant for defining exercise intensity?
- Can tele-rehabilitation technologies improve mobility in post-stroke patients?

2. Methods

To respond to some of the unmet needs, we have conducted eight studies between 2012 and 2023 aiming to better understand how to support stroke survivors as they return home.

Individuals with post-stroke sequelae were recruited from patients hospitalized or followed in consultation in a Physical Medicine and Rehabilitation Department of the University Hospital center. Recruitment was performed by the department’s doctors according to the following inclusion/exclusion criteria. Inclusion criteria were the following: a single stroke confirmed by brain imaging and the ability to walk continuously for 6 minutes with or without mobility aids. Exclusion criteria were the following: acute cardiac or respiratory pathologies or decompensated chronic pathologies.

To answer these questions, we followed the plan presented in Figure 1.

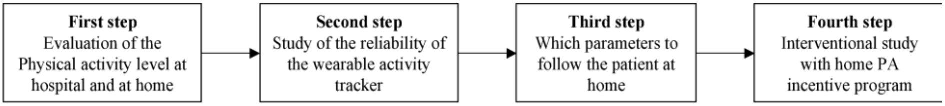

Figure 1. Model used to provide a response to the problem of monitoring and encouraging activity at home in post-stroke patients.

We proposed different strategies of intervention, and we used wearable activity tracker technologies to obtain various information about the physical activity of the patient:

- Actigraph GT3x-BT (Actigraph Pensicola, Florida, USA). This tri-axial accelerometer records the number of steps, EE and active EE (kcal), as well as the period of sedentary, moderate, vigorous and very vigorous activity expressed in minutes.
- Armband Sensewear (BodyMedia Inc., Pittsburg, Pennsylvania, USA). This bi-axial accelerometer estimates the EE and active energy expenditure (kcal), the time spent at each level of activity in minutes and the number of steps.
- Actical (Respironics Philips). This bi-axial accelerometer estimates the period of sedentary, light, moderate, vigorous activity measured in minutes, the number of steps and the level of active EE.
- Pedometer (ONStep 400, Geonaute). The pedometer records the number of steps and an estimation of EE.

3. Results

3.1. Study of the physical activity of post-stroke patients:

We conducted two studies to evaluate the level of physical activity of post-stroke patients in the sub-acute phase (during hospitalization) and in the chronic phase (at home with private physiotherapy). In these two studies we used the Armband Sensewear (BodyMedia Inc., Pittsburg, Pennsylvania, USA). In the hospital, it was found that 62% of patients did not achieve the recommended amount of physical activity [9]. In private and home settings, we showed similar results with an average of 3% moderate physical activity per day. We also showed that, in 200 recordings of physiotherapy sessions in private practice, on average, patients were in moderate activity for 6.3 (12.8) minutes of PA ≥3 MET. However we found that when we used HR as an indicator of intensity, the time per session in moderate activity was 24.5 (23.1) minutes of PA ≥3 METs [10].

3.2. Reliability study of activity trackers in monitoring patients during daily activities:

Our previous study showed that heart rate could be a reliable parameter for assessing physical activity levels. However, current commercial activity trackers are able to record heart rate over a few hours, possibly 48 to 72 hours but no longer. The batteries are not powerful enough to maintain a longer recording. Storage capacity is also often limited. Also, the easiest way to collect the activity of patients is to use tools with accelerometer technology. In several of our works, in which we proposed to study the reliability of several activity trackers, worn on different parts of the body (wrists, ankles, hip), we show an important difference with the energy expenditure given by the sensor and the gold standard, by indirect calorimetry [11]. We also found a significant difference depending on the position of the sensor, but also depending on the type of activity performed [12]. The measurement of distance by some of these sensors during walking activity seems however rather good, even with low-cost pedometers [13].

3.3. Which parameters are needed to customize support and rehabilitation of the patient at home?

For this work we performed stepwise linear regression analysis in order to determine the factors that would best explain the functional independence of patients. For both the mFAC and the Barthel Index, comfort speed emerged as a dependent variable [14]. Free walking speed seems to be a very good predictive factor. However, this parameter is difficult to apply to customized rehabilitation at home. We have developed an equation to determine the energy cost (CW) of walking in post-stroke patients [15]: CWfree=0.2109.Sfree-0.877. This formula has been included in a patented application and now makes it possible to determine the CW of patients from a simple walking test at comfort speed and thus to give them indications of walking distance for their rehabilitation at home.

3.4. Study of the effects of a home activity incentive program in post-stroke patients: contribution of technologies.

We conducted a randomized controlled trial, TICAA'Dom proposing a six-month program with an activity incentive using activity trackers [16]. The experimental participants underwent an individualized coaching program. This phase included monitoring, weekly phone calls, and a home visit every 3 weeks for 6 months. An activity tracker (SenseWear armband, BodyMedia, Pittsburgh, PA, USA) was used to monitor physical activity at home. The participant was asked to wear the activity tracker when they woke up and remove it before going to bed. We chose this sensor because it is regularly used in the analysis of activity in participants and it has the advantage of starting only when it is in contact with the person's skin. Therefore, the data we get corresponds to the activity tracker wearing time. As part of the protocol the experimental participants were routinely monitored:

- each day to complete a simple chart to measure subjective perception of physical activity for the therapist to compare with the objective
- each week with a phone call to encourage regular physical activity and to inquire about the physical activity measuring device;
- each three weeks, the home visit allowed participant feedback on the physical activity level. At the end of the visit, the physical activity therapist and the participant set objectives for the next home visit.

Our study reports an improvement in functional independence (mFAC) and quality of life (EQ5D-5L) after 6 months of the program and especially 6 months after stopping the program. However, the program did not lead to a significant difference in the patient's walking distance in the 6-minute walk test.

4. Discussion

The results of these studies show that home rehabilitation of post-stroke patients requires the use of individualized monitoring criteria to optimize patient care. To encourage the patient to increase his level of moderate physical activity and reduce their sedentary time, it would be recommended to propose a structured program regularly monitored on the basis of his comfort walking speed and his energy cost of walking. In addition, our longitudinal study confirms the fact that the follow-up should be much more regular in order to better regulate the program and the intensity of the intervention. The activity tracker allowed us to monitor the patient's daily physical activity, but the data was insufficient to propose a more adapted activity program. Other alternatives could be proposed based on exergame technology. Our systematic review and meta-analysis [17] showed that upper limb home-based exergaming interventions were no more effective in terms of activity than conventional therapy after stroke. Moreover, rates of compliance with this exergame training were relatively high [18]. These solutions can provide positive value in the rehabilitation of post-stroke patients at home. It is likely that these technologies, when they will be more mature, will improve the social participation of patients. Two studies are underway (RGS@home, Figure 2, EIT Health and AISN, Horizon Europe) to evaluate the effectiveness of a home exercise program, particularly on social participation and the acceptability of this program. We are also starting another study on the interest of using a digital platform and a web application (ADEPINA, Figure 2) to propose individualized rehabilitation exercises to patients at a distance. Many studies are still to be conducted to show a sufficient level of scientific evidence for these interventions. However, the results to date are very promising.

Figure 2: Technology used in the RGS program (on the left) and ADEPINA program (on the right).

References

[1] Lord SE, McPherson K, McNaughton HK, Rochester L, Weatherall M. Community ambulation after stroke: how important and obtainable is it and what measures appear predictive? Arch Phys Med Rehabil. 2004;85:234–9, doi:10.1016/j.apmr.2003.05.002.

[2] Billinger SA, Arena R, Bernhardt J, Eng JJ, Franklin BA, Johnson CM, et al. Physical activity and exercise recommendations for stroke survivors: a statement for healthcare professionals from the American Heart Association/American Stroke Association. Stroke. 2014;45:2532–53, doi:10.1161/STR.0000000000000022.

[3] Gabet A, de Peretti C, Woimant F, Giroud M, Béjot Y, Schnitzler A, et al. Admission in Neurorehabilitation and Association with Functional Outcomes after Stroke in France: A Nation-Wide Study, 2010-2014. J Stroke Cerebrovasc Dis. 2018;27:3443–50, doi: 10.1016/ j.jstrokecerebrovasdis.2018.08.005.

[4] Ezekiel L, Collett J, Mayo NE, Pang L, Field L, Dawes H. Factors Associated with Participation in Life Situations for Adults with Stroke: A Systematic Review. Arch Phys Med Rehabil. 2019;100:945–55, doi: 10.1016/j.apmr.2018.06.017.

[5] Erler KS, Sullivan V, Mckinnon S, Inzana R. Social Support as a Predictor of Community Participation After Stroke. Front Neurol. 2019;10:1013, doi: 10.3389/fneur.2019.01013.

[6] Walsh ME, Galvin R, Loughnane C, Macey C, Horgan NF. Factors associated with community reintegration in the first year after stroke: a qualitative meta-synthesis. Disabil Rehabil. 2015;37:1599–608, doi: 10.3109/09638288.2014.974834.

[7] Chen T, Zhang B, Deng Y, Fan J-C, Zhang L, Song F. Long-term unmet needs after stroke: systematic review of evidence from survey studies. BMJ Open 2019;9:e028137, doi10.1136/bmjopen-2018-028137.

[8] Daviet J-C, Compagnat M, Bonne G, Maud L, Bernikier D, Salle J-Y. Individualized home-based rehabilitation after stroke in France: a pragmatic study of a community stroke rehabilitation team. Can J Neurol Sci. 2022:1–6, doi:10.1017/cjn.2022.26.

[9] Lacroix J, Daviet J-C, Borel B, Kammoun B, Salle J-Y, Mandigout S. Physical Activity Level Among Stroke Patients Hospitalized in a Rehabilitation Unit. PM&R. 2016;8:97–104, doi:10.1016/j.pmrj.2015.06.011.

[10] Goncalves, S, Lebourvellec M, Lafite R, Duclos N, Mandigout S. Intensity of outpatient physiotherapy and physical activity level in community-dwelling stroke survivors: Preliminary results of multicenter cross sectional study, 2022.

[11] Mandigout S, Lacroix J, Ferry B, Vuillerme N, Compagnat M, Daviet J-C. Can energy expenditure be accurately assessed using accelerometry-based wearable motion detectors for physical activity monitoring in post-stroke patients in the subacute phase? Eur J Prev Cardiol. 2017;24:2009–16, doi: 10.1177/2047487317738593.

[12] Compagnat M, Mandigout S, Chaparro D, Daviet JC, Salle JY. Validity of the Actigraph GT3x and influence of the sensor positioning for the assessment of active energy expenditure during four activities of daily living in stroke subjects. Clin Rehabil. 2018;32:1696–704, doi : 10.1177/0269215518788116.

[13] Compagnat M, Batcho CS, David R, Vuillerme N, Salle JY, Daviet JC, et al. Validity of the Walked Distance Estimated by Wearable Devices in Stroke Individuals. Sensors. 2019;19, doi: 10.3390/s19112497.

[14] Compagnat M, Mandigout S, Perrochon A, Lacroix J, Vuillerme N, Salle JY, et al. The Functional Independence of Patients With Stroke Sequelae: How Important Is the Speed, Oxygen Consumption, and Energy Cost of Walking? Arch Phys Med Rehabil. 2021;102:1499–506, doi: 10.1016/j.apmr.2021.01.085.

[15] Compagnat M, Mandigout S, Chaparro D, Salle JY, Daviet JC. Predicting the oxygen cost of walking in hemiparetic stroke patients. Ann Phys Rehabil Med. 2018;61:309–14, doi : 10.1016/j.rehab.2018.03.001.

[16] Mandigout S, Chaparro D, Borel B, Kammoun B, Salle J-Y, Compagnat M, et al. Effect of individualized coaching at home on walking capacity in subacute stroke patients: A randomized controlled trial (Ticaa'dom). Ann Phys Rehabil Med. 2021;64:101453, doi: 10.1016/j.rehab.2020.11.001.

[17] Gelineau A, Perrochon A, Robin L, Daviet J-C, Mandigout S. Measured and Perceived Effects of Upper Limb Home-Based Exergaming Interventions on Activity after Stroke: A Systematic Review and Meta-Analysis. Int J Environ Res Public Health. 2022;19:9112, doi: 10.3390/ijerph19159112.

[18] Gelineau A, Perrochon A, Daviet J-C, Mandigout S. Compliance with Upper Limb Home-Based Exergaming Interventions for Stroke Patients: A Narrative Review. J Rehabil Med. 2022, doi: 10.2340/jrm.v54.2270.

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I Know My Rights! A Longitudinal Study of Discrimination due to Physical Inaccessibility from the Perspective of Wheelchair Users

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Abstract. It is a fundamental right to be able to access society and the services in it. From the perspective of disability rights, people with mobility-related disabilities who use wheelchairs must have equal opportunities to participate in and contribute to society – whether it is school, work, or (activity) leisure. This ongoing study is a longitudinal document study with qualitative content analysis. The document study is based on incoming complaints of discrimination due to inaccessibility received by the DO in Sweden, 2015 – 2023. The study explores how the users of wheelchairs and scooters experience discrimination due to their inaccessibility, using the ICF framework, among reported complaints to the DO from 2015-2023. The preliminary results show an increase in the number of complaints about discrimination across the entire period of 2015-2023. Responding to peoples' lived perspectives has often been cited as crucial to understanding how inclusion and exclusion play out in real life. A more accessible world depends on the extent of our knowledge and the politics of knowing-making, according to recently published research. Analyzing complaints about lack of accessibility over time generates essential knowledge for how discrimination against people who use wheelchairs can be prevented. This project also contributes to essential knowledge for social sustainability, economic sustainability, and a sustainable, accessible environment for people who use wheelchairs.

Keywords. Assistive technology, discrimination, accessibility, participation, disability, wheelchair, document analysis, mobility

1. Introduction

It is a global and national goal that society ensures us an equally accessible society. Inequality has many different layers and exists on different levels, whether on an individual or a societal level. From the perspective of disability rights, people with mobility-related disabilities who use wheelchairs must have equal opportunities to participate in and contribute to society (1). Mobility, to move around independently in society and at home, is crucial for participation, and accessibility in the environment is necessary to enable people to use a wheelchair to move around.

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Furthermore, the ability to move around in the community is essential to participating in leisure, social, and other activities and is vital for health and well-being. Physical and social environments can also constitute external circumstances that prevent meaningful activities (2) In accordance with the UN Convention on the Rights of Persons with Disabilities (CRPD) (3), public buildings and places must be accessible to people using wheelchairs. This study is based on an occupational therapy perspective, defined as a "way of looking at or thinking about a human doing" (4) (p. 233). An occupational therapy perspective is based on specific knowledge about the complex relationships between a person, environment, and occupation (activity). Among occupational therapists, the Canadian Model of Occupational Performance and Engagement (CMOP-E) (5,6) is a well-known theoretical model, focusing specifically on the components of person, environment, and occupation (activity) that interact in a dynamic relationship. People are regarded as occupational beings, with occupation denoting human doings involving self-care, productivity, and leisure are important for health and well-being (5,6); the results from the study will be discussed in relation to this model.

1.1. Accessibility and participation

According to the UN, public buildings and places must be made more accessible for people with mobility limitations. This aligns with legislation passed by the Swedish Parliament in 2010 (SFS 2010:900) (7). Research has also revealed that accessibility problems, for example, in public buildings and outdoor spaces (8, 9, 10), as well as the homes of friends and family, hinder the use of wheelchairs, which also impacts social occupations such as meeting friends. Another aspect of participation that Eide and his co-authors write (11) they identified from their review of the subject was the environmental invitation for participation. A specific physical- and social environment can impact participation based on matching the persons doing in that environment, which can be affected by the adaptation and accessibility of the environment (11). Furthermore, the fit of the person and environment of the occupation (activity) is meant to strive towards the quality of experienced level of satisfaction and functioning in an occupation (12,13).

1.1.1. The Swedish context

Several Swedish laws support persons in wheelchairs. According to the Building and construction law (sv. Plan och Bygglagen, chapter 8, §1), the public environment must be accessible and usable for persons with difficulties in either physical or orientation skills. According to the Act concerning the Equality Ombudsman 2008:568, the Ombudsman (DO) works to ensure that discrimination associated with sex, transgender identity or expression, ethnicity, religion or other belief, disability, sexual orientation, or age does not occur in any areas of society (14)

When it comes to inaccessibility, according to this Act, *inadequate accessibility is when a person with a disability is disadvantaged through a failure to take measures for accessibility to enable the person to achieve a situation comparable with that of persons without this disability, where such measures are reasonable based on accessibility requirements in laws and other statutes, and with consideration to; the financial and practical conditions; the duration and nature of the relationship or contact between the operator and the individual; and other circumstances of relevance.*

People who experience discrimination can submit a complaint to DO. A recently published study concluded that complaints to DO during 2015-2016 filed by people using mobility devices showed that they were denied access to various contexts, including offices, school environments, theatres, restaurants, schools, and public transportation. However, they desired to live an active and social life outside their homes. Filing a complaint was a way to act, highlight present inaccessibility, and express hope for change (15).

With the law of DO in mind, a student in a wheelchair might have accessibility problems to the lecture hall, which can be seen from the view of DO. The DO law states in Chapter 1 (§4) that people with disability should not be disadvantaged due to accessibility problems caused by not taking proper action or adaptation in the building. Furthermore, the solution for the disadvantage should consider the practical circumstances, economic and duration, and extent in relation to contact between the school and the individual in the situation (16). According to the working environment law (17) (sv. Arbetsmiljölag), adaptions due to an employee´s physical and psychosocial conditions should be made to enhance and develop learning, and all employees should be able to evacuate in case of emergency, including people with disabilities as well. As a next step in this research area, using an environmental framework such as the International Classification of Functioning, Disability and Health (ICF) (18) is critical to align with a policy-relevant framework that can provide direction for policy change. The ICF is a reference framework for functioning that may contribute to improved outcome research.

The ***objective of this study is to explore how the users of wheelchairs and scooters experience discrimination due to their inaccessibility, using the ICF framework, among reported complaints to the DO from 2015-2023.***

2. Method

The study's design is a longitudinal document study with a qualitative content analysis (19). The document study is based on incoming complaints of discrimination due to inaccessibility received by the DO in Sweden, 2015 - 2023. These complaints (documents) grant us unique access to descriptions and experiences of many situations related to inaccessibility by many people using wheelchairs. Qualitative document analysis, as a systematic procedure for reviewing or evaluating documents, will capture the participants' experiences of inaccessibility and discrimination related to the complaints. One of the authors has contacted the DO to inform them about the study and collection of reports of discrimination due to the lack of accessibility received by the DO during the period 2015-2023. Complaints to DO are public documents but DO always carries out a confidential check before making them available. The reports provide information about disability, type of wheelchair, accessibility problems, and the person's experience of and consequences of risks, insecurity, and discrimination.

The selection of reports/complaints: All complaints received by DO during 2015-2023 have been read through and compiled. Subsequently, reports describing the use of wheelchairs have been selected for analysis.

The analysis has used content analysis to identify, describe and categorize themes and compare the findings with an international system such as the ICF. Further, a clear framework is necessary, which identifies various environmental barriers and facilitators and enables the DO complaints to be understood in relation to the environment. The ICF (18) will be used as a framework to identify various environmental obstacles and facilitating factors. This enables the structure of accessibility problems in various areas, such as schools and workplaces. The reports to DO are analyzed based on intersectional factors such as age, gender, ethnicity, and socioeconomic context, as well as the use of a wheelchair, location of the incident described in the report, type of activity reported, insecurity, risks, and consequences of lack of accessibility. This implies difficulty coping with everyday life and a lack of participation.

3. Preliminary Results

Briefly, there is an increase in the number of complaints about discrimination across the entire period of 2015-2022. In percentage terms, age-related complaints have increased the most (121%). There is also a sharp increase in the number of complaints relating to healthcare from 2019 to 2021, which can be related to the Covid 19 pandemic.

Our further analysis of the documents of complaints of people using wheelchairs submitted to the DO provides insights and increased knowledge of requirements for accessibility, the consequences of insufficient accessibility and participation difficulties, and ways to prevent discrimination in the future.

Attention to peoples' lived perspectives has often been cited as crucial to understanding how inclusion and exclusion play out in real life (15). A more accessible world depends on the extent of our knowledge and the politics of knowing-making (15). Documentation of facilitators and barriers in different environments is of significant value to articulate the needs of wheelchair users and advocate for the recognition of those in need (20). People who use wheelchairs are in different phases of life, and many depend entirely on a wheelchair to get to, e.g. work or school. Facilitating mobility and preventing the risk of injury is, therefore, crucial proactive work. One way is to identify risks in public environments early before they result in injuries and possible subsequent rehabilitation and sick leave.

Occupational therapy has a specific differentiation between the concept of activity and occupation. These are described as not being synonymous because people perform tasks and activities that, in turn, build up occupations (4,6). According to some authors (6), occupation is the overarching concept that includes activities and tasks, described as levels subordinate to occupation. In addition, the focus is on participation in occupations in different environmental arenas (21). Since wheelchairs aim to facilitate mobility and enable activities and occupations, both activity and occupation are thus relevant to research into the use of wheelchairs.

In Sweden, the welfare system promotes universal rights and social equality. The importance of having an occupation is strongly related to health, as declared in the literature (22,23,24). Furthermore, as Njelesani and friends (4) reveal in their study, occupation (activity) is critical, central, and even a determinant of health. This implies that if you don't have a wheelchair and an accessible environment to support or enhance your everyday life, you cannot access the essential occupation.

The significance of this project on mobility, safety, and accessibility are important factors for people who use wheelchairs to be given security in everyday life and participation in society. It is also important to develop knowledge about the complex relationships between lack of accessibility, participation, and independence in public environments for people who use wheelchairs.

When public environments are designed to enable activities, security is also created. According to goal §23 in the UN´s Agenda 2030 (25), sustainability is described for all citizens, and everyone should be given the opportunity to cope with everyday life on equal terms. Stakeholder groups for this project are municipalities and regions in Sweden and Functional rights in Sweden. This project will make an important contribution to the mapping requested by the disability movement: namely to longitudinally highlight the extent to which people with disabilities can participate in society and accessibility in different environments, likewise, how the experience that people with disabilities have can be used in community planning and shared with various stakeholders and actors to enable accessible society (26).

4. Discussion

Within occupational therapy, there have been many attempts to explain the relationship between a person's environment and their participation in life when living with a disability. Ranging from concept definitions to various kinds of models. It is a relevant and critical topic to depict so we can move towards equality for all members of society. Participation is described as an individual experience that includes meaningful engagement where the persons can participate, affect and support others, and control the social connection and inclusions (11,12). Based on this project, participation can be challenging due to the environmental barriers that problematize a person's ability to take control.

WHO addresses the importance of accessibility (1), emphasizing the right to participate and live independently. It also says that state parties should strive towards equal access to all members of society, regarding the physical environment, such as public transport, information, and services in society. Barriers to accessibility are mentioned for indoor and outdoor structures such as buildings, and this study specifically includes schools, workplaces, transportation, and public spaces.

The importance of having an occupation (activity) is strongly related to health, and access to these activities is therefore critical.

5. Conclusion

This ongoing project thus makes the person in wheelchairs' voices visible through people's stories about discrimination due to lack of accessibility and the consequences of being unable to live on equal terms. Similarly, analyzing complaints about lack of accessibility over time generates essential knowledge for how discrimination against people who use wheelchairs can be prevented. The project also contributes to essential knowledge for social sustainability, economic sustainability, and a sustainable, accessible environment for people who use wheelchairs.

References

[1] WHO, UNICEF. Global report on assistive technology. Geneva: WHO & UNICEF; 2022. 140 p.

[2] Stadnyk R, Townsend E, Wilcock A, et al. Introduction to occupation: the art and science of living. 2nd ed. UpperSaddle River (NJ): Pearson Education; 2011.

[3] World Health Organization. The UN Convention on the Rights of Persons with Disabilities. Available from: https://www.un.org/development/desa/disabilities/convention-on-therights-of-persons-with-disabilities.html
[4] Njelesani J, Tang A, Jonsson H, Polatajko H. Articulating an Occupational Perspective. Journal of Occupational Science. 2014;21(2):226-235, doi: 10.1080/14427591.2012.717500
[5] Wilcock A. Occupation and health: Are they one and the same? Journal of Occupational Science. 2007;14(1):3-8.
[6] Townsend E, Polatajko H. Enabling Occupation II: Advancing an occupational therapy vision for health, well-being, & justice through occupation. Ottawa: CAOT Publishers; 2007.
[7] *Planning and Buildings Act SFS 2010:900* (Sweeden).
[8] Fomiatti R, Moir L, Richmond J, Millsteed J. The experience of being a motorized mobility scooter user, Disability and Rehabilitation: Assistive Technology. 2014;9(3):183-187, doi: 10.3109/17483107.2013.814171
[9] Welage N, Liu K. Wheelchair accessibility of public buildings: a review of the literature. Disabil Rehabil AssistTechnol. 2011;6(1):1–9.
[10] Carlsson G, Slaug B, Schmidt SM, et al. A scoping review of public building accessibility. Disabil Health J. 2022;15(2):101227.
[11] Eide AH, Josephson S, Vik K, Ness NE. Participation in health and welfare services: Professional concepts and lived experience. Taylor & Francis Group; 2017. p. 1–19, doi: 10.4324/9781315628554
[12] Iwarsson S, Ståhl A. Accessibility, usability and universal design-positioning and definition of concepts describing person-environment relationships. Disability and Rehabilitation. 2003;25(2):57–66, doi: 10.1080/dre.25.2.57.66
[13] Strong S, Rigby P, Stewart D, Law M, Letts L, Cooper B. Application of the Person-Environment-Occupation Model: A practical Tool. Canadian Journal of Occupational Therapy. 1999;66(3):122–133, doi: 10.1177/000841749906600304
[14] *The Discrimination Act 2008:167* (Sweeden). Available from: https://www.do.se/download/18.71c46fcf184c78ffadd1164/1683824143983/stod-laws-act-ombudsman-discimination-parental-leave.pdf
[15] Pettersson C, Baudin K, Hedvall P-O. The struggle for access – a qualitative document study of how people using wheeled mobility devices experience exclusion and discrimination. Disability and Rehabilitation: Assistive technology. 2022, doi: 10.1080/17483107.2022.2107094
[16] *Diskrimineringslagen SFS 2008:567* (Sweeden). Available from: https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/diskrimineringslag-2008567_sfs-2008-567
[17] *Arbetsmiljölag SFS1977:1160* (Sweeden). Available from: https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/arbetsmiljolag-19771160_sfs-1977-1160
[18] World Health Organisation. International Classification of Functioning, Disability and Health (ICF). Geneva: World Health Organisation (WHO); 2001. Available from: https://www.who.int/standards/classifications/international-classification-offunctioning-disability-and-health
[19] Bowen GA. Document analysis as a qualitative research method. QRJ. 2009;9(2):27–40.
[20] Labbé D, Mahmood A, Miller WC, Prescott M, Mortenson WB. Examining the Impact of Knowledge Mobilization Strategies to Inform Urban Stakeholders on Accessibility: A Mixed Method study. International Journal of Environmental Research and Public Health. 2020;17(5).
[21] Law M, Cooper B, Strong S, Stewart D, Rigby P, Letts L. The Person-Environment-Occupation Model: A Transactive Approach to Occupational Performance. Canadian Journal of Occupational Therapy. 1996);63(1):9–23, doi: 10.1177/000841749606300103
[22] Whalley Hammell K. Editorial: Occupational therapy and the right to occupational participation. Irish Journal of Occupational Therapy. 2022;50(1):1-2, doi: 10.1108/IJOT-05-2022-031
[23] Hemmingsson H, Jonsson H. An occupational perspective on the concept of participation in the International Classification of Functioning, Disability and Health–some critical remarks. Am J Occup Ther. 2005;59(5):569–576.
[24] Wilcock AA. Reflections on Doing, Being and Becoming. Canadian Journal of Occupational Therapy. 1998;65(5):248-256, doi: 10.1177/000841749806500501
[25] UN Sustainability Goals 2030. Available from: https://sdgs.un.org/goals
[26] Rigby P, Letts L. Environment and Occupational Performance: Theoretical Considerations. In: Letts L, Rigby P Stewart D, editors. Using environments to enable occupational performance. Slack Incorporated; 2003. p. 18–32.

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A Novel Geospatial Assistive Navigation Technology for Seamless Multimodal Mobility of Wheelchair Users

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Abstract. Mobility is fundamental for social participation of people with disabilities. Unfortunately, traditional design of urban environments, including infrastructure and services are developed based largely on a standard perception of an independent, fully functional citizen without disability which limits the mobility social participation of PWD. This paper presents the design and development of a novel geospatial assistive navigation technology to support multimodal mobility of people with disabilities, especially those using manual wheelchair in urban areas.

Keywords. Multimodal, Mobility, Navigation, Wheelchair, Bus, MobiliSIG.

1. Introduction

Mobility and social participation of people with disabilities (PWD) are of increasing concern in the light of major demographic changes such as aging populations throughout the world. Undoubtedly, mobility constitutes an important contribution to social participation and, any action seeking to reduce mobility constraints will promote social participation and health status. According to the latest Canadian Survey on Disability (CSD), an estimated one fifth of Canadians aged 15 and over (representing 6.2 million people) have one or more disabilities. This number could be even higher depending on certain definitions of disability. In Quebec, a recent study on activity limitations, chronic diseases and aging suggested that 33% of Quebec residents have some form of functional limitation and this percentage increases to more than 57% among people aged 65 and over [1-2]

The mobility challenges faced by PWD are substantial. Unfortunately, traditional designs of urban environments (social and physical), including infrastructure and services are developed based largely on a standard perception of an independent, fully

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functional citizen without disability. Most urban infrastructure and services (pedestrian networks, subways, airports, stores, restaurants, etc.) still pose substantial accessibility problems for PWD. Social factors (e.g., rules, laws, standards and practices) influencing the mobility of PWD are also barely documented. Furthermore, the majority of mobility aids (e.g., GoogleMap, Waze) are not adapted for the needs of PWD and rarely address users' profiles (impairments, capacity, preferences, etc.) or the characteristics and dynamics of their physical and social environments (HandiMap & Wegoto). Other mobile devices (e.g., smart watches) still raise issues of security and usability or provide only general information regarding the accessibility of urban places (WheelMap, Mapp4all, OnRoule, Jaccede).

A comprehensive mobility solution for PWD needs to consider a broader range of human-environment-technology interactions. Within this paper, we propose to study the mobility of PWD within an innovative ecosystem framework. This metaphor for mobility is grounded in a vision that sees mobility as the result of complex human-environment-technology interactions. Indeed, within an ecosystem perspective, the delivery of services could be substantially enhanced, thereby rendering mobility safer and more effective for PWD. Although the ecosystem metaphor as applied to information systems is not new, the systematic study and use of such a framework in the context of disability is new. Advances in geospatial data science and technologies (e.g., location-based information and communication technologies, Internet of things, and ubiquitous wireless connectivity, digital Twins, etc.) profoundly transforms the face of our cities and the way people move and interact with urban places and offer new opportunities for innovation in geospatial assistive technologies to help PWD in their daily mobility and social participation.

The overall objective of this paper is to present the design and development of a novel geospatial assistive navigation technology to support multimodal mobility of PWD, especially those using manual wheelchair, in urban areas. The remainder of the paper is organized as follows. The following section presents a brief state of the art on the navigation technologies specially developed for the guidance of PWD by including information on the accessibility of the routs. Section three presents the proposed technology for multimodal mobility of wheelchair users followed by the presentation of the implementation and test and preliminary results in the section 4. Finally, we present the conclusions and perspectives of the current research work.

2. Literature Review

Going from an origin to a destination in an urban area might implicate travelling a long distance with diverse accessibility challenges and may require using several transport modes in addition to the mobility on pedestrian network. Accessibility issues may not only be specific to each mobility mode but also complexities may arise during the transition from one mobility mode to another specially for people with disabilities. For instance, steep slop, ramps, steps and intersections, presence of crowed might cause problems for wheelchair users on the pedestrian network. Restricted spaces might also be problematic for mobility maneuvers within a bus. Other accessibility issues may arise that are more specifically related to the bus stops as the interface between two modes of transportation as well as the availability of the ramps that allow transition from bus stops to the bus itself. In such situations, PWD might face mobility problems given their specific profiles and capacities as well as their preferences.

Recent advances in assistive navigation technologies have significantly facilitated the mobility of people in familiar and unfamiliar urban environments. However, wheelchair users still face many challenges in their multimodal mobility because of the lac of the information on the accessibility of their routs (ex. Information on overcrowded bus stops, absence of bus ramps, occupancy of sites, etc.). This information can be defined based on standards and accessibility of the environment and services. Different organizations have proposed accessibility criteria for multimodal mobility including the Canadian Standards Association, the Americans with Disabilities Act (ADA) (United States Access Board) [3] and the practical guide to universal accessibility [4]. The accessibility standards can be used to evaluate the accessibility of the mobility network and provide the information to the users with disabilities to help them in their mobility using the geospatial assistive navigation technologies.

Table 1. Examples of available navigation tools, their functionalities for planning and navigation of itineraries for multimodal mobility of wheelchair users in urban areas.

Navigation tool	functionalities	Limitations
Google Maps	Multimodal route planning and navigation, available in the most cities around the world.	Does not offer multimodal itineraries with accessible stops and transportation information.
U-Acces	Adapted toll for route planning and navigation for users with different abilities and profiles.	Rout planning is possible only on pedestrian networks.
WheelMap	provide accessibility information on public places for wheelchair users (POIs, photographs, comments, etc.).	No multimodal route planning and navigation function are included.
Streetco	Offers an accessible itinerary based on the user's profile and informs on accessible stops	No multimodal route planning and navigation function for PWD.
Handimap	Provides accessibility information and itineraries for PWD with different profiles.	No multimodal planning and navigation possibility with accessibility information.

Intensive efforts have been made in recent years to facilitate navigation of wheelchair users by different navigation applications [5-10]. However, most of the current navigation tools including Google Maps, WheelMap, AccèsSIG and, etc. are not fully adapted for the multimodal mobility of wheelchair users. For example, Google Maps enables multimodal mobility and navigation (on foot, by bus, by car, by subway, etc.) however, it does not suggest accessible and adapted itineraries for the wheelchair users. Beale et al. [11] have developed U-Acces, which is a web-based route planning system. However, it does not offer any functionality for multimodal route planning and navigation. WheelMap [12] is a project with the aim of facilitating the sharing of information on access to public places for wheelchair users. This is done through a mobile application that enables the search, display and addition of points of interest (POIs) with photographs and comments. WheelMap does not propose accessible itineraries and rather provides photographs and user opinions on the accessibility of public places on a web-based platform. Handimap [12] proposes accessible routes for PWD but does not include multimodal mobility. Table 1 summaries a list of available technologies with their main strengths and functionalities and highlight their limitation for multimodal mobility and navigation for wheelchair users.

To address some of these limitations, in the next sections we present a novel geospatial assistive navigation technology called MobiliSIG. The application provides capabilities for planning and navigation of multimodal accessible routes for wheelchair users.

3. Proposed multimodal geospatial assistive navigation technology

The proposed navigation technology is designed and developed based on the principles of the Disability Creation Model (DCP). The tool, which is called MobiliSIG, proposes accessible multimodal itineraries which can be personalized and adapted to the capacity and preferences of each user. To do so, the tool allows capturing the level of the confidence of a user to conduct a mobility action in the presence of diverse environmental factors. For instance, we ask users to give their level of confidence to move on a sidewalk with a slop higher than 8 %. Other questions include factors such as quality of the surface, intersection, presence of snow, presence of the crowd and, etc. For the interface between pedestrian network and public transportation, several other factors that affect the mobility of wheelchair users considered. Among those factors we could identify factors such as waiting for the bus at a stop without a bus shelter, getting on and off the bus with a ramp of more than 8%, getting on/off the bus in a busy stop area, etc. (see **Figure 1**) [3-4].

Accessibility measurement of the pedestrian network is personalized based on the perception and capabilities of manual wheelchair users. We account for both actual and perceived capabilities of the users. User confidence is considered as a criterion to measure the user's perceived capabilities. Hence, the accessibility assessment process is undertaken in seven steps: 1) capturing location-based data from pedestrian network using different technologies such as Lidar technology, City open data, volunteered geographic information (VGI), 2) partitioning the pedestrian networks into segments to better reflect its variations, 3) capturing user profile information, 4) linking segment properties with the corresponding user confidences, 5) aggregating the confidence levels for each segment, 6) evaluating the accessibility level of each segment based on the total confidence, and finally, 7) visualizing the accessibility level of each segment on the pedestrian network map.

Finally, the accessibility of each segment is calculated by aggregating user confidence with respect to each attribute of the segment as follows [3]:

$$A_{ijl} = \sum_{p=1}^{7} Con_{ijp} \quad (1)$$

Where, A_{ijl} is the index of accessibility of segment j for a person i by travel type l; Con_{ijp} is the confidence level of the person i for the segment j in relation to the property p. The obtained value of the accessibility is unique and belongs to the specific user i.

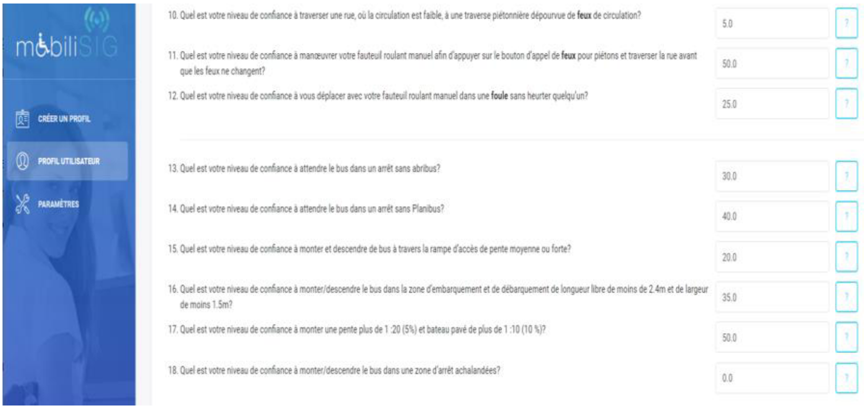

Figure 1. Extract of MobiliSIG interface for capturing the user profile and confidence for specific environmental factors.

4. Case Study and Results

The proposed multimodal navigation system was developed and implemented for a case study in Quebec City. In this city, the RTC (Réseau de Transport en Commun) provides and oversees the public transportation system. The organization aims at making the entire network accessible to all the citizens including those using wheelchairs for their mobility by 2027. The City is responsible for the accessibility of sidewalks. Providing wheelchair users with relevant information on the accessibility of the network through data obtained from RTC and the City would help these people to plan and navigate on accessible and secure itineraries adapted to their profile and their preferences. In our case study, the multimodal mobility network consists of both pedestrian and public transportation network. These two networks are connected only by links that are generated in bus stops. All the data for the generation of the multimodal network was obtained from Quebec City open databases and in some cased was complemented by data from Open Street Map (OSM). Data on the environmental factors are also obtained from different sources including the city open geospatial database. The network as well as attribute data were pre-processed and integrated to the MobiliSIG application database.

Once the necessary data on the multimodal network was integrated in the database, the tool was ready for planning and navigation of personalized accessible routes including both pedestrian network as well as the public transportation network. **Figure 2**, shows an example of a multimodal route planning for a wheelchair user whose profile information is already captured in the previous step. As we can see from the figure, the user chooses his origin and destination using an interactive interface offered by the application. Then, the tool proposes an accessible multimodal itinerary based on the profile of the user as well as the information on the network already included in the database. For each segment, there is an accessibility code is computed. Then the most optimal route in terms of distance as well as the accessibility information is proposed to the user. As we can see in the figure, accessible bus stops are presented in green and the non-accessible bus stops are identified with red colour. This implies that a wheelchair user won't be able or not allowed to get on or get off the bus in those bus stops which limits greatly their access to public transportation system in the city.

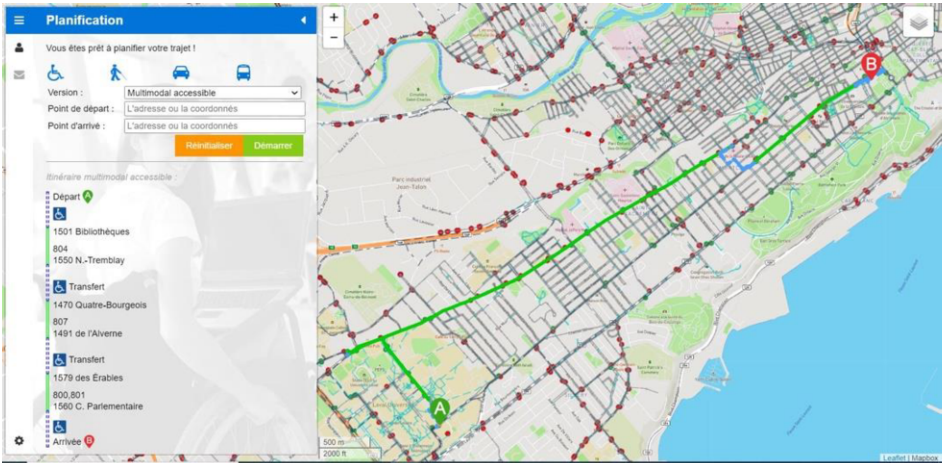

Figure 2. An example of a multimodal accessible route planning using MobiliSIG.

The web-based system we developed was designed to be an itinerary planning aid for multimodal mobility for wheelchair users. However, in Quebec City, we have only considered two mobility modes namely using the bus network combined with the pedestrian network. Mobile version of the application which includes navigation and guidance modes is still under development. In addition, the proposed system needs several improvements before it can be fully operational for the target population. For instance, we have not yet access to the temporal information such as waiting time for the next bus, or the information on the occupancy rate of each bus. Such information can be crucial for decision by wheelchair users to use the public transportation for their mobility needs.

5. Conclusions

In this paper, we have proposed and implemented a novel geospatial assistive navigation technology to support multimodal mobility of wheelchair users. The application allows capturing both personal and environmental information for planning of a personalized multimodal accessible route. The tool has been implemented and tested for the proof of concept. The preliminary results are promising and allow a seamless multimodal mobility with accessible routes which are also personalized. However, the tool needs further improvement especially when it comes to the integration of the temporal information (ex. Time of bus arrival). As perspective to this work, we plan to extend the capability of the proposed tool to help other group of people with disabilities (e.g., visually impaired) to plan and navigate multimodal routes for their mobility in their daily activities. Other modes of transportation including subways, tramways, etc. need to be considered for further developments in the future.

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References

[1] Statistics Canada. Canadian Survey on Disability. [Internet] 2017; Available from: https://www150.statcan.gc.ca/n1/daily-quotidien/181128/dq181128a-eng.htm.
[2] Fournier C, Godbout M, Cazale L. Enquête québécoise sur les limitations d'activités, les maladies chroniques et le vieillissement 2010-2011. Méthodologie et description de la population visée. Institut de la statistique du Québec (ISQ): Québec. 2013. 71 p.
[3] United States Access Board. Americans with Disabilities Act and Architectural Barriers Act Accessibility Guidelines. 2004, WBDG.
[4] Savard MJ. Guide pratique d'accessibilité universelle manuel d'utilisation avant- propos. 2010.
[5] Gharebaghi A, Mostafavi MA, Edwards G, Fougeyrollas P. User-specific route planning for people with motor disabilities: A fuzzy approach. ISPRS International Journal of Geo-Information. 2021;10(2):65.
[6] Kairy D, Mostafavi MA, Blanchette-Dallaire C, Bélanger E, Corbeil A, Kandiah M, Wu, TQ, Mazer B. A mobile app to optimize social participation for individuals with physical disabilities: Content validation and usability testing. International Journal of Environmental Research and Public Health. 2021;18(4):1753.
[7] Hashemi M, Karimi, HA Collaborative personalized multi-criteria wayfinding for wheelchair users in outdoors. Transactions in GIS, 2017;21(4):782–795. https://doi.org/https://doi.org/10.1111/tgis.12230
[8] Hillman R., Pool RF. GIS-based innovations for modelling public transport accessibility. Traffic Engineering and Control, 1997;38:554–559.
[9] Kasemsuppakorn P, Karimi H. A Personalized routing for wheelchair navigation. In Journal of Location Based Services. 2009;3(1). doi.org/10.1080/17489720902837936
[10] Matthews H, Beale L, Picton P, Briggs D. Modelling Access with GIS in Urban Systems (MAGUS): Capturing the experiences of wheelchair users. Area, 2003;35(1):34-45. doi.org/10.1111/1475-4762.00108
[11] Beale L, Field K, Briggs D, Picton P, Matthews H. Mapping for wheelchair users: Route navigation in urban spaces. Cartographic Journal, 2006;43(1):68–81.
[12] Mobasheri A, Deister J, Dieterich H. Wheelmap: the wheelchair accessibility crowdsourcing platform. Open Geospatial Data, Software and Standards 2, 2017, Article 27. doi.org/10.1186/s40965-017-0040-5
[13] Handimap. Handimap. Communiquer sur l'accessibilité.2010.
[14] Mohamed B. Conception et développement d'une application de navigation pour le déplacement multimodal accessible des Personnes en fauteuil roulant. Mémoire de maitrise, Université Laval, Canada. 2023.
[15] Gharebaghi A, Mostafavi MA, Chavoshi, SH, Edwards G, Fougeyrollas P. The Role of Social Factors in the Accessibility of Urban Areas for People with Motor Disabilities. ISPRS International Journal of Geo-Information. 2018;7(4). DOI 10.3390/ijgi7040131.

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Towards a Model for the Transfer of Technology-Driven Innovation in Accessible and Inclusive Public Transport

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Abstract. This article reports on work undertaken by AAATE researchers in the framework of the EU-funded TRIPS Project. The project (2021-2023) has aimed to contribute to transforming public transport in Europe and beyond toward more inclusive models, leaving no one behind. The reported findings refer to a specific aspect of the transformation process that has been investigated by the authors, namely the factors that impact the transfer of innovation in accessibility by the public transport providers. A framework model was created due to a process of factor extraction from existing literature and their validation by a sample of decision-makers in the public transport sector.

Keywords. Accessible public transport, inclusive mobility, technology transfer, transfer of innovation, accessibility.

1. Introduction

Even with significant investments in research and innovation in the technological domain, many interesting innovations that have proven to work in the context where they have been developed and tested do not manage to scale up or be transferred to other contexts. The exploitation of innovation, often not an easy and straightforward process, becomes even more complex when upscaling and transfer are involved. There is no reason to presume that what seems true for many technology domains differs for technology-based innovations in accessible and inclusive public transport.

It is crucial for advancing accessible and inclusive public transport in Europe that what is successful in one city or region is transferred, localised and deployed elsewhere. (1,2,3). To support that process better, it is important to understand the challenges faced by a public transport company or authority in such transfer of innovation, particularly the factors that impact the decision to transfer and the uptake of an innovation developed and tested elsewhere, compared to developing an innovation in-house.

Within the TRIPS project (a project aiming at advancing accessible transport for all and funded under the Horizon 2020 programme of the European Commission, GA 875588), the authors have looked at factors that impact the successful transfer of

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technology-driven innovation from one context to another. Compared to other technology transfer projects that assess mainly technology-related and economic factors, the TRIPS project examined additional aspects to consider, namely "accessibility" and "societal impact". Ideally, these aspects should not be neglected in decision-making. However, there are still many examples where they are overlooked or not considered sufficiently, leading to the need to subsequently retrofit, adjust, substitute or provide additional services to travellers to whom certain barriers matter, which have a cost.

Seeking to find a model for the successful transfer of innovation in the transport sector, the authors have realised that the local situations for implementation are very different. The "landscape" or "context" where public transport occurs and innovations are implemented varies. Variations relate to geography, population, policies, available resources, and culture, making it difficult to build a universally prescriptive model. What is a given context is appropriate might not be applicable in another. What is affordable for a Norwegian city might not be affordable in Sofia. What works for surface transport might not work underground. What is economically sustainable in an urban area might not be in a rural area with low population density. Instead, it may be possible to identify factors that should be considered before any decision to invest in the transfer of innovation. Such a conceptual framework model can help decision-makers and innovation managers fully understand their decisions' impact and gather information and evidence to support their choices. The quality of the model depends on the completeness of the concepts and factors considered, and the quality of the application depends on the teams using the model.

2. Methodology

In an initial stage, we assessed scientific and grey literature on two related topics: Transfer of innovation and Diffusion of Innovation. The first describes the process by which results derived from research reach the marketplace and wider society, along with associated skills and procedures. In contrast, 'diffusion' seeks to explain how innovations are taken up within a population. In each case, an innovation is an idea, behaviour, or object perceived as new by its audience. Diffusion of Innovation is an intrinsic part of the innovation process (4,5,6). In this scoping review of models, various factors that are relevant for the transfer and diffusion of innovation have already been identified.

During a second round of review, factors that were more specifically related to public transportation and accessibility have been identified. A scoping review was implemented with the following features:

Resources included scientific and non-scientific articles, reports, reviews, and books, including public transport operators and regional authorities' guidance documents, reports on specific innovation implementations, and policy roadmaps published after 2015.

The combination of keywords used for the search are listed in **Table 1**.

Table 1. Strings of keywords used for the scoping review

Primary keywords	Secondary keywords	Tertiary keywords (used for further refinement)
Travel, Public transport, Accessibility	Innovation, Innovation process, Social Innovation, Transport sector, Models for transfer of innovation	Rules, values, impact on quality, perceived values, equality, accessibility, environment, decision-making process, governance, sustainability, compatibility, infrastructure, innovation strategies, scaling and diffuse innovation, innovation quadruple helix, collaborative innovation, participatory approach, bottom-up process, inclusion, inclusive practice, social innovation, public transport network, public transport services, CSR in public transport, travel accessibility, good practices, pilots, factors for impact, factors ease the innovation transfer.

After a preliminary analysis of the publications found, a subset of 16 publications was selected for more careful study and factor extraction (**Table 2**).

Table 2. An overview of the 16 publications used for factor extraction.

(1)	Centre on Regulation in Europe (CERRE). Ambitions Of Europe 2024 – A Decarbonised Transport System, Long Distance Mobility, Urban Mobility. 2019.
(2)	Welsh Government. Llwybr Newydd. The Wales Transport Strategy. 2021.
(3)	European Bank For Reconstruction And Development. Disruptive Technology And Innovation In Transport - Policy Paper On Sustainable Infrastructure. 2019.
(4)	UK Department For Transport. The Inclusive Transport Strategy: Achieving Equal Access For Disabled People. 2018.
(5)	International Association Of Public Transport (UITP). Demystifying ticketing and payment in public transport. 2020.
(6)	International Transport Forum (OECD). Transport Innovations From The Global South. Case Studies, Insights, Recommendations. 2019.
(7)	CIVITAS. Innovative urban transport solutions. How 25 cities learned to make urban transport cleaner and better. 2014.
(8)	International Association Of Public Transport (UITP). Urban mobility indicators for walking and public transport.
(9)	European Conference of Ministers of Transport (ECMT). Improving Transport Accessibility for All: Guide to Good Practice, OECD Publishing, Paris. 2006. https://doi.org/10.1787/9789282101407-en.
(10)	Rupprecht Consult (editor). Decision makers summary for Developing and Implementing a Sustainable Urban Mobility Plan. European Platform on Sustainable Urban Mobility Plans. 2020.
(11)	Rupprecht Consult (Editor), Annex To The Guidelines For Developing And Implementing A Sustainable Urban Mobility Plan. 2020.
(12)	Rupprecht Consult (Editor). Guidelines For Developing And Implementing A Sustainable Urban Mobility Plan. 2019.
(13)	P3ITS consortium. Pre-Commercial Procurement for Intelligent Transport Systems. The P3ITS Handbook. A Guide for PCP Actors. 2011.
(14)	ITF International Transport Forum (OECD). Improving Transport Planning and Investment Through the Use of Accessibility Indicators. 2019.
(15)	Iossa E, Biagi F & Valbonesi P. Pre-commercial procurement, procurement of innovative solutions and innovation partnerships in the EU: rationale and strategy. Economics of Innovation and New Technology 27:8, 730-749, 2018. DOI 10.1080/10438599.2017.1402431.
(16)	Tsakalidis A, Van Balen M, Gkoumas K, Haq G, Ortega Hortelano A, Grosso M, and Pekár F. Research and innovation in smart mobility and services in Europe. Publications Office of the European Union, Luxembourg. 2020. DOI:10.2760/732047, JRC120305.

Most of the selected publications presented different perspectives on the determinants of a successful transfer. However, some recurrent issues emerged (numbers between brackets refer to the sources in Table 2.)

- A **policy** roadmap could act to inspire a "groove" where innovation transfer could be conceived and take place (1) and as an opportunity to think forward innovative solutions (6), thus having a combined push-pull role for innovation in the mobility sector (16).
- **Rules and regulations** may act as a "double-sided" factor. Acting to force innovation processes, placing new rules to be accomplished, so fostering innovation transfer processes (e.g. identifiable norms for reducing emissions in public transport). At the same time, they could act as a possible barrier in implementing innovations where the norms are not "ready" for the proposed changes (4,8).
- A model for **financing** innovation is crucial in ensuring sustainability (5,13,15) as a key decision factor for future implementation, considering the full range of proven options already in place, ranging from:
  - Full Opex (rental) (i.e. Operational Expense);
  - Revenue sharing;
  - Full Capex (i.e. Capital Expenditure).
- The **trialability** of innovation transfer is acknowledged as a way to test possible solutions in a controlled operational environment (i.e. economically, technically), making an objective evaluation of the innovation possible (5,14,16): piloting an innovation (when it is possible) could reduce investment risks and helps to identify pros and cons of a viable solution.
- **Integration** (including data integration) is the key factor in implementing MaaS (Mobility as a Service) solutions. Services offered by public and private providers should be combined to provide enhanced mobility for the traveller (1).
- The **maturity level** of a proposed solution is often prioritised in the implementation of innovation (3,16): it may reduce the perceived overall risk for the decision, assuring the chance to respect time schedules in implementation and improving the reliability of any final release.
- **Compatibility** with infrastructure already in place is crucial and should be considered in any decision on investment in new solutions (3,5).
- **Security** is a key factor that should be included in the decision-making process. Security is part of the quality of the service, considering the strict integration of IT in management and customer-facing functionalities such as ticketing or timetables of transport services. Equally, it is critical for data retention (7,5): any data breach could expose sensitive data, such as financial information, to illegal use. Privacy is often associated with security (3) as imposed "by law", but it also is reflected in the increasing concerns of travellers and regulated by GDPR and stemmed norms.
- An **open-data approach** is a pathway that may be investigated carefully to gauge risks and benefits. It offers a way to assure integration (1) between different services in public transport, including multimodal accessibility issues.
- **Digital "fragmentation"**, intended as the variety of solutions available (at technical and implementation levels), is both an opportunity to foster innovative solutions and a possible barrier to their integration. The integration of ICT

solutions should be considered to obtain effective and future-proofed innovation transfer (3).

- **Safety** is a concern to be considered even in pilot implementations and has operational implications for all operators (7).
- The **involvement of citizens** is important. It is a strategic approach in the implementation of regional transport policies (2) and a key issue in the decision-making process in local transport, as described in sustainable urban mobility planning (10,11,12).
- Wider **stakeholder involvement** often appears as a "recommendation" (7) (10), but it is also practised and reported as a well-established practice in case reports of innovation in European cities (7).
- The **training and professional development of staff** is a key factor to take into account. It is a common concern which is explicit in any generic approach to innovation in transport (1,2) and more accessibility-focused publications (4) (14).
- **Equality**, defined in a wider sense to include physical, attitudinal, environmental, systemic, linguistic and economic barriers, is specifically recognised in incremental and disruptive innovation processes (2,3): it has important implications for staff training and service standards.

The potential implication on the transfer of innovation of each finding, conclusion or recommendation in the publications has been assessed to obtain a draft list of factors. The draft list of factors has been further reviewed and refined, and factors have been clustered in domains.

Some factors may specifically impact those who select innovations and investments to make services more inclusive. Such factors guide and support the sector in driving the adoption and transfer of innovations in accessible transport easier, faster and less risky were considered highly relevant to the model under development.

A draft model of factors impacting innovation transfer in the public transport sector was obtained by mapping the 40 factors obtained onto the PEST model (Political, Economic, Social and Technological domain) (7). To accommodate the factors specifically related to accessibility and social inclusion, an additional domain was added to the PEST model, namely "Accessibility & Equality factors". The resulting model has been named PESTÆ.

3. Validation

To validate the model, an online survey was developed and submitted to a selected group of experts. Twenty-six (26) qualified respondents fully completed the survey questionnaire from 8 EU countries, with a prevalence of Italy (11/26) and Portugal (4/26). The respondents covered different roles in Public Transport Organisations, mainly related to Management and Innovation Management (8/26), Research and Innovation (4/26), and Process implementation planning (3/26). The respondents' most represented areas of competence were: innovation process management and organisation, methodologies, route planning and travel information, fleet management optimisation, ticketing and payment systems, accessibility and inclusion. The participants were asked to rate each factor's relevance level for decision-making in the transfer of technology-enabled innovation in public transport systems and services. A

10-point rating scale was used throughout the survey questionnaire for each factor: 10 (extremely relevant) ....1 (not relevant at all).

4. Results

The average score for each factor was calculated to analyse the results at first, which was obtained by discarding the highest and the lowest scores for each item or factor.

The questionnaire listed factors belonging to different domains: political, economic, social, technology and accessibility+equality, which made it possible to analyse the average values for each domain. This analysis demonstrated a slightly higher average rating for factors in the technology and economic environments, followed by the political domain. However, it has to be noted that all factors received notable consensus. 22 out of 40 factors received an overall average score of 7.9 or higher.

The overall validity of the list of factors to be considered in the transfer of innovation process in the public transport sector, as extracted from the literature, is confirmed by the survey outcomes. The analysis demonstrated the relevance of the factors selected for each domain.

The summative analysis of the impacting factors considered most important by the respondents shows the importance of the Political, Economic, and Technological factors. This result is consistent with the background of the respondents. Irrespective of the innovation transfer process, they suggest the main factors that should be considered, regardless of the process developed.

The factors for each domain that emerge from the survey can be observed in Figure 1 which also represents a graphic representation of the TRIPS model for transferring technology-based innovation for an increasingly accessible public transport sector. The model highlights the importance of the factors related to accessibility and equality in the overall process of transfer of innovation in public transport.

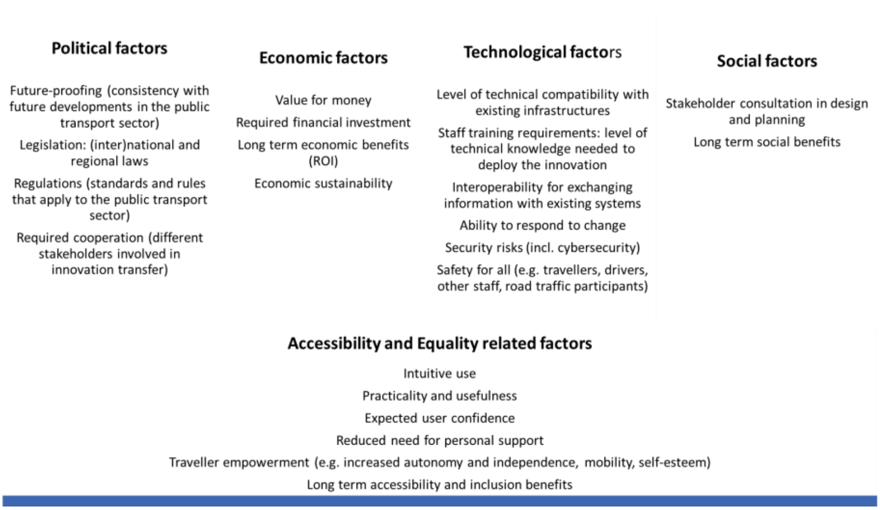

Figure 1. Conceptual framework model of impacting factors on transfer of technology-based innovation in accessible and inclusive public transport

As a next step and to facilitate the use of the framework model, a self-assessment tool was made to help decision-makers in public transport companies manage technology adoption processes. Testing the validity of such a self-assessment framework could be the next step of the efforts of AAATE in this field.

References

[1] European Bank For Reconstruction And Development. Disruptive Technology And Innovation In Transport - Policy Paper On Sustainable Infrastructure. 2019.

[2] Tsakalidis A, van Balen M, Gkoumas K, Haq G, Ortega Hortelano A, Grosso M, and Pekár F. Research and innovation in smart mobility and services in Europe, EUR 30212 EN. Publications Office of the European Union, Luxembourg. 2020. ISBN 978-92-76-18821-6, doi:10.2760/732047, JRC120305.

[3] UK Department For Transport. The Inclusive Transport Strategy: Achieving Equal Access For Disabled People. 2018.

[4] Berman E and Khalil T. US technological competitiveness in the global economy: A survey. International Journal of Technology Management. 1992 Vol.7 (4-5):347-358

[5] Chiesa V and Manzini R. Profiting from the Virtual Organisation of Technological Innovation: Suggestions from an Empirical Study. International Journal of Technology Management. 1998 (15): 109-123.

[6] Robinson L. A Summary of Diffusion of Innovations. 2009. Retrieved 01.05.2023. Available from: https://twut.nd.edu/PDF/Summary_Diffusion_Theory.pdf

[7] Aguilar, F. Scanning the Business Environment. Macmillan. 1967.

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Robotics at the Service of Wheelchair Mobility for People with Disabilities: Story of a Clinical-Scientific Partnership

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Abstract. The mobility of people with motor disabilities combined with sensory or cognitive disabilities, sometimes leads to safety issues that make independent travel impossible. In this context, teams based in Rennes in the west of France have been working together for several years to design two devices: - an power wheelchair simulator to promote learning to drive in an immersive virtual environment - a driving assistance module that can be added to an power wheelchair to pass and avoid obstacles. This transdisciplinary work was made possible by the geographical and human proximity of the scientific, technical and clinical teams in order to best meet the needs of the end users who were integrated into this co-design approach. This article describes the evolution of this work and future prospects.

Keywords. power wheelchair, driving assistance, driving simulators, neurological impairments,

1. Introduction

Most of people with disabilities need help to move but also to use mobility technical aid. These aids can be assistive, such as canes or walkers, or can even supplement the action such as when using wheelchair. In this context, a Power Wheelchair (PWC) may be the only solution to enable people with severe limitations to perform long and safe trips, allowing them to be more mobile and independent. The benefits of using a wheelchair with this population have already been demonstrated: an improved mobility and participation, a reduced caregiver burden, and a reduced likelihood of referral to long-term care facilities. However, while only 10% of wheelchair users have powered models, 25% of accidents are related to their use. In addition, because of cognitive or behavioral disorders or because of a motor deficiency that is too disabling (uncontrolled movements, non-functional spasticity, etc.), it is not always possible to be eligible to use a wheelchair. This is related to the risk of facing a difficult situation or being a danger for the surrounding people, despite regular training in a rehabilitation center with occupational therapists. In 2006, 100,000 accidents involving wheelchair users were recorded in the United States.

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Figure 1. photograph of the power wheelchair simulator in the Immersia platform : view of a street in the Rennes center

Edwards [1] reports a 21% annual accident rate among wheelchair users in Australia in 2010. 54.7% of subjects in Chen's Taiwan study [2] (2011) reported having at least one crash in the past three years. The risk of accidents involving a collision is thus one of the main problems reported, and is strongly linked in particular to environmental factors (obstacles, quality of the road) and human factors (difficulties related to the disability, or the behavior of others). This has major consequences for health and social participation.

Yet the importance of improving quality of life, users' autonomy, and social inclusion has been highlighted by Helal [3] and Edwards [1]. In this context, encouraging learning and driving in safety, scientists of INSA Rennes and clinicians of the rehabilitation center Pôle St Hélier in Rennes combine theirs skills in order to improve mobility for people with disabilities since 2011 [4] [5]. They developed 2 assistive technologies: a smart power wheelchair and a virtual reality simulator to learn driving. These devices were created and tested following a users-centered approach through this partnership [6] [7]. This trans disciplinary approach required human and geographical proximity. All teams are based in Rennes in Brittany in France and know well each other. Collaborative work required the adoption of a common clinical and technical language while respecting each other's expertise and listening to wheelchair users to formulate their needs in terms of technical specifies. Cross-theses were carried out: a roboticist in a thesis immersed in the rehab center, a physician in the computer laboratory. cross-theses were carried out: a roboticist in a thesis immersed in the rehabilitation centre, a doctor in the computer laboratory. This paper combines the results of 10 years and opens the next perspectives of development.

2. Virtual simulator to promote learning to drive

This PWC simulator is composed of three connected parts: the platform moving at four degrees of freedom (pitch, roll, yaw, and heave) composed with a Quickie salsa M2 seat, a joystick to drive the wheelchair in the virtual environment and one interface.

Figure 2. photograph of the power wheelchair simulator with virtual reality helmet

The driving simulator was developed by computer science researchers from the INSA Rennes. These circuits were modelled in 3D using Unity game engine to create three test scenarios in virtual reality (VR). Vestibular feedbacks were generated by a mechanical platform for entertainment and simulation D-BOX - Gen II Actuators 1.5. The interface can be VR HMD (HTC Vive Pro), *cf.* figure 2, or immersive room [8] [9], *cf.* figure 1.

A first randomised controlled trial validated the comparison between driving in the virtual reality simulator and in real life on a racetrack among regular electric wheelchair users. The number of collisions and travel time were similar on 31 PWC users [10]. A second trial compared 4 different virtual reality interfaces : 2 immersive one (platform moving with VR helmet or in an immersive room) and 2 non immersive (platform moving with computer screen or PWC with computer screen). The main criterion was the number of collision during 3 courses in an indoor traffic situation modelled in 3D. Number of collisions, time of completion, cognitive load, sense of presence and cybersickness were assessed. 25 participants who were expert drivers with neurological disorders were included in the study. Participants had a better performance and a higher sense of presence using a HMD (head mounted device) or an immersive room than using only screen, thus highlighting the benefits of a high level of immersion *cf.* table 1. The cognitive load was not affected by the visual condition.

The next step is to use the simulator in a learning study with patients who are not yet PWC drivers in a populated environment with virtual pedestrians having realistic

Variable	CAVE n=23	screen n=24	HMD n=22	simscreen n=92	Overall	Kruskal-Wallis (p value)
Collisions	10.33 (9.23)	25.81 (18.14)	13.45 (15.07)	24.43 (18.50)	18.45 (16.81)	< 0.001***
Time (sec)	290.50 (110.42)	335.04 (119.75)	272.14 (98.19)	364.29 (130.96)	315.16 (118.94)	0.008***
Missing values	3	2	3	4	12	

Table 1. Comparison of number of collisions and driving time in the four conditions. Format: mean(SD) with SD= standard error. *$\leq$ 0.05, **$\leq$ 0.01, ***$\leq$ 0.001, cave = immersive room, HMD= head mounted device, screen = no simulator and feedback on screen, simscreen = simulator and feedback on screen.

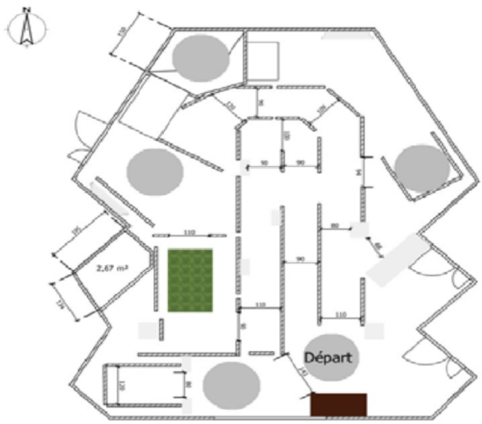

Figure 3. Representation of the power wheelchair test circuit during clinical trials. It was defined to condense the maximum number of difficulties of daily life on the basis of a questionnaire carried out beforehand with occupational therapists

social behaviors, especially during crossings. To do this, two biomechanical studies were carried out, one in the laboratory and the other in the museums of the city of Rennes in order to model these locomotor behaviors.

3. Smart powered wheelchair to avoid obstacles in everyday life

We proposed a perceptive shared control system that progressively corrects the trajectory as a user manually drives the wheelchair, by means of a sensor-based shared control law capable of smoothly avoiding obstacles. This control law is based on a low complex optimization framework validated through simulations and extensive clinical trials. The provided model uses distance information. Therefore, for low-cost considerations, we use ultrasonic sensors to measure the distances around the wheelchair. The solution therefore provides an efficient assistive tool that does not alter the perceived quality of experience, while ensuring drivers security [11] [12].

In a first study[13], we showed that in 23 patients (11 women, 12 men, mean age of 48 y.o.) there was a statistically significant reduction in the number of collisions on the most complex circuit *cf.* figure 3: 61 per cent experienced collisions without assistance versus 39 with assistance.

The second trial dealt with users with driving difficulties. For the most complex circuit incorporating the maximum number of risky situations, 100 of the users experienced collisions and the assistance significantly reduced their number from 7.30 (8.90) to 1.33 (1.40) (p=0.0007). The effect size was significant for routes 2 and 3 (r= 0.714 and r=0.827). There was no significant difference between the two conditions on course duration. The use of the assistance module did not affect the time taken to complete the route for people with driving difficulties. The use of the assistance module did not affect the time taken to complete the route for people with driving difficulties. The mental load was similar on the NASA Task load.

The main objective of the next clinical trial will be to evaluate the benefit of using a PWC equipped with the assistance module on the confidence in driving for elderly people in institution, during the period of use of the module and at the end. Confidence will be measured by the confidence subscore of the WST-Q questionnaire. We will highlight the interest of a robotic driving assistance module on driving skill in terms of ability and performance of tasks performed measured by the WST-Q score and its subscores, the amount of travel evidenced by the distance traveled in the smart wheelchair compared to the personal PWC, measured by sensors embedded, the mental load related, user satisfaction with the system and the acceptability of this tool by the participants.

4. Discussion

The summary of this work during about 10 years shows that it is possible and even necessary to have a multidisciplinary approach to technological innovations especially in technical mobility aids. The user-centred approach that was employed involved academic researchers, clinicians, and power wheelchair users in specifying their needs. It was made possible by the joint existence of a Living Lab within the rehabilitation center and a university chair dedicated to disability in the same city. Starting from the needs of the users, both patients and the professionals who accompany them, this work summarises 2 of the 3 axes that had been defined: the design of a driving simulator for learning and a driving assistance module. The project also included training in new online technical aids so that professionals know how to prescribe such innovative technical aids.

It should be noted that few studies of the various wheelchair or smart chair driving simulators have managed to include so many people with disabilities. concerning smart wheelchairs, Sharma et al. [14] evaluated an anti-collision assistance system for PWC in 19 healthy people blinded by a blindfold on a standardized circuit. Boucher [15] compared the driving performance of 17 participants, 8 of them were healthy participants. Studies involving only users involve much smaller numbers: 4 children suffering from cerebral palsy for McGarry et al.[16], 7 people with visual disturbances for Sharma and 5 elderly people with moderate cognitive impairment for How [17]. It is the same for simulators. Arlati [18] can be found at 62 articles concerning 29 differents simulators but with few participants in clinical trials. For example Archambault et al. tested the MiWE on 12 expert PWC users with min 2 years of driving [19], or 17 new users [20]. The VieW simulator were tested on 12 children or young adults with cerebral palsy [21]. Mahajan tested on 10 participants [22]. So there are various simulators in the litterature but rather few in the clinical trials and very few in every day clinical practises.

It is that why, from the beginning of this trans disciplinary assistive technologies work, we defined a ambitious specifications in terms of technology and needs, but at low cost. this had an impact on the technological choices (choice of sensors on the smart wheelchair for example). Nevertheless, the regulatory process to bring such medical devices to market and thus to use by the patients who need them is long and costly. This slows down the process of making them available to end-users and makes the process rather expensive for entreprises. As a result, few manufacturers are willing to start marketing such mobility aids, in a market that is still considered a niche market, even though demographics and the ageing of the population are creating ever greater needs. Today, both the simulator and the smart wheelchair have not found a manufacturer to market them, despite the user centered approach, the technological barriers that have been lifted and the clinical studies conducted to validate them.

5. Conclusion

The geographical and human proximity of the clinical teams of rehabilitation and scientific teams of robotics and data processing allowed the conception of 2 devices having for objective the improvement of the safety during the driving in wheelchair. This work, which started from a need of users with disabilities, has taken up scientific challenges and has been the subject of joint theses and publications. The approach is now that of industrialization to bring these innovative technologies to the market.

References

[1] Edwards K, McCluskey A. A survey of adult power wheelchair and scooter users. Disability and Rehabilitation: Assistive Technology. 2010;5(6):411-9.

[2] Chen WY, Jang Y, Wang JD, Huang WN, Chang CC, Mao HF, et al. Wheelchair-related accidents: relationship with wheelchair-using behavior in active community wheelchair users. Archives of physical medicine and rehabilitation. 2011;92(6):892-8.

[3] Helal S, Schmalz M, Mokhtari M, Abdulrazak B. Introduction to the Book. The Engineering Handbook of Smart Technology for Aging, Disability, and Independence. 2008:1-26.

[4] Ragot N, Fraudet B, Leblong E. ADAPT: A EU transdisciplinary research project for assistive robotics rehabilitation. In: 2018 13th Annual Conference on System of Systems Engineering (SoSE). IEEE; 2018. p. 114-6.

[5] Ménard L, Petit A, Leblong E, Stein M, Hatzidimitriadou E, Khemmar R, et al. Novel robotic assistive technologies: choosing appropriate training for healthcare professionals. Modelling, Measurement and Control C. 2020;81(1-4):43-8.

[6] Vailland G, Grzeskowiak F, Devigne L, Gaffary Y, Fraudet B, Leblong E, et al. User-centered design of a multisensory power wheelchair simulator: towards training and rehabilitation applications. In: 2019 IEEE 16th International Conference on Rehabilitation Robotics (ICORR). IEEE; 2019. p. 77-82.

[7] Leblong E, Fraudet B, Benoit N, Dandois M, Babel M, Ceze E, et al. Training and Provision Concerning Power Wheelchair Driving: a Survey Comparing Practices in France and United Kingdom. In: SOFMER 2020-35th Congres de Médecine Physique et de Réadaptation; 2020. .

[8] Devigne L, Babel M, Nouviale F, Narayanan VK, Pasteau F, Gallien P. Design of an immersive simulator for assisted power wheelchair driving. In: 2017 International Conference on Rehabilitation Robotics (ICORR). IEEE; 2017. p. 995-1000.

[9] Vailland G, Devigne L, Pasteau F, Nouviale F, Fraudet B, Leblong E, et al. VR based power wheelchair simulator: Usability evaluation through a clinically validated task with regular users. In: 2021 IEEE Virtual Reality and 3D User Interfaces (VR). IEEE; 2021. p. 420-7.

[10] Fraudet B, Leblong E, Piette P, Nicolas B, Babel M, Gouranton V, et al. Evaluation of Powered Wheelchair Driving Performance in Simulator Compared to Driving in Real-life Situations. the SIMADAPT (Simulator ADAPT) project: a pilot study. 2022.

[11] Devigne L, Narayanan VK, Pasteau F, Babel M. Low complex sensor-based shared control for power wheelchair navigation. In: 2016 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS). IEEE; 2016. p. 5434-9.

[12] Morbidi F, Devigne L, Teodorescu CS, Fraudet B, Leblong E, Carlson T, et al. Assistive Robotic Technologies for Next-Generation Smart Wheelchairs: Codesign and Modularity to Improve Users' Quality of Life. IEEE Robotics and Automation magazine. 2022:2-14.

[13] Leblong E, Fraudet B, Devigne L, Babel M, Pasteau F, Nicolas B, et al. SWADAPT1: assessment of an electric wheelchair-driving robotic module in standardized circuits: a prospective, controlled repeated measure design pilot study. Journal of NeuroEngineering and Rehabilitation. 2021;18:1-12.

[14] Sharma V, Simpson RC, LoPresti EF, Schmeler M. Clinical evaluation of semiautonomous smart wheelchair architecture (Drive-Safe System) with visually impaired individuals. J Rehabil Res Dev. 2012;49(1):35-50.

[15] Boucher P, Atrash A, Kelouwani S, Honoré W, Nguyen H, Villemure J, et al. Design and validation of an intelligent wheelchair towards a clinically-functional outcome. Journal of neuroengineering and rehabilitation. 2013;10(1):1-16.

[16] McGarry S, Moir L, Girdler S. The Smart Wheelchair: is it an appropriate mobility training tool for children with physical disabilities? Disability and Rehabilitation: Assistive Technology. 2012;7(5):372-80.

[17] How TV, Wang RH, Mihailidis A. Evaluation of an intelligent wheelchair system for older adults with cognitive impairments. Journal of neuroengineering and rehabilitation. 2013;10(1):1-16.

[18] Arlati S, Colombo V, Ferrigno G, Sacchetti R, Sacco M. Virtual reality-based wheelchair simulators: A scoping review. Assistive Technology. 2020;32(6):294-305.

[19] Tao G, Archambault PS. Powered wheelchair simulator development: implementing combined navigation-reaching tasks with a 3D hand motion controller. Journal of neuroengineering and rehabilitation. 2016;13(1):1-13.

[20] Archambault PS, Blackburn É, Reid D, Routhier F, Miller WC. Development and user validation of driving tasks for a power wheelchair simulator. Disability and rehabilitation. 2017;39(15):1549-56.

[21] Morere Y, Bourhis G, Cosnuau K, Guilmois G, Rumilly E, Blangy E. ViEW: a wheelchair simulator for driving analysis. Assistive technology. 2020;32(3):125-35.

[22] Mahajan HP, Dicianno BE, Cooper RA, Ding D. Assessment of wheelchair driving performance in a virtual reality-based simulator. The journal of spinal cord medicine. 2013;36(4):322-32.

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Vocal Behavior Acquisition with a Toy Operating by Sound Detection

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Abstract. We investigated a speech training support system targeting students in special needs education classes who are engaged in training to acquire a binary relationship where their vocalizations elicit reactions from others. Previously, there was a challenge in maintaining interest and achieving learning effectiveness when teachers intervened to encourage vocalizations using teaching aids such as picture books. To address this, we designed and integrated an electronic circuit with a movable toy that captures the interest of the supported students. The circuit includes a switch that turns on and activates a secondary circuit only when vocalizations are detected. In this paper, we report on the training using the developed speech support system and validate its functionality.

Keywords. Mastering vocalization with toys, Special needs education, Voice detection equipment.

1. Introduction

Children with intellectual disabilities may have an imbalance in developmental age in the domains of physical-motor, cognitive-adaptive, and language-social skills compared to their actual age in life. When children with intellectual disabilities cannot interact smoothly with others through eye contact and language, there are various effects on their lives at home and their academic activities at special-needs schools. For example, there are children who have not been able to acquire a binary relationship by voice, such as when they call out to others and the people around them respond in some way. When they have a problem or complaint, they may not be able to communicate it to others, and they may act in a way that others and themselves do not intend because of their confusion.

This study was started after a special-needs school, which is working to enhance educational materials including assistive technology, requested cooperation in the development of educational materials. The content of the project is to jointly develop learning support tools utilizing ICT by combining the needs of the field of special-needs education and the seeds of engineering, and to continue activities to evaluate their effectiveness by using them for learning in the field of special-needs education. When we think about what we should aim for in our interventions, we need to consider three

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concepts: effectiveness, sustainability, and versatility of the intervention or training (Alant E, 2005).

In this paper, we propose a system to support vocal training for a child who can make voices in daily life, but has never used his voice for communication with others. We also report on the vocal training for establishing a binary relationship using the developed system in a special-needs education setting.

2. Background

The purpose of this theme is to elicit spontaneous speech in children with special needs, to increase the variation of speech, and to enable them to communicate their thoughts to others. We are developing educational materials for intellectually disabled children who are unable to use language well to interact with others. We have devised a system that works with their favorite toys only when he speaks. By training with it, we aim to shorten the time required to acquire vocalization skills.

As mentioned in the previous chapter, children with intellectual disabilities may not balance their developmental age against their actual age. The subject child is a 10-year-old boy. When the boy's name is called or spoken to, he may respond by holding out his hand and touching it. He is interested in anything that moves in sight, such as a toy train, a toy dog, an electric fan, or a running car, and will turn his head or move closer to it. He can also play alone, throwing balls and spinning bottle containers. He expresses his reaction of rejection by bending over or sitting up to do something he doesn't like.

He rarely speaks spontaneously to communicate his thoughts to others. Although he was able to move around mainly by walking while holding onto something and had no major problems with physical movements in daily life, he did not communicate with others with vocalization. Although he would vocalize when his emotions were high, he never vocalized in order to relate to others, and he had not yet acquired the binary relationships necessary to relate to others.

For example, he likes to watch videos of trains running on his tablet device, but when he unintentionally touches the screen and it switches to another screen, he throws the tablet device to the floor. **Figure 1** shows the current status of the target children and the effects expected after training with the support system.

Figure 1. Current situation of the target and expected effects.

Regarding the use of ICT devices, he was enthusiastic about watching train videos on tablets and smartphones and playing with apps that move when operated by hand. However, while he was operating the touch screen, an unexpected swipe operation with more than one hand would cause the multi-finger action to fire, which would sometimes transition to another application screen or display the home screen. By chance, the same swipe in the opposite direction would sometimes bring up the original screen, but when things went wrong, he would throw his tablet or smartphone. Whenever he had a problem or complaint, he would repeat the act of throwing things.

Parents want him to voice out and get help from those around him instead of throwing things when he has a problem. This requires the learning of a binary relationship in which he calls out aloud for help and others respond. In the following chapters, we consider the specific methodology of the project.

3. Method

This chapter investigates the methodology of training through play for the acquisition of binary relations in vocal communication. According to his homeroom teacher, when she was reading a picture book to him, he would vocalize onomatopoeic parts of the story or in response to emotional ups and downs, but she did not see him using them for communication. The requests from the educational field were that animated train movies and songs stored on iPads and PCs be played in response to vocalizations, or that toys and plush toys be made that move in response to vocalizations.

Currently, when the target child is operating a tablet terminal or other device and gets into an unwanted situation, he throws the device to the floor. Prelinguistic communication includes any communication mode that does not involve language, including behaviors such as gestures, hand or body movements, gross vocalizations, and facial expressions (Ogletree & Pierce, 2010). Parents are expecting that an adult around them should be called when such a situation occurs.

In the field of education, teachers use picture books and other materials to encourage vocalization in order for the child to be able to communicate with others vocally, but it is difficult for the child to sustain this interest. Although students listen to the storybook immediately after it begins and vocalize when characteristic onomatopoeic words appear on the page, they soon become bored, making it difficult to repeat the training. In other words, he was not able to maintain his interest in the training tool, which made it ineffective.

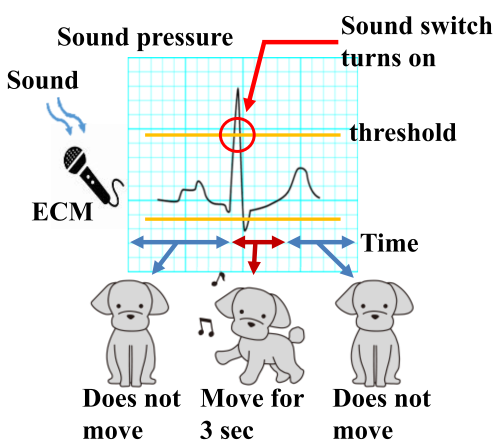

Figure 2. Sound switch operation for input waveform.

The basic solution idea is shown in **Figure 2**. A condenser microphone (ECM) detects sound and inputs it to a microcontroller, which turns on the secondary side of a relay when it determines that sound input has occurred. Then, the target child's favorite toy is connected to the secondary circuit. A microcontroller was used to input analog voltage values amplified by an amplifier from sound data acquired by the ECM, and to judge that a vocalization had occurred when the standard deviation exceeded a threshold value. The reason for calculating the standard deviation by the change in voltage value is to cancel ambient noise and stationary noise emitted from air conditioners and other devices.

In the field of special-needs education, there is an example in which a robot as a social agent was used as an intermediary, and the interaction was analyzed to see how children reacted to the behavior of a robot with intentions (Cook, et al. 2011). These are tools for communicating intentions and learning social behavior, and can be said to contribute to the acquisition training of the so-called triadic relationship. Play is essential in the development of every child and is a fundamental right for every child (Barbara Prazak-Aram, et al. 2004).

In this study, we are developing a vocal training support system that contributes to communication through vocalization. The system will provide an incentive for vocalization and can be implemented on any moving toy or plush animal that is of interest to the learner. By using an object of interest to students as a training tool, we aim to extend the duration of training and increase the effectiveness of training.

4. Implementation

Therefore, we developed a prototype training material to encourage him to vocalize his spontaneous voice. The teaching material is a toy that moves for a certain period of time in response to sounds and vocalizations. The toy was modified based on a dog toy that barks and moves intermittently when switched on. In place of the original switch, a sound switch was implemented in the electronic circuit so that the toy would move only when it detects sound.

As proposed in the previous chapter, we will develop a sound switch unit to be incorporated into any vocal training equipment. Specifically, an electronic circuit that turns on the secondary circuit only when a voice is uttered is devised, and this circuit is made into a unit. We call this a sound switch. The sound switch is a device that does not respond in a steady state, but turns on the secondary circuit only when a voice is uttered. The unit is designed to be compact and can be incorporated into any device for safe use in special-needs education.

Based on observations of the classroom setting where the training was conducted and the behavior of the trainees, it was determined that a specification requiring an external power source would be impractical. Therefore, we decided to use a device that obtains its power source from the equipment in which it will be embedded. Many moving toys are powered by two AA batteries (DC+3V), so the sound switch would need to operate at a low voltage in order to be integrated into these toys without requiring an external power source. Commercially available sound switches were considered, but were eliminated from the candidates because they require a power supply of about DC+9V. The first prototype was designed on the assumption that it would be incorporated into a stuffed dog, a favorite toy of the target child.

The specifications of the developed sound switch are shown in Table 1 and its schematic in **Figure 3**.

Table 1. Specifications of the developed sound switch

Parameters	Ratings
DC Power supply	1.7~5V
Secondary voltage	~40V
secondary current	~2A (continuous) / ~6A (pulse)
Microphone	ECM
Latch timer	3sec (Any value can be set)
Unit size	(W)30 x (D)18 x (H)8mm

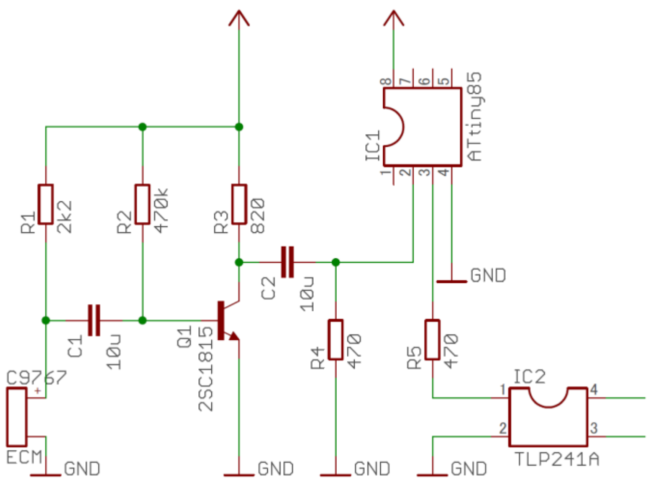

Figure 3. Circuit diagram of sound switch.

The sound switch shown in **Figure 4** has a board size of 30 x 18 mm and was incorporated into a dog toy. When the ECM detects a sound, the circuit is switched on for 3 seconds. Switch-on time can be adjusted programmatically. To cancel steady-state noise, the switch is turned on only when the input sound pressure dispersion exceeds a threshold value. The basic design was prototyped using Arduino Uno, but an Attiny85 AVR microcontroller, which can also operate as an Arduino-compatible chip, was selected to implement the sound switch unit. The reason for this was to keep the size of the unit small enough to be incorporated into a stuffed dog toy, as shown in **Figure 5**.

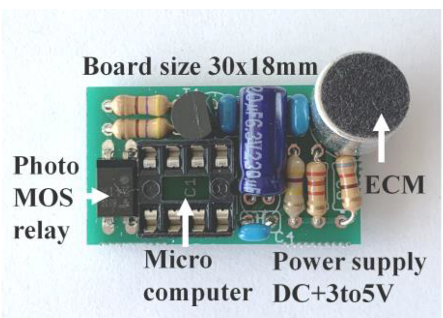

Figure 4. Outline of the sound switch unit for built-in.

Figure 5. Favorite toys remodeling with sound switch.

A Toshiba TLP241A photorelay was used for on/off control of the secondary circuit, with a withstand voltage of 40 V and an output current of 6 A, which is sufficient to pass enough power to drive a typical toy circuit. The size of the board is small enough to be integrated into any toy device. The prototype sound switch circuit was inserted into a gap in the buttocks of a stuffed dog. Once the stuffed dog's cover is back on, the modification cannot be seen from the outside.

5. Results

The target child was a 10-year-old boy. When we brought the developed toy to a special needs school and offered it to him, we observed that he was interested in the toy, looked at it, touched it, and tried to engage with it. Therefore, we started trial use of the device as one of the supports to increase the variation of language in his education. The following is a report on the results of the nine-month trial.

The main power switch of the modified stuffed dog is turned on by the teacher in advance and placed on the floor. The original stuffed dog begins to move when the switch is turned on, but it remains stationary until it detects a vocalization of a specified level or higher. When speech is detected, the sound switch is turned on and the stuffed dog begins to move. After 3 seconds, during which the sound switch is on, the switch is turned off and the stuffed dog stops moving. When the stuffed dog returned to the waiting state, it was observed to vocalize again and attempt to engage with the stuffed animal. **Figure 6** shows them.

First, there was the behavior of trying to touch the toy and trying to pick it up when it falls over. When the toy left his side, he reached out, grabbed it, and placed it back by his side. He was interested in the toys and followed the teacher's example in speaking.

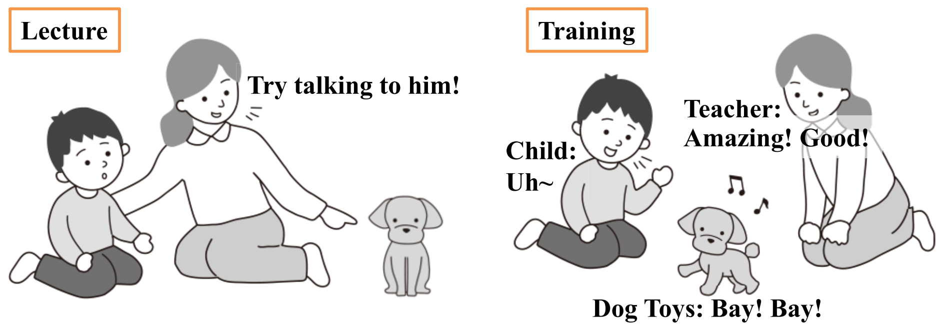

Figure 6. Vocalization training with the support system.

After a trial period of approximately one month, an interview was conducted with the homeroom teachers. In response to the question, "Has vocal training using this support system improved the effectiveness of learning?" the teachers answered that they were able to spend more time on training than with picture books and other teaching materials. In addition, the number of vocalizations per unit of time increased, and the children began to imitate the timing of natural interactions with people. Furthermore, they requested that sound switches be built into other equipment that the target children are interested in, such as toy trains and electric fans.

When the teacher imitates animal noises in learning with picture book reading, he recites and vocalizes them. The vocalization of vowels in the words became louder and easier to hear. In addition to vocalizing and moving toys, his continued interest and engagement with the material may have been a factor in expanding his language along with other activities. Lasker & Bedrosian (2000) report that one-third of assistive technology devices are usually abandoned within three months of being put into use, but the prototypes developed are used for longer than that period.

However, a new problem was discovered. With the current implementation, the sound switch was designed to respond to vocalizations, but it also responds to noises other than vocalizations. For example, sound or vibration could be detected even when the user rolled a stuffed dog by hand, causing the sound switch to turn on. Therefore, it was necessary to place him behind the table during training to prevent his hands from touching the toy, because the sound switch would be activated by rolling it by hand or by extraneous noise.

In the current implementation, the sound switch responds to loud noises and when the user touches the dog animal, in addition to vocalizations. Since the system is incorporated into an object that the target child is interested in, it is expected that there will be cases in the future when the child tries to interact with the system by touching it in addition to vocalizations. Therefore, it is necessary to consider and introduce an algorithm to cancel vibrations other than vocalizations.

6. Conclusion

We conducted this research with the aim of encouraging children with intellectual disabilities to speak spontaneously, to increase the variation of their speech, and to communicate their thoughts to others well. We developed a sound switch that cancels the steady noise and turns on an arbitrary external circuit when it detects vocalization, and incorporated it into a stuffed dog that the children were interested in.

The goal was for him to be able to vocalize and call for help when he is in trouble or when things are not going his way. At present, he has not yet shown any signs of trying to relate to others by vocalizing, but his vocal training time has increased and he is now vocalizing more often than before. Although the subject child had been encouraged to induce language with support from the people around him, he has learned through play using a moving dog toy as a teaching tool, and has come to enjoy the toy's movements by vocalizing them on his own. His response to the moving toys may have been a way for him to expand his language activities.

Even without an ICT support system, vocal training is possible through the use of analog materials. For some subjects, the time when the binary relationship is established through vocalization may come earlier than expected. However, if the frequency and efficiency of training can be increased and the duration of training can be shortened by providing a vocal training support system that matches the subject's interests, it would be useful to increase the time available for other studies.

While push-button switches are commonly used in the field of special-needs education to indicate intentions and input timing, we would like to expand the use of the sound switch proposed in this research as another input modality by taking advantage of its hands-free functionality.

We would like to express our sincere gratitude to the teachers, children, and their families of the Kagoshima Prefectural Nansatsu Special Needs School for their cooperation in conducting this study.

7. Future works

In the future, we will improve tolerance to ambient noise so that the sound switch responds only to the voice he makes. We are considering offering the developed voice switch as a general-purpose module that can be embedded in any device. We will also continue to support him to expand his language variation by using other methods in addition to the devices we have developed.

References

[1] Alant E. Intervention issues. In: Alant E, Lloyd L L, eds. Augmentative and Alternative Communication and Severe Disabilities: Beyond Poverty: Whurr; 2005. p.9-29, doi:10.1191/0265659006ct312xx

[2] Ogletree BT, Pierce HK. AAC for individuals with severe intellectual disabilities: ideas for nonsymbolic communicators. Journal of Developmental and Physical Disabilities. 2010;22(3):273-287. doi: 10.1007/s10882-009-9177-1

[3] Cook A, Adams K, Volden J, Harbottle N, Harbottle C. (2011). Using Lego robots to estimate cognitive ability in children who have severe physical disabilities. Disability & Rehabilitation: Assistive Technology. 2011;6(4):338-346. doi:10.3109/17483107.2010.534231

[4] Prazak B, Kronreif G, Hochgatterer A, Fürst M. A toy robot for physically disabled children. Technology and Disability. 2004;16(3): 131–36. http://dx.doi.org/10.3233/tad-2004-16303.

[5] Lasker JP, and Bedrosian JL. “Acceptance of AAC by adults with acquired disorders”. In: Augmentative communication for adults with neurogenic and neuromuscular disabilities, Edited by: Beukelman, D., Yorkston, K. and Reichle, J. Paul H. Brookes (Baltimore). 2000. p. 107–136.

Building Policies and Initiatives for Inclusive Educational Contexts

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Requirements, Barriers and Tools for Participation in an Inclusive Educational Digital Environment

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Abstract. An inclusive digital environment in education is considered a cornerstone for a modern society and particularly important for learners with disabilities. This paper delves into this topic and presents the findings from a one-week "Learning, Teaching and Training Activity" (LTTA) conducted as part of the Erasmus+ project on the "Digital Readiness of Vocational Educational Institutions in an Inclusive Environment." The LTTA involved discussions on the requirements, barriers, and applicable tools for digitalization in Vocational Educational Institutions (VET) with educators and self-representatives (learners with disabilities). The feedback from participants was analyzed and included evaluations of various tools in terms of their effectiveness and usefulness. These tools encompassed document accessibility, onboard Windows accessibility features, AI in the form of large language models (LLM) as assistive technology, and image recognition-based assistive technologies. Results, presented in this paper, indicate that especially learners with disabilities can benefit from participation in an inclusive digital environment.

Keywords. inclusive digital environment, education, vocational education, accessibility, people with disabilities

1. Introduction

An educational digital environment can be defined as the use of technology to bridge the gap between learners and educators, minimizing the need for face-to-face interactions [1,2]. Especially in the last three years, during the Covid-19 pandemic, there has been a complete or partial need for a transition from traditional in-person education to digital platforms. This transition is partly negatively impacting various target groups, including the teaching staff responsible for learners with disabilities, the students themselves and their social environment [3–7].

Many educators find themselves at least partially unprepared for the emerging, but sudden digital transition in the educational sector. They have taken on a new role, guiding their students in the independent utilization of digital media and tools [7]. There was a notable absence of suitable and customized learning programs [3]. On the other hand, certain learners with disabilities were unable to access digital resources due to insufficient technical capabilities and limited individual support in the teaching-learning process.

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2. Inclusion in a digital educational environment

Digital technologies have a remarkable potential to promote the inclusion of learners with disabilities. Online resources and materials are generally more accessible compared to traditional classroom materials. However, it is important to note that if the specific needs of this group are not taken into account, these technologies can lead to their further exclusion [8]. Therefore, it is absolutely essential that educators are able to select appropriate tools for their target group of learners.

On the other hand, an inclusive digital environment can provide opportunities for learners to access education regardless of their location or circumstances [9]. By utilizing technology and appropriate tools, distance learning can be made possible and educational processes can be facilitated [2,10]. Especially learners with disabilities can benefit from participation in an inclusive digital environment [2,11,12]. Their diverse learning needs can be handled by offering alternative as well as individualized methods of instruction and assessment, such as multimedia materials, online discussions or adaptive assessments. This allows learners with disabilities to engage with the material in a way that works best for them, as long as this digital content is accessible [10,12,13]. Digital accessibility is the process of making digital content and technologies accessible and can be understood as a crucial requirement for inclusion in a digital environment [10,14]. Thereby, digital accessibility can support the process of "going digital" by providing appropriate tools and settings for learners with disabilities.

3. Methodological approach

During an intensive one-week "Learning, Teaching and Training Activity" (LTTA) in the framework of the Erasmus+ project "Digital Readiness of Vocational Educational Institutions in an Inclusive Environment", requirements and barriers for going digital as well as applicable tools for learners with disabilities were discussed. In the discussions with participating educators of Vocational Educational Institutions (VET) as well as self-representatives (learners with disabilities), experiences and knowledge were exchanged.

In particular, the online tool Mentimeter was used to moderate the discussion, fueling participation and preserving feedback of participants during group discussions of specific topics. Additionally, areas and topics of special interest, raising by the participants themselves, were discussed. This feedback was collected and in an evaluation stage, the comprehensive feedback was analyzed: Answers were clustered, and gaps and requirements for tool support identified. This step also allowed for an analysis of the conception among participants about the accessibility and usefulness of tools for their daily practice in VET.

The participants came from Austria, Belgium, Bulgaria, Cyprus, Greece, Germany, Latvia and Malta and first discussed in smaller groups and afterwards in an open group with all other participants.

4. Gaps and barriers towards inclusive digital educational environments

The emerging gaps and barriers can be summarized in clusters and provide an overview of the challenges associated with digital education, including technical and access barriers, awareness and motivation issues, support and resource constraints, and the absence of a consistent concept for online learning.

4.1. Technical and access barriers resulting from lacking infrastructure and hardware

One cluster of challenges in digital education includes the lack of technical skills and knowledge of technology, which affects educators, learners with disabilities and their social environment. Lacking digital competencies often arise from the absence of training in this field and the individual speed at which digital skills are acquired varies among educators and learners with disabilities.

Additionally, a lack of appropriate infrastructure and hardware exacerbates the challenges in digital education. Insufficient infrastructure, such as inadequate internet connectivity or outdated equipment, creates additional barriers for every person who is involved in the educational process. Without the necessary infrastructure, conducting online classes and accessing educational resources becomes even more challenging. Similarly, the scarcity of suitable hardware, such as computers or tablets, further hinders the ability of learners to participate effectively in digital learning environments. The absence of proper infrastructure and hardware amplifies the existing difficulties, limiting the potential for quality digital education.

4.2. Awareness and Motivation

Another set of challenges stems from inadequate awareness towards digitalization. Insufficient awareness of digitalization and inadequate understanding of how to use digital tools are prevalent among both educators and learners. This lack of awareness hampers effective utilization of technology for educational purposes. Insufficient motivation and a dearth of interaction tools further contribute to the difficulties. Affordability and practical issues also play a role in hindering access to digital education.

The workload associated with the preparation of regular lessons and the need for documentation can prevent educators from dedicating personal resources to enhance their own digital competencies. These resource limitations hinder the professional development of educators in the digital realm.

4.3. Support and Resources

Challenges related to support and resources encompass several factors. Families often lack support in terms of financing and acquiring the necessary skills for digital education. Support is required to ensure these families can meet the technological requirements and support their children's learning effectively.

Affordability and sustainability of digital education are significant concerns among the participants. The cost of acquiring necessary devices and maintaining an internet connection can be prohibitive for some learners and families, limiting their ability to fully engage in digital education. Additionally, there is a disparity in connectivity and infrastructure between schools and families. The infrastructure available in schools may not match the capabilities of individual households, further exacerbating the access problem. The shortage of devices during online sessions and the limited availability of devices at home create obstacles to seamless digital learning experiences. The lack of access to devices negatively impacts participation and engagement in online education.

4.4. Lack of Consistent Concepts

A distinct challenge arises from the absence of a consistent concept for online education. This lack of clarity regarding what should be done online further complicates the digital education landscape. The lack of a clear and cohesive framework or strategy for implementing online education can lead to confusion and inefficiencies in the teaching and learning process.

The findings from the group discussion points at various factors, such as motivation, access to modern gadgets, and the individual speed of acquiring digital skills that can influence the success of digital education. These factors vary from person to person and can impact engagement and proficiency in using digital tools.

5. Requirements for going digital in inclusive digital educational environments

In addition to discussing the requirements for going digital in an inclusive educational environment, another significant aspect of the event involved exploring and presenting tools that assist educators and learners, which was thoroughly discussed within the group.

The group discussion on requirements for going digital in an inclusive education environment was intense and focused on topics around awareness raising, strategic implementation of digitalization in an educational setting, appropriate infrastructure and provision of hardware, improvement of digital qualifications and also policies facilitating the process of going digital.

Spreading awareness about the importance of digitalization is a crucial step in promoting inclusive and effective digital education. Educating stakeholders, including educators, learners, families and policymakers about the benefits and opportunities of digital education can support the development of an inclusive digital educational environment.

Developing a consistent concept for online education within vocational education and training (VET) organizations is vital. This concept should include clear policies and guidelines that outline the objectives, methodologies and assessment practices for online learning. This clarity can help ensure that everyone involved understands the expectations and can work towards achieving them.

Infrastructure development is a key aspect of enabling digital education. Implementing usable Wi-Fi connectivity in educational institutions allows learners and educators to access online resources, collaborate, and engage in remote learning activities.

Providing access to necessary equipment, devices, and hardware is another critical factor in supporting digital education. Educational institutions should prioritize providing learners and educators with the tools they need, such as computers, tablets, or smartphones, to participate in online learning effectively. Additionally, ensuring that the infrastructure can handle the increased demand for digital resources is important.

Alongside infrastructure development and equipment provision, it's essential to offer training programs that enhance the digital capabilities of educational institutions. This training can cover various aspects, including the effective use of digital tools and platforms, online pedagogy, and data security and privacy. By equipping educators and staff with the necessary skills, they can effectively leverage digital technologies for teaching and learning purposes.

6. Accessible and inclusive tools for going digital

According to the feedback gathered from participants, various tools were evaluated in terms of their effectiveness and usefulness.

Document accessibility: Among these tools, document accessibility techniques in Microsoft Word, including styling templates, alternative texts, were deemed crucial by almost everyone, with many participants already using them and the rest benefiting from the introduction to these techniques in the workshop.

Onboard Windows Accessibility Features: The onboard accessibility features in Windows, such as the magnifier and high-contrast mode, were found to be particularly helpful by many participants. Participants stated that they would recommend them to their colleagues, family, and friends, particularly the elderly population who may have difficulty reading small text or distinguishing between different colors.

AI-based Language model as AT: It was discovered that many participants were not aware that ChatGPT could be used as an assistive technology. However, once introduced to this concept, they found it to be a useful tool for explaining complex terms in simple language, as long as the questions were phrased in the right way. Participants were pleased with the ease-of-use and natural user interface of ChatGPT. Additionally, they appreciated the fact that it supports multiple languages and found the answers to be helpful in addressing their queries. However, the workshop also clearly highlighted the need for awareness raising of the limitations of ChatGPT and similar technologies. Particularly important was to outline the fact that the correctness of a statement cannot be guaranteed and this type of technology has (nowadays) no access to recent data and information.

Image Recognition-based AT: According to the feedback received from participants, image recognition-based assistive technologies such as Seeing AI and Google Lens were found to be helpful for many different user groups. In particular, Seeing AI was praised for its effectiveness in assisting those with visual impairments, as it allows them to navigate their surroundings and identify objects with greater ease. However, participants also noted that these tools have a wider range of applications beyond just accessibility, making them a versatile and valuable tool for many different use cases, such as translation, scanning barcodes, and recognizing faces.

7. Conclusion and Discussion

The group discussion showed that digital accessibility of content, as well as tools, is considered relevant among all participants. There was a general understanding that digital accessibility is important not only for persons with disabilities but also for many other stakeholders, including educators, the elderly and society in general. There was a collective agreement that digital accessibility is important in their working lives, but that it may take on different forms.

The participants had varying levels of knowledge about the selected tools and who can benefit from them. Some educators of the VET centers that participated in the discussion were already using them as well as other tools such as Miro, Google Forms, Canva, Mentimeter, visual aids, Word Accessibility, Google Drive, Kahoot, Wordwall, and WordFreeform. However, some VET centers were still at the beginning stages of implementing digital tools.

The group discussion also highlighted gaps and barriers in going digital, including the lack of knowledge of technology, technical skills, connectivity, missing or inadequate infrastructure, missing hardware in schools and at home, affordability and sustainability, concepts on how to implement change in the organization, and bureaucracy. Therefore, awareness-raising, the development of guidelines for going digital and training of educators were identified as significant factors that influence the process of digitization. Additionally, limited support and resources hinder families' ability to afford and acquire the necessary technology and should be addressed by responsible bodies. Moreover, if digital tools are implemented in VET and training, the discussion concluded that training for learners with disabilities as well as educators is needed.

References

[1] Petretto DR, Masala I, Masala C. Special Educational Needs, Distance Learning, Inclusion and COVID-19. Education Sciences. 2020;10(6), Article 6. https://doi.org/10.3390/educsci10060154
[2] Sholikhati NI, Prayogo MM, Santoso J. The Effect of Distance Learning on Learning Outcomes of Children with Special Needs in Inclusive Schools in the New Normal. Indonesian Journal of Disability Studies, 2021;8(1), Article 1. https://doi.org/10.21776/ub.ijds.2021.008.01.11
[3] Bešić E, Holzinger A, Komposch U, Wohlhart D. Fernunterricht für Schüler*innen mit Behinderungen Perspektiven von Lehrpersonen [Internet]. 2020; Available from:. https://www.phst.at/fileadmin/News/SS_2020/Factsheet_Fernunterricht_SchuelerInnen_mit_Behinderungen_final.pdf
[4] Calahorrano L, Henk A, Kugelmeier D. Wünsche von Familien mit beeinträchtigten Kindern an die Politik – Befragungsergebnisse vor dem Hintergrund der Corona-Pandemie. Fraunhofer-Institut für Angewandte Informationstechnik FIT. [Internet] 2021; Available from: https://www.fit.fraunhofer.de/content/dam/fit/de/documents/W%C3%BCnscheAnDiePolitik_2021_12_01.pdf
[5] Fettweis N, Zorn I. Wie inklusiv ist „digitale Schule“ in COVID-Zeiten aus Sicht von Schulsozialarbeiter:innen? Eine explorative Studie zu Inklusionschancen und Exklusionsrisiken digitaler Schulbildung aus Sicht der Sozialen Arbeit. Zusammenfassung für das Amt für Schulentwicklung der Stadt Köln. TH Köln. 2022.
[6] Fickermann D, Edelstein B. Schule und Corona. Ein Überblick über Forschungsaktivitäten an Hand von Projektsteckbriefen. In Schule während der Corona-Pandemie. Neue Ergebnisse und Überblick über ein dynamisches Forschungsfeld Waxmann Verlag GmbH. 2021. p.103-212. https://doi.org/10.31244/9783830993315.05
[7] Schwab S, Lindner, KT. Schulschließungen, Homeschooling und Bildungsungleichheit. WISO. Wirtschafts- und sozialpolitische Zeitschrift, 2021;43(4/20):50–61.
[8] Pierrés O, Darvishy A. Gauging Awareness of Accessibility in Open Educational Resources. In K. Miesenberger, G. Kouroupetroglou, K. Mavrou, R. Manduchi, M. Covarrubias Rodriguez, & P. Penáz (Hrsg.), Computers Helping People with Special Needs. 18th International Conference, ICCHP-AAATE 2022, Lecco, Italy, July 11-15. Springer Nature Switzerland AG. 2022. p.335-342.
[9] Kelland JH. Distance Learning: Access and Inclusion Issues. The 46th Annual Adult Education Research Conference, 2005. p.253–258.
[10] Fajardo Bravo I, Gómez-Merino N, Jury M, Mannik S, McDougal E, Klang N, Lüke T, Perrin AL, Pittas E, Ranzato E, Rubio Jimenez AL, Sormunen K, Van Herwegen J. Guidance for the inclusion of students with Special Educational Needs for online learning / Ohjeita erityistä tukea tarvitsevien oppijoiden inklusiiviseen verkko-opetukseen. European Association for Research on Learning and Instruction EARLI. 2020.
[11] Bešić E, Holzinger A, Komposch U, Wohlhart D. Fernunterricht für Schüler*innen mit Behinderungen Perspektiven von Lehrpersonen. Zeitschrift für Inklusion. 2020.
[12] Dianne C, Zeynep V, Irmgarda KB. Learning for All: Guidelines on the inclusion of learners with disabilities in open and distance learning. UNESCO Publishing. 2016.
[13] Kaur M. Tools of ICT in Open and Distance Learning for Inclusive Education in Developing World. In Anjana (Hrsg.), Technology for Efficient Learner Support Services in Distance Education: Experiences from Developing Countries. Springer. 2018. p. 23-41. https://doi.org/10.1007/978-981-13-2300-3_2

[14] Miesenberger K. Sonderpädagogik in der digitalisierten Lernwelt. In S. Calabrese, B. Egloff, C. Monney, G. Pelgrims, C. S. Lozano, D. Sahrai, C. Straccia, & M. Wicki (Hrsg.), Beiträge der nationalen Tagung Netzwerk Forschung Sonderpädagogik. Edition SZH / CSPS. 2020. p.11-28.

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Building Policies and Initiatives for Inclusive Educational Contexts: The GLIC Italian Experience

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Abstract. Inclusive education has emerged as a global priority, and the integration of assistive technology (AT) is recognized as a crucial component for creating inclusive educational environments. However, the successful implementation of AT hinges on supportive policies and initiatives. This article delves into the experience of the GLIC Association in collaboration with the Italian Ministry of Education, exploring their efforts in developing policies and initiatives to facilitate the introduction of AT in educational contexts. The GLIC Association has devised a service provisioning model in state schools that ensures adequate support for the integration of AT, thus promoting inclusive education.

Keywords. GLIC, Assistive Technology, Inclusive schools, Italian experience

1. Introduction

In Italy, the journey towards inclusive education has evolved over several decades. The push for inclusive education can be traced back to the 1970s where a growing movement for integration was pushing towards an equal access to education and promoting the social inclusion of all students and in particular for those with disabilities. Just to briefly mention, the Law 517/77 marked a crucial milestone in the development of inclusive education in Italy. This law recognized the right of all students, including those with disabilities, to receive an education in regular schools. It emphasized the principle of normalization and called for the integration of students with disabilities into mainstream classrooms, de facto abolishing all special classrooms and schools [1].

After a growing awareness in the 1980s, the Law 104/92 [2] further reinforced the concept of inclusive education in Italy. It introduced the concept of individualized educational plans (IEPs) for students with disabilities, ensuring personalized support and accommodations. This law emphasized the importance of integrating students with disabilities into mainstream schools. Later, the law 170/2000 aimed to further enhance the inclusion of students with disabilities through the provision of support services and resources in mainstream schools. It emphasized the role of support teachers, specialized

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services, and the involvement of families and local communities in promoting inclusive education.

While progress has been made, challenges remain in fully realizing the vision of inclusive education in Italy. Ongoing collaboration among government bodies, NHS, National Research Council and other educational institutions, non-profit organizations, and stakeholders is crucial to continue advancing inclusive practices and ensuring that all students have equal opportunities to thrive in the educational system. The ratification of the United Nations Convention on the Rights of Persons with Disabilities (UNCRPD) in 2009 fostered the promotion of inclusive education and removing barriers to learning for students with disabilities. Efforts have been made to improve accessibility, enhance teacher training, and provide appropriate support services to ensure the successful inclusion of all students in mainstream classrooms [3].

In this remit, the GLIC Association – the Interregional working group - Network of independent AT counselling centres in Italy - played, since its foundation, a significant role in promoting the use of assistive technology and developing service provisioning models to support the introduction of inclusive practices in educational contexts. To champion the use of AT, the GLIC Association has been instrumental in developing a service provisioning model.

2. The Importance of Inclusive Education in Italy

In 2015, the Italian Ministry of Education issued a circular, an official directive, emphasizing the need for schools to provide reasonable accommodations, including assistive technology, to ensure the full participation of students with disabilities in educational activities. This circular underscored the commitment to inclusive education and set the stage for further initiatives and policies to support its implementation [4].

Since its establishment in 1996, GLIC has played a vital role in promoting inclusive practices in Italy. Comprised of stable non-profit entities, whether public or private, with no commercial interests, these centers have fostered a dynamic environment of technical-scientific discourse and continuous collaboration on shared objectives. Guided by the GLIC Position Paper of 2015 [5], these centres, while accounting for local differences and variations, offer a comprehensive range of common services. These services encompass the provision of information, guidance, support, as well as opportunities for training and research. Equipped with dedicated teams, cutting-edge technologies, and tailored solutions, the centers address a wide array of challenges related to enhancing autonomy in various life contexts.

One of the key strengths of the GLIC network lies in its ability to harness the power of collaboration between centers. By leveraging shared knowledge, expertise, and resources, the network magnifies the impact of assistive technologies on improving the quality of life for individuals with disabilities. The focus now shifts from a phase of technological experimentation to one of empowerment, aiming to ensure the practical and effective utilization of tools and services. The ultimate goal is to empower individuals, granting them greater independence and enabling them to participate fully in society. The GLIC Association's service provisioning model adopts a systematic approach to the provision of AT services in educational contexts. This model involves several essential steps, including a needs assessment to identify individual student requirements, the selection of appropriate AT based on these needs, the implementation of AT within the educational context, and ongoing monitoring and evaluation to assess the effectiveness of AT and make any necessary adjustments.

For this reason, GLIC worked with the Ministry of Education to sign an agreement in 2015 where both parts decided to work at different levels and stakeholders to increase an appropriate introduction and use of the ICT and assistive technology for inclusive environments. With this purpose the Ministry of Education established a permanent committee to oversee and support the activities of the CTS (Centri territoriali di supporto), which are schools providing local AT consultancy and support. GLIC had both the institutional role to support the preparation of guidelines and a local level to actively train school principals, teachers and educators on AT. All monitoring activities, led by INDIRE (the Italian Institute of Research for Innovation of the Italian School System), have shown improvements in the utilization of AT. While preliminary analysis suggests a positive impact on inclusive contexts, further time is required to obtain a comprehensive understanding of the results.

As a significant outcome of this collaboration, under the scientific management of the GLIC Association and the auspices of INDIRE, the pioneering MOOC titled "Gli snodi dell'inclusione" ("The hubs of inclusion") was conceived, developed, and implemented in 2020, despite the strong limitations to activity due to the spread of the COVID pandemic, indeed, to offer practical support [6]. This MOOC, available for free for all registered schoolteachers, provides training on strategies and technology implementation for building inclusive educational environments. It has been made freely accessible to all school staff: principal, administrative, teachers, educators and others. To

2.1. The Ministry of Education "Bando Sussidi" – AT Directive Project

The "Bando Sussidi" project, initiated in 2017, operates on an annual basis with a substantial yearly funding of 10 million euros. Its primary objective is to provide technology to disabled students by directly allocating funds to schools. This funding is granted based on the submission of applications that comprehensively address the individual needs of each student with a disability. Within the framework of this directive, the GLIC Association and the Ministry of Education joined forces to support the Service Provisioning Model. This collaboration was reinforced by a formal agreement between the Italian Ministry of Education and the GLIC Association, with the common goal of fostering inclusive educational contexts in Italy through the integration of ICT and AT.

2.2. Implementing the Service Provisioning Model

The service provisioning model developed by the GLIC Association adopts a systematic approach to the provision of AT services in the educational context. Key stakeholders involved in this model include the Ministry of Education, the CTS Centri territoriali di supporto (Schools for local support in AT), and the GLIC Association along with its 22 centers situated throughout Italy. The model comprises several carefully designed steps to ensure the appropriate introduction and support of AT [7]. These steps encompass:

1. Needs assessment: The initial stage involves the comprehensive assessment of the student's needs through various tools and methodologies, including interviews, observations, and standardized tests where necessary. This process aims to identify the specific requirements of each student accurately.

2. Selection of AT: Building upon the needs assessment, the appropriate AT is selected, taking into consideration factors such as the student's needs, preferences, abilities, the educational context, including teachers ICT competences, and available resources. This step prioritizes the customization of AT solutions to suit individual requirements.

3. Implementation: The selected AT is then implemented within the educational context. This phase includes configuring the AT, providing training to both students and teachers on its effective usage, and making any necessary modifications to the educational environment to optimize accessibility.

4. Monitoring and evaluation: Once the AT has been implemented, continuous monitoring and evaluation are crucial to gauge its effectiveness and impact on the student's learning outcomes. This involves collecting relevant data on the student's performance, conducting surveys or interviews to gather feedback, and making any necessary adjustments to the AT or the educational context based on the findings.

3. Results

Recognizing the importance of the CTS activities, the Ministry of Education has established a permanent committee to oversee and provide support for these initiatives. Through the diligent efforts of the committee, in conjunction with the monitoring activities led by INDIRE, positive improvements in the utilization of AT have been observed. Furthermore, the MOOC has been made freely accessible to all Italian teachers, and to date, it has garnered an impressive attendance of 15,000 teachers who have provided highly positive feedback. The MOOC has proven instrumental in equipping teachers with the knowledge and skills required to effectively utilize AT in supporting students with disabilities and special educational needs. Additionally, the GLIC Association has focused on supporting schools locally during the application process for individual projects, ensuring that the necessary assistance is provided at the grassroots level.Although a preliminary analysis of the impact on inclusive contexts has yielded positive results, it is essential to allow more time to obtain a comprehensive understanding of the long-term outcomes.

4. Conclusion

The experience of the GLIC Association in collaboration with the Ministry of Education underscores the significance of policies and initiatives in supporting the introduction of AT in educational contexts. By implementing the service provisioning model, which ensures systematic support throughout the process, the GLIC Association has made significant strides in promoting inclusive education. This experience serves as a positive example of successful collaboration between government entities, non-profit organizations, and educational institutions, all working towards the common goal of fostering inclusive education in Italy. The collaboration between the GLIC, the Ministry of Education, and various educational institutions underscores the importance of policies and initiatives in facilitating the integration of AT in educational contexts. The service provisioning model developed by the GLIC Association serves as a systematic approach that ensures the appropriate support for AT implementation. This collaborative effort stands as a positive example of how government entities, non-profit organizations, and educational institutions can work together to promote inclusive education.

As odd side, we must report the huge limitation due to political changes: government or Ministry changes imply a reorganisation within the Ministry's leadership often leads to significant changes and, regrettably, a reset of ongoing discussions. This unfortunate consequence brings about a slowdown in progress and occasionally requires restarting with individuals who are unfamiliar with the previous work that has been done.

The next steps and the hope of not undermining all the work done so far lie in the ongoing efforts to consolidate the model at an international level and promote its adoption from a global perspective, as suggested in the Global report on assistive technologies [8].

References:

[1] Il Sistema Educativo Italiano [Internet]. Ministero dell'Istruzione; 2018 [cited 2023 Jul 11]. Available from: https://www.miur.gov.it/web/guest/sistema-educativo-di-istruzione-e-formazione

[2] Legge-quadro per l'assistenza, l'integrazione sociale e i diritti delle persone handicappate 1992/104 (Parlamento Italiano). Available from: https://www.gazzettaufficiale.it/eli/id/1992/02/17/092G0108/sg

[3] Digital Learning and ICT in education. EU Commission; 2020-2022 [cited 2023 Jul 11]. Available from: https://digital-strategy.ec.europa.eu/en/policies/digital-learning

[4] Piano Nazionale Scuola Digitale 2015 (MIUR-Ministero dell'Istruzione dell'Università e della Ricerca). Available from: https://www.miur.gov.it/scuola-digitale

[5] GLIC Position Paper on AT Centres and Service Delivery. 2015 [cited 2023 Jul 11]. Available from: https://www.centriausili.it/download/position-paper-2015-modello-di-centro-ausili

[6] Gli Snodi dell'inclusione. 2020 [cited 2023 Jul 11]. Available from: https://www.indire.it/progetto/gli-snodi-dellinclusione-ripartire-dai-centri-territoriali-di-supporto

[7] Desideri L, Salatino C, Pigini L, Andrich R, Cristofani R, Bravi S, Marchetti G, Martocchi V, Riccio A, Mattia D, Zanfardino F, Brusa F, Magni R, Guerreschi M, Bitelli C, Hoogerwerf EJ. Using a standard procedure to assess assistive technology service delivery outcomes: a proposal from the Italian Network of Independent Assistive Technology Centres. In: Global perspectives on assistive technology: proceedings of the GReAT Consultation 2019; 2019 Aug 22-23; World Health Organization, Geneva, Switzerland. Geneva (Switzerland): World Health Organization; 2020. vol 1, p269-281. Available from: https://apps.who.int/iris/handle/10665/330371. Licence: CC BY-NC-SA 3.0 IGO.

[8] World Health Organization & United Nations Children's Fund (UNICEF). Global report on assistive technology. World Health Organization. 2022. p15, [cited 2023 Jul 11]. Available from: https://apps.who.int/iris/handle/10665/354357. License: CC BY-NC-SA 3.0 IGO.

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Tool for Digital Inclusion in Italian Schools: The Use of Self-Assessment Framework from ENTELIS Project

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Abstract. The use of technology in education has the potential to create more inclusive environments for all students, including those with disabilities. In Italy, the Ministry of Education has recognized the importance of digital literacy in schools and has issued several documents outlining the steps necessary to build a more inclusive educational system. However, in order to achieve these goals, it is important to assess the current situation and identify areas for improvement. The Entelis Self-assessment framework, particularly the Italian short version, can be used as a tool to help schools assess their digital inclusion practices and develop strategies for improvement. In 2015, the Ministry of Education issued the new Law 107/2015, called "La Buona Scuola", which included the New National Plan on School Digital Literacy - PNSD (MIUR, 2015) and the Three-year plan of in-service teachers' education and training. These documents aimed to consolidate the path of innovation and digitization in schools through a strategy that invested in the technological, epistemological, and cultural dimensions. The PNSD focused on the initial and in-service training of teachers, recognizing that educational innovation through digital technologies requires a reformulation of traditional teaching-learning methods to include pedagogical accessibility and inclusion. However, the success of these initiatives depends on the readiness of teachers to implement new technologies in their classrooms. The European Union (EU) identified teacher training as a critical factor for the success of ICT-related educational innovation in 2003. Teachers themselves recognize the need for training, with TALIS results (OEDC, 2014) showing that the need for training related to teaching with information and communication technology (ICT) skills and using new technologies in the workplace was a priority for teachers..

Keywords. Inclusive education, ICT, teachers training

1. Introduction

In 2015, the Ministry of Education issued the new Law 107/2015, called "La Buona Scuola", which included the New National Plan on School Digital Literacy - PNSD [1] and the Three-year plan of in-service teachers' education and training. These documents aimed to consolidate the path of innovation and digitization in schools through a strategy

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that invested in the technological, epistemological, and cultural dimensions. The PNSD focused on the initial and in-service training of teachers, recognizing that educational innovation through digital technologies requires a reformulation of traditional teaching-learning methods to include pedagogical accessibility and inclusion.

However, the success of these initiatives depends on the readiness of teachers to implement new technologies in their classrooms. The European Union (EU) identified teacher training as a critical factor for the success of ICT-related educational innovation in 2003. Teachers themselves recognize the need for training, with TALIS results [2, 3] showing that the need for training related to teaching with information and communication technology (ICT) skills and using new technologies in the workplace was a priority for teachers.

The need for innovative ICT training is also affirmed by the European Commission, within the framework of the Europe 2020 Strategy (2015/C 417/04), recognizing the opportunity to educate and train teachers to support the individual needs of learners, given their increasing heterogeneity and diverse social, cultural, economic, and geographic backgrounds. These challenges had already been embraced by the Italian Ministry of Education (MoE), which, in implementation of Action 4.5 of the Teacher Training Plan, activated training courses for the *"inclusion coordinators"*, teachers that are the reference in their school and manage the coordination activities for the inclusion and integration of students with disabilities, according to the MoE note n. 32839/2016).

It is in this scenario that the Consultancy Center for Assistive Technology, of the GLIC network - the Ausilioteca Mediterranea Onlus in Naples, with long experience on teachers' education and training, has been involved in the training of the aforementioned *inclusion coordinators*. The experience gained in teachers' training brought to implement a monitoring system through self-assessment tools to measure the actual impact on the "digitalization" processes in schools. In other words, it was and still is necessary to evaluate whether the changes inherent in the adoption of new technologies facilitates and fosters the predetermined goals of inclusion and integration [4, 5, 6, 7]. This implies the adoption of tools that support teachers involved in change processes and contribute to the construction of self-assessment reports (SARs) necessary for preparing improvement plans (IPs) and the design of the entire school institution (Education Project and Territorial Education Project).

In this perspective of improvement and teachers' empowerment through self-assessment, we chose the ENTELIS self-assessment framework, emerging as a particularly suitable tool, as it was created to help schools reflecting on the potential they have to support students through the use of ICT and AT [8].

2. Methods

This study aimed to assess the effectiveness of The Entelis Self-assessment framework as a tool to help schools improve their digital inclusion practices.

2.1. Sample

The study involved using the Italian short version of the framework with 44 schools di Neapolitan area in the Campania Region, Italy. The schools were selected based on their level of digital inclusion and willingness to participate in the study. The framework was administered to the school principals, who were asked to complete in collaboration with a team of teachers and administrative staff.

2.2. Methodology

A total of 170 teachers, with the role of *inclusion coordinators,* from the 44 involved schools participated in a training course on topics related to school inclusion, which included a workshop on the use of ICT. In this workshop, a section was dedicated to the use of self-assessment tools, where the ENTELIS framework was presented [9].

Subsequently, time was allocated for shared completion and discussion to understand if the different items were clear. The questionnaire was filled out as a group by teachers belonging to the same school.

The questionnaire has two parts: the self-assessment sheet and the in-depth sheet.

The first part is a self-assessment of the level of implementation and commitment regarding cultural and policy aspects (first section) and practices (second section) in favour of inclusion. It consists of 10 items evaluated on a Likert scale (1 = not started, 2 = getting started, 3 = some progress made, 4 = good progress made, and 5 = good practices in place).

The second part aims to assess the achievement of optimal conditions for the development of digital skills in the educational field through open-ended questions regarding:

- Discovery: what works and what needs improvement.
- Vision: the objectives to be achieved.
- Design: the actions to be taken to achieve the objectives and the people involved.
- Implementation: the necessary resources and the identification of individuals who should manage the activities. For each of the 7 questions in the second part of the questionnaire, participants were asked to provide three responses.

3. Results

In the key descriptors that make-up the first section, it emerges that all schools have implemented cultures and policies in favour of digital inclusion. As shown in the graph below, all schools have developed an inclusive culture and policies, reaching high levels (over 72% in all cases) of good progress made.

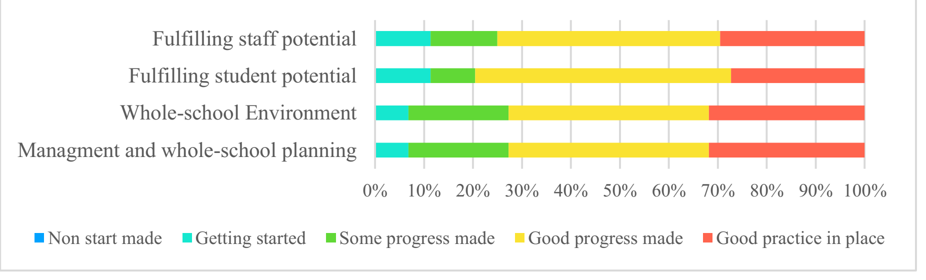

Figure 1: Section 1 Cultures and Policies

In Section 2, regarding practices, the results are not as homogeneous as in the Section 1. As in the figure below, the situation is still very positive about teaching and learning strategies, Individualized Education Programs (IEPs), and instructional design, with an average of 94% of practices being implemented. However, in terms of classroom management and teaching personalisation, there are ongoing progress but with lower percentages, around 60%. As expected, the integration of ICT and AT in instructional design and its subsequent use in teaching practice is the lowest value, with less than 50% of schools having activated the process.

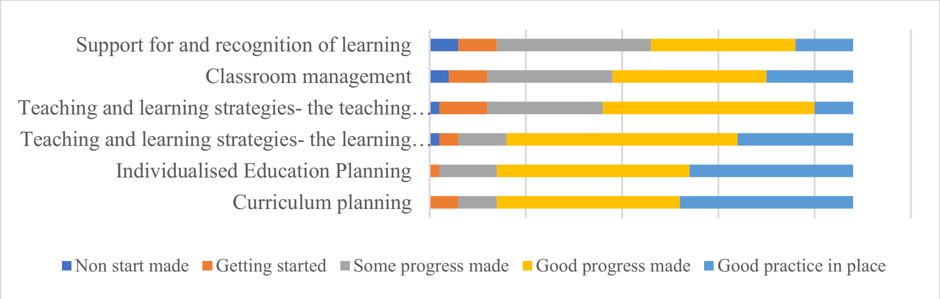

Figure 2. Section 2 Practices

The results related to the second part of the questionnaire (in-depth sheet), where respondents were given the opportunity to freely indicate three possible options for each question, are as follows.

- Discovery
  - What works well? The best-performing aspects are technological infrastructure (18%), electronic register (13%), use of ICT for learning purposes (11%), school website (11%), individualized and personalized design (9%), organization of teaching activities (9%), teachers' commitment (6%), use of ICT to facilitate communication with families (6%), inclusion processes (6%), coordination among teachers (5%), teacher training (4%), promotion of innovative practices (1%), and inclusion of digital skills in the curriculum (1%).
  - What needs to be improved? Areas that need improvement include technological infrastructure (33%), teacher training (16%), cooperation and communication among teachers (12%), increased use of ICT in teaching (9%), BYOD (6%), use of ICT to communicate with families (6%), inclusive teaching (6%), digitalization of documents (4%), use of ICT for students with special educational needs (2%), teacher motivation (3%), use of compensatory tools (1%), and integration of digital skills into the curriculum (1%).
- Vision
  - The school's goals primarily focus on improving the following areas: inclusive and quality teaching with the use of ICT (27%), teacher training (25%), inclusion of digital skills in the curriculum for all students (12%), technological infrastructure (11%), adopting an inclusive approach (10%), collaboration and coordination within the educational community (5%), and teacher motivation (5%).
- Design:
  - What actions are needed to achieve these goals? The predominant response is teacher training (31%), followed by increasing the use of ICT in teaching (15%),

  strengthening technological infrastructure (13%), and improving coordination among members of the educational community (8%).
  - Who should be involved? Primarily teachers (27%), families (16%), specialized entities and personnel (15%), students (11%), and the school principal (7%).
- Implementation:
  - Required resources: They are divided between human resources, primarily qualified and experienced teachers capable of providing training (31.7%), and material resources, particularly computer infrastructure (37.8%) and financial resources (9.8%).
  - Responsible parties for implementation: Mainly internal figures within the school, as specified below: teaching teams (25%), specialized teachers (19.4%), digital facilitator (13.9%), school principal (11.1%), and management staff (11.1%).

The results related to the second part of the questionnaire (in-depth sheet), where respondents were given the opportunity to freely indicate three possible options for each question, are as follows:

- Discovery:
  - What works well?
    What works best are technological infrastructure (18%), the electronic register (13%), the use of ICT for learning purposes (11%), the school website (11%), individualized and personalized design (9%), organization of teaching activities (9%), teachers' commitment (6%), the use of ICT to facilitate communication with families (6%), inclusion processes (6%), coordination among teachers (5%), teacher training (4%), promoting innovative practices (1%), and integrating digital skills into the curriculum (1%).
  - What need to be improved?
    Improvements are needed in technological infrastructure (33%), teacher training (16%), cooperation and communication among teachers (12%), increasing the use of ICT in teaching (9%), BYOD (6%), using ICT to communicate with families (6%), inclusive teaching (6%), digitalization of documents (4%), use of ICT for students with special educational needs (2%), teacher motivation (3%), use of compensatory tools (1%), and integration of digital skills into the curriculum (1%).
- Vision: The objectives that the school sets primarily focus on improving the following areas: inclusive and quality teaching using ICT (27%), teacher training (25%), integrating digital skills into the curriculum for all students (12%), technological infrastructure (11%), adopting an inclusive approach (10%), collaboration and coordination within the educational community (5%), and teacher motivation (5%).
- Design:
  - What actions are needed to realize these goals?
    The predominant response is teacher training (31%), followed by increasing the use of ICT in teaching (15%), strengthening technological infrastructure (13%), and improving coordination among members of the educational community (8%).
  - Who should be involved?
    Primarily: teachers (27%), families (16%), organizations and specialized personnel (15%), students (11%), and the school principal (7%).

- Implementation:
  - Necessary resources:
    They are divided between human resources, primarily qualified and expert teachers capable of providing training (31.7%), and material resources, particularly computer infrastructure (37.8%) and financial resources (9.8%).
  - Those responsible for implementation:
    Primarily internal figures within the school, as specified below: teacher teams (25%), specialized teachers (19.4%), digital animator (13.9%), school principal (11.1%), and management staff (11.1%).

4. Discussion / Conclusion

The framework, included in a training path, has proven to be a valuable tool for initiating or consolidating, depending on the case, the dialogue among teachers working in the same school but with different roles. The discussion led to the completion of all the questionnaires, although there were moments of difficulty in working as a team and reaching shared answers. Depending on the role within the school, there was not always a unanimous opinion, especially regarding the second part of the questionnaire.

One critical aspect of this study is that a longitudinal follow-up over time could not be conducted to see if the framework was reused and shared with other colleagues. As a continuation of this investigation, there is a willingness to contact some of the schools that participated in the training to delve deeper into their use of the framework and to expand the research in order to understand if this tool can be a valuable long-term aid, not only within a training program where the presence of external teachers guides the understanding and use of the questionnaire as a means of reflection, growth, and professional development.

References

[1] MIUR. Piano Nazionale Scuola Digitale [Internet] 2015. Available from: http://www.istruzione.it/scuola_digitale/allegati/Materiali/pnsd-layout-30.10-WEB.pdf
[2] OECD [Internet] 2015. Talis 2013 Results: An International Perspective on Teaching and Learning, OECD Publishing. Available from: http://dx.doi.org/10.1787/9789264196261-en
[3] OECD [Internet]2019. Results from TALIS 2018 Italia. Available from: https://www.oecd.org/education/talis/TALIS2018_CN_ITA_it.pdf
[4] Calvani A. La competenza digitale: un modello di riferimento per la scuola. In: Calvani A, Fini A, Ranieri M, La competenza digitale nella scuola. Modelli e strumenti per valutarla e svilupparla. Trento: Erickson. 2010 p. 35-63.
[5] Calvani A. L'innovazione tecnologica nella scuola: come perseguire un'innovazione tecnologica sostenibile ed efficace. LEA – Lingue e letterature d'Oriente e d'Occidente. 2013 p. 567- 584. Available from: https://oajournals.fupress.net/index.php/bsfm-lea/article/view/7611/7609 DOI: http://dx.doi.org/10.13128/LEA-1824-484x-14592.
[6] Pagliara SM. Il significato e il senso della tecnologia nella scuola. In: de Anna L, Gaspari P, Mura A. L'insegnante specializzato. Itinerari di formazione per la professione. Milano: Franco Angeli. 2015 p. 151-161.
[7] Pagliara SM. Use of Different Media and Technologies in the Inclusive Educational Didactis. In: de Anna L, Teaching accessibility and inclusion. Roma: Carocci. 2016. p. 71-83.
[8] Hoogerwerf EJ, Mavrou K, Traina I. The Role of Assistive Technology in Fostering Inclusive Education. Strategies and tools to support change. New York: Routledge. 2022.
[9] ENTELIS. [Internet] 2015. Project Framework, training materials. Available from: https://entelisplus.entelis.net/training-materials/

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MSc Educational Assistive Technology: Training an Emergent Professional Group

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Abstract. The MSc Educational Assistive Technology (EduAT), is a recently established course, having welcomed the first cohort in January 2021, this group have recently completed their studies. At time of writing (summer 2023) the course is actively recruiting it's fourth cohort who are due to commence in January 2024. The course is now an established part of the AT training offer as the curriculum has been developed and delivered. This paper supports the presentation prepared for AAATE 2023. The EduAT approach uses the ESCO definition of the Assistive Technologist role, which is briefly summarised. The paper continues with how and why MSc EduAT was developed and explores how this MSc fits into a wider AT training ecosystem, noting roles that EduAT has been designed to support. An overview of the curriculum developed to train assistive technologists is included alongside a summary of what has been learned since the course began. The paper concludes by briefly summarising AT and AAC research group plans that have been informed by the experience of developing and delivering the MSc EduAT, and through the contributions students have made to the authors wider understanding of the assistive technology landscape in the UK and beyond.

Keywords. Assistive Technology, Assistive Technologist, Educational Assistive Technologist, EduAT, Education

1. Developing MSc Educational Assistive Technology

The name 'Educational Assistive Technology' was chosen to differentiate the MSc EduAT [1] from AT courses for rehabilitation engineers and clinical scientists, which have established professional routes available. The name also emphasises the educational context of the role, which includes an important 'train the trainer' aspect. Not all MSc EduAT students are employed in education contexts such as schools, colleges and universities, with some being drawn from health, social care, third sector or charity organisations and private AT or therapy-based practice. A common element however is that lifelong learning is an important aspect of the role, with support being provided by the Educational Assistive Technologist to the users of AT as well as the staff group who support the users of assistive technology. In late 2020 the first author established the EduAT competency framework (CF), based on work done to define the Assistive Technologist role in the ESCO database [2]. The first author collaborated with Natspec

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TechAbility [3] colleagues to support the creation of the ESCO 'Assistive Technologist' definition:

> "Assistive technologists work to improve access to learning or/and improving independence and participation for individuals with disabilities. They do this through learner support and staff support with activities such as assessments, training and guidance. Assistive technologists have a good understanding of learners' needs and a wide technology knowledge relevant to learning, living or work context. The role requires knowledge of assistive technology hardware and software such as text to speech, prediction, dictation, vision and physical access tools" [2].

Whilst this definition does not have the power to make the 'Assistive Technologist' a protected title, it is useful to point to this definition, clarifying what the role and by association the MSc EduAT is, and what it is not. The Assistive Technologist role is transdisciplinary, with knowledge, skills and experience drawn from education or teaching, health or therapy and technology-based roles. The Assistive Technologist role has previously been explored by the first author [4]. The EduAT CF is a superset of the ESCO definition of the role. The AT specific elements in the EduAT CF map to the TechAbility Standards [5], as the standards are widely known and used in the UK this supported understanding and acceptance in the target audience for the MSc EduAT. The ESCO definition maps across to a range of skills and knowledge present in health, education and technology-based roles.

The Dart (Disseminating Assistive Roles and Technology) Project [6] was funded by LSIS (learning and skills improvement service) and Jisc 2010-2015. The project sought to replicate the Assistive Technologist role from the specialist colleges that ran the Dart Project to the specialist and mainstream further education colleges that took part. This was achieved through offering consultancy as well as through running an AT workshop series. Due to the lack of a formal route into the Assistive Technologist role and to support the wider activities of the project, a curriculum was developed to train assistive technologists, this effort has been previously described the by the first author [7]. The research undertaken within the Dart Projects established that those organisations that had a dedicated AT role were ahead of other organisations in terms of developing their wider AT maturity than those organisations which had not established such a role [6]. Much of the consultancy activity focussed on recruitment support for the Assistive Technologist role. It was difficult for organisations to recruit experienced individuals to Assistive Technologist roles. This further necessitated the development of the Dart Curriculum which identified existing academic and commercial training opportunities and offered a set of workshops targeted at gaps in AT training availability.

The Dart curriculum inspired the approach taken in MSc EduAT and has been expanded upon considerably. In early 2019 a group of interested parties gathered at UoD to consider the core module scope and structure. By the end of 2019, the first author had drafted the core modules and the programme specification, this effectively defined the MSc EduAT curriculum. During 2020 the modules and the programme specification were scrutinised internally and approved mid-2020.

The programme team are fortunate to have support from colleagues interested in AT from across the education sector and academia who formed the MSc EduAT advisory group, this group functions as 'critical friends' to the programme team. The purpose of this group is to review the curriculum to ensure it supports the requirements of students and the organisations they work for. As the members of this group include individuals who work in or with organisations that typically employ MSc EduAT students there is a direct link to this important group of stakeholders. The group also includes disabled expert users of assistive technology, this ensures that the programme team uphold the commitment made in the groups terms of reference to foster co-production through user led experiences (for example through the input of the Universities User Centre [8] participants), with the views of disabled people clearly used to shape the programme content and methods of curriculum delivery.

2. A wider AT training ecosystem

It is important to note that the MSc EduAT is part of a wider ecosystem of AT training and development opportunities. A range of training is required at multiple levels, for people in different roles, and at different stages of their careers. This includes advanced courses such as the MSc EduAT, for those wishing to become AT specialists. Higher level courses for existing professionals (including teachers, speech and language therapists, occupational therapists and various technical roles) are needed for a range of colleagues already working to support users of AT. There are a range of reasons as to why such professionals do not have the need, nor the time, to complete an MSc. It may be that a specific development opportunity has been identified, and this can be met by a shorter course. To meet the needs of professionals' CPD, the EduAT team are developing some of the MSc EduAT modules so that they can be offered as short courses. In addition a partnership has been established between Ace Centre Learning and the UoD to deliver accredited masters modules from Ace Centre starting from April 2023. This arrangement includes options for students to exit with a 60-credit PGCert (Post Graduate Certificate) in Specialist Assistive Technology [9].

A very much larger number of CPD (continuing professional development) entry level training opportunities are required for teaching assistants, teachers, therapists, parents, social care staff, and anyone else working to support AT users. All teaching, learning and care support staff should have some AT knowledge. To support this, Ace Centre, Natspec TechAbility and the University of Dundee (UoD) have partnered to produce a CPD course: Understanding the Benefits of Assistive Technology [10]. This is a short, free online course, providing a basic introduction for all staff to what AT can achieve and which learners will benefit from AT.

3. The MSc EduAT Curriculum

The MSc EduAT has six core modules totalling 100 credits, these modules build knowledge sequentially and are taught in a specific order. Students choose 40 elective credits and complete a 40-credit project dissertation, totalling the 180 credits required for an MSc award. The first core module, the Educational Assistive Technologist establishes the modular nature of the role, including how it can change for different contexts. This is supported through sharing various assistive technologist role and person specifications from a range of contexts. This enables concepts such as multi-disciplinary, inter-disciplinary and trans-disciplinary working to be considered. Models of inter-professional collaboration such as the community of practice are introduced, and linked to assistive technology assessment, provisioning and ongoing support. The wider research, policy, legislative and regulatory context is explored along with background information drawn from disability studies, curriculum development and educational theory. This establishes the EduAT method, a person-centred approach that puts user priorities first, involves users of assistive technology to the maximum expect possible and ensures that professional standards are maintained. A guided tutorial includes a supportive gap analysis using the EduAT Competency Framework (EduAT CF), this identifies learning opportunities that specific elective modules can address.

The second module, Introduction to AT systems and the third module, Mainstream and Specialist AT includes AT software, access hardware and the approaches needed to make best use of these technologies. Examples range from assistive technology from software to support people with a specific learning difficulty through to the most complex physical access systems and AAC (augmentative alternative communication) systems. To cover the full range of AT guest speakers are invited, comprising expert users of assistive technology, experts working in a range of AT services, developers of AT products or services and academics from other higher education organisations. This benefits students as they hear a wider range of views, have current material included and can ask questions of colleagues who have a broader range of expertise than the programme team alone could provide.

Assessment for AT provides students with the theoretical basis for AT assessment. AT assessment frameworks such as SETT and HAAT, as well as specific implementations of such frameworks are examined. This supports students to identify suitable assessment models for their working contexts. This can include considering templates, proformas or processes that are needed to undertake a high quality, person centred, needs based assessment. A range of examples of AT assessments, inclusive of AAC assessments, DSA (disabled students allowance) needs assessment and EAT (electronic assistive technology) assessment are presented by invited experts. These guest seminars explore specific AT assessment contexts. This includes referral routes and eligibility criteria, which is directly relevant to the working contexts of students.

The fifth core module, AT in Educational Programmes provides students with the tools to embed AT within taught programmes. Various AT or therapy outcome measures are considered to support evidence of progression, alongside education approaches such as RARPA (recognising and recording progress in non-accredited learning). Curriculum levels in the UK context are included, with examples of curricula from a range of organisations discussed. Professional standards drawn from teaching and the allied health professions are related to the Assistive Technologist role.

The final core module AT Partner Relationships covers the professional context of the AT role and potential professionalisation routes for the Assistive Technologist profession. The module includes making appropriate referrals into other parts of the education, health and social care systems in the UK. Further details of the core modules may be found on the MSc EduAT website [1].

The computing led elective modules include Assistive Technology Interaction (ATI), a reimaging of HCI (Human Computer Interaction) with AT specific examples. ATI provides opportunities for students to understand interface design and other usability and accessibility concepts. Work Based Skills and Innovative Practice provides opportunities for students to agree a specific learning contract with module tutors, this could be designed to address a specific learning opportunity such as writing up a work placement, it could also include conducting a literature review or developing a specific research skill. The flexibility of this module is it's strength as it provides academic support to students to develop a skill or knowledge area that has been identified as a learning opportunity. It is possible for both ATI and Work Based Skills and Innovative Practice to be used to develop research skills ahead of their application to the dissertation project. Students may also select from education led modules, The Inclusive Educator and Innovation in Education. Health led modules are also offered. The inclusion of modules from Education and Health further broadens student learning opportunities.

The 40-credit dissertation project is smaller than in other MSc programmes, to allow for a broader range of electives to be chosen. Students are encouraged to select a dissertation project that aligns with development requirements in their employing organisation, or placement context in the case of full-time students.

4. MSc EduAT students and course delivery

The course is 'blended', with the majority of delivery undertaken online as students are dispersed. Most students are employed full-time in organisations that support the use of AT, and students therefore undertake MSc EduAT coursework in their workplace. All assessment is coursework based and is designed so students may utilise work they are conducting within their employment as a basis for academic work, making assessment relevant and achievable. Further accommodations are made to support those who are working full time, such as scheduling synchronous online sessions outside of the core teaching day, due to many of the students working in educational contexts and teaching beyond the standard University teaching weeks to ensure that core module synchronous delivery is confined to a single afternoon per week.

One on-campus teaching and conference week is undertaken per year of part-time study, this includes delivery from the programme team, input from students, and invited expert guests. Second year's present their initial dissertation project ideas, so that peers, the programme team and invited members of the UoD User Centre [8] groups may provide useful feedback to the students whilst they are still at an early stage of developing their work. The involvement of expert users of AT ensures projects are informed by disabled peoples experiences. The on-campus week includes an exhibition from AT suppliers and developers, to which interested parties from the university and the region are invited. This adds to the breadth of experiences that we can offer to students. Social and collaboration opportunities are provided to ensure that students can get to know each other to support cooperation and groupwork and to encourage enjoyment of the on-campus experience.

Entry requirements are as flexible as possible to support a diverse range of students to join. Where students do not have a relevant first degree the programme team request evidence of AT experience gained from working in a suitable context. Students are drawn from a range of professions, this includes teachers, teaching assistants, therapists, therapy assistants or technicians and technologists from a variety of backgrounds. Most students have prior AT experience and are employed in a suitable AT environment, inclusive of education, social care or third sector organisations. This has meant that the part time route has been the most popular mode of delivery. Where a student is not employed in a suitable context, work placements may be identified, this is especially relevant to students who wish to undertake the course full time over the course of a single year.

Students are employed in a range of different organisations inclusive of membership bodies, specialist and mainstream schools and colleges, charities, third sector and care organisations, higher education, private AT or AAC practice and therapy services, local authority advisory teachers and electronic AT specialists, and NHS or healthcare services. The first cohort included people working in AT mature organisations, this is to be expected as some aimed to develop their skills, address learning opportunities and validate existing skills and knowledge. The second and third cohorts are drawn from a diverse range of organisations. Overseas students have been made offers for 2024 entry and the EduAT team are developing AT placement opportunities to support this route.

5. What have we learned?

Some students are fully supported by their organisations; they have leadership buy-in and ownership of AT as a core part of their offer. This leads to improved AT training and development and active engagement in improving the wider AT service. Engagement is not always straightforward as there is huge variance in organisations AT maturity and very different expectations are made of the AT role. Where leaders or organisational commitment to AT is less well-defined students can find it difficult to embed the EduAT curriculum. In practical terms this can mean that there is variable budget support, the ability to buy assessment equipment is constrained and limited budget is available to support additional staff as the AT service scales. The EduAT programme team have seen occasional concerns with other professionals or groups around accepting the need for a 'professionalised AT role' in the unfounded belief that this may encroach on existing roles. More experienced students are undertaking MSc EduAT where they wish to fill gaps in knowledge and skills, or where they wanted to validate existing skills and knowledge and to update their own skills. Some students chose MSc EduAT where they wished to improve recognition for a professional AT role within their own organisation.

For those starting out with AT, MSc EduAT can provide knowledge skills and understanding to undertake assessment, provisioning and ongoing support of AT in a range of organisations. This point also supports organisations that wish to establish AT services, and due to difficulties inherent in the recruitment of AT professionals, some leaders may identify an existing member of staff who they wish to train up to become an Educational Assistive Technologist. This approach does have benefits such as the individual having a good understanding of the organisation and the supported AT users. There is now a 'formal' route into AT training for those who wish to train as an Assistive Technologist, this means students can develop as an Assistive Technologist or embed AT skills into other roles such as teacher, technologist or allied health professional.

The EduAT team have seen a wide range of examples of how AT is implemented, in some organisations the EduAT student may be the only person who is working to support AT, in others they are part of a wider AT team. There is variation in where AT is located in organisational structures, sometimes within education teams, therapy services, IT or within a dedicated AT or a broader technology team. The development of strong links between IT and AT colleagues is seen as vital for the development of high-quality AT services, due to the underpinning nature of IT services. If IT services are not responsive to the requirements of AT, then it is likely that AT services will be highly constrained. This point is explored within the EduAT curriculum.

The EduAT team have supported students and their leadership teams to embed the AT role. A useful feature of the course has been peer review and development through active learning within the student body. The programme team plan to encourage alumni to remain engaged within this community upon graduation.

6. Research priorities

The AAC and AT Research Group at the UoD has a long history of innovative user centred computing research [11]. The group are working to 'productise' previous research to ensure that the outputs are useful to people who may benefit. For example, ACE-LP [12] a novel word, sentence and phrase predication method also uses AI (artificial intelligence) and ML (machine learning) scene analysis continues to be developed. The projects identified below are intended to address some of the challenges that have become evident during the development and delivery of MSc EduAT, they are also informed by the collective experience of the programme team and students.

6.1. SROI project: Modelling the impact of the AT role

Evidencing the impact of dedicated AT roles (such as the Educational Assistive Technologist), by investigating the social return on investment gained by society, AT providing or supporting organisations and critically the people who these organisations support to use AT. This project can be summarised as an interdisciplinary social return on investment project, aiming to inform evidence-based policy making. This project can consider quantitative data such as outcomes, destinations, achievement rates and where possible exam or course pass rates. In addition there is value in specific stories or case studies as they can bring a richness to the lived experience of individuals, it is acknowledged that it will be important not to represent these stories as data. Undertaking a medium to long term project looking at the impact of the Assistive Technologist role on organisations will investigate how changes are sustained, and subsequent policy proposals can be evidenced appropriately. It is thought to be helpful to clearly evidence the impact of AT roles, as it will be difficult to validate further investment in training, ringfenced funding for organisations to resource AT posts and for support around the creation of a national AT support organisation. The latter could underpin all related activity and link what is happening 'on the ground' to inform decision makers.

6.2. AT assessment tool development

The project proposes the building of a web-based AT Assessment software tool to support suitably qualified and experienced staff to undertake high quality needs-based assessment. It is not intended to replace people with AT skills, rather to support them. The aim is for the same tool to be useful for assessments undertaken at multiple educational stages, levels, ages, transition points, and for it to output useful reporting and guidance materials (e.g. AT or AAC passports), training and support materials for staff members who will be setting up or preparing AT equipment or software for the AT user.

6.3. AT training framework and discovery tool

Improving the discoverability of AT resources and training through the design of an AT training framework that identifies what training is needed by people in a range of roles, in different organisational contexts and at different stages of their AT journey. This is a relatively small-scale project centred on the proposal to develop of a web-based discovery tool that catalogues AT training and resources offered from within education contexts, health and social care contexts and commercially available training. The discovery tool would require the development of system logic to ensure that useful courses and resources were presented to people who are working in various roles in different types of organisations and at various stages of their AT learning journey. To that end it is proposed that the research team would work with colleagues to develop a broad AT framework, possibly based on the AAC specific IPAACKS (NHS Education for Scotland, 2014) tool, which should permission be granted to create a child work would require both reworking to be more broadly applicable as well as the inclusion of an additional level 0 'awareness raising' level below the Level 1 in the current framework. The process by which existing courses are identified and catalogued with metadata to enable them to be selected by the web-based tool's system logic would also enable gaps to be identified, enabling future AT training course development to be targeted.

References

[1] University of Dundee. Educational Assistive Technology [Internet]. University of Dundee; 2022 [cited 2023 May 30]. Available from: https://www.dundee.ac.uk/postgraduate/educational-assistive-technology-part-time

[2] Esco [Internet]. Assistive Technologist. 2022 [cited 2023 May 30]. Available from: https://esco.ec.europa.eu/en/classification/occupation?uri=http://data.europa.eu/esco/occupation/4e82464b-e9d7-4d51-9116-294ab40c5169

[3] Natspec. Natspec TechAbility [Internet]. TechAbility; 2023 [cited 2023 May 30]. Available from: https://www.techability.org.uk/

[4] Slaughter R. Connect to Control: How we can do the 'bells and whistles'. Communication Matters Journal. 2014;28(1):11–4.

[5] Natspec. TechAbility Standards [Internet]. TechAbility; 2023 [cited 2023 May 30]. Available from: https://www.techability.org.uk/techability-standards/

[6] Maudslay L. Assistive technology in further education organisations 2014-15 [Internet]. 2015 [cited 2023 May 30]. Available from: https://repository.jisc.ac.uk/6243/1/NATSPEC-report-Oct15.pdf

[7] Slaughter R, Mobbs T. The DART Project: Improving Assistive Technology Provision in Further Education. Communication Matters Journal. 2015;29(2):24–6.

[8] Dundee AAC Group. User Centre [Internet]. 2023 [cited 2023 May 30]. Available from: https://aac.dundee.ac.uk/user-centre/

[9] Ace Centre. Assistive Technology for Complex Communication, Physical & Learning Needs [Internet]. Ace Centre; 2023 [cited 2023 May 30]. Available from: https://acecentre.org.uk/

[10] Ace Centre. Understanding The Benefits of AT [Internet]. Ace Centre; 2022 [cited 2023 May 30]. Available from: https://acecentre.org.uk/

[11] Waller A. Telling tales: unlocking the potential of AAC technologies: Telling tales: unlocking the potential of AAC technologies. International Journal of Language & Communication Disorders. 2019 Mar;54(2):159–69.

[12] AAC Research Group. ACE-LP: Augmenting Communication using Environmental Data to drive Language Prediction | Dundee AAC Group [Internet]. 2023 [cited 2023 May 30]. Available from: https://aac.dundee.ac.uk/ace-lp/

Culture

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Assistive Technology: Shaping a Sustainable and Inclusive World
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Inclusion for Cultural Education in Museums, Audio and Touch Interaction

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Abstract. Inclusive access to culture for all people in institutions, such as museums, is an important issue specified in French laws and is also recognized internationally. This article investigates inclusion of blind and partially blind visitors in museums. The pilot study conducted involves blind, partially blind, and sighted people and observes their perception of audio descriptions and different tactile representations within a museum. 12 participants were asked to experience three different conditions for 3 scenes of the Bayeux Tapestry using inclusive and co-created audio descriptions, simplified swell paper representations, and high relief representations. Overall, a high level of interest was found across all conditions, with multimodality through audio and tactile stimulus found to have enriched participants' experience. However, more guided tactile exploration would be better. From participants' feedback, some observations have emerged which could be explored for the development of new technologies to better respond to museum visitors' expectations.

Keywords. Blind, partially blind, inclusion, cultural education, multisensory, museums

1. Introduction

At the international level, access to culture is a right for all persons, with or without a disability. This is recognized by the United Nations Convention on the Rights of Persons with Disabilities in 2006 and signed by France in 2007 (article 30) [1]. This implies very concrete measures. Thus, the first paragraph of that article stipulates that the signatory parties to the Convention "shall take all appropriate measures to ensure that persons with disabilities enjoy access to cultural materials in accessible formats". Museums are prime locations for cultural life and learning. In France, the 2001 decree established the National Commission on Culture and Disability, whose "mission is to facilitate access to culture for persons with disabilities, whatever the nature of the disability, with a view to enabling them to participate fully in cultural life" (art. 1).

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In addition, the 2006 law "on freedom of creation, architecture and heritage", stipulates, in its article 3, that the State must "support a policy of accessibility of artworks for the public with disabilities and promote professional, associative and independent initiatives aimed at making culture and arts accessible for people with disabilities (...)". The "Inclusive Museum Guide" project, focusing on two-dimensional works of art (primarily paintings, embroidery and wall-hangings) and access to such works for blind and partially blind (BPB) people, is part of this legislative framework. Thus, for our team, and in accordance with international and national law, making works of art accessible is a necessity of the states and institutions concerned, a necessity that we help to achieve by working in collaboration with several museums [2].

In our previous publications [3,4], we have pointed out that despite the efforts, often crowned with success, made in this direction by many French museums [5,6] the major survey of the Direction of Museums of France in 1992 had shown their very low rate of accessibility [7,8]. The right to cultural participation through the accessibility of works of art is still far from being realized for people with disabilities, especially for blind and partially blind people, because of the persistent prioritization of sight over the other senses, but also, more broadly, of the "taboo and intolerance towards disability that persists in France" [9]. According to several blind and partially blind people interviewed on this subject, [10] "we are left with only crumbs": most of the works remain inaccessible to them, and the few devices put in place consist mainly of guided tours or specific workshops. Although they are often acclaimed by the people concerned [11], they do not offer to BPB autonomous access to the museum and, above all, help to keep BPB apart from other members of society.

In the 1990s, such visits and workshops were the only accessibility devices envisaged by the Directorate of Museums of France (1992) [12]. These measures are still the ones that are first mentioned in the "Charter for the reception of disabled persons in cultural facilities", published in 2007 by the National Commission "Culture-Disability": “In the context of specific visits, multisensory manipulations, fun and educational devices, tours in the museum and/or workshop are all new approaches that make visitors actors” - Even though this charter stated a little earlier, that “it is not a question of creating a ghetto around disabled people” (p.42). This Charter nevertheless has the merit of also mentioning devices that not only allow access to works of art in complete autonomy, but are still inclusive. First of all, the audio guide: just like people who see, "Blind or visually impaired people appreciate it, if it is descriptive enough. It must be easy to use and always associated with signage and lighting (an audio guide is useless if the identification of the work described is unreadable) (p.49). Then, tactile reproductions: "Tactile models and images must meet the criteria of tactile and visual readability. Their use allows a better representation – partial or global – of the volumes of a building, a work, an object, certain details" (p. 50). However, the Charter does not mention the importance of associating audio with touch for it to make sense [2].

We propose that a multisensory inclusive museum approach can make museums accessible to all, create in any visitor, BPB or sighted people (SP), new aesthetic impressions while experiencing multimodal representations of 2D artworks, deepen and enrich experience of 2D artworks and enhance memorability of the observed elements of art. These impressions can be shared with others, irrespective of visual experience.

A haptic tablet, F2T, was developed to induce the perception of a shape through force feedback applied through a joystick and audio feedback accompanying the exploration [14]. To articulate perceptions of audio with touch and to prepare for future tests with F2T, we did some preliminary pilot evaluations of different test conditions in a museum to get feedback from an inclusive audience. The purpose of this exploratory evaluation is to find out how blind or partially blind people and the sighted public perceive the same audio descriptions and tactile representations in a museum atmosphere; what can we learn about the responses to different types of multisensory interpretation, within a museum environment.

2. Evaluation

This qualitative study focuses on the combination of audio (audio description) and tactile (relief representations) stimuli applied to the Bayeux Tapestry [15]. The museum has 3 high-relief scenes made by the partially blind artist Rémi Closset with the support of the Valentin Haüy Association. The same scenes were made in a simplified way, in swell paper at the Centre Normandie Lorraine (see Fig.1) following the rules of tactile representations [16].

The research questions considered in this evaluation are: 1) How the combined use of audio description and tactile supports affects the experience of the Bayeux Tapestry. 2) How can technology be developed to facilitate access to visual art for all (inclusiveness).

The evaluation involved 12 participants recruited on a voluntary basis, 7 of them were blind or partially blind (BPB) and 5 were sighted people. In the BPB group there were 5 men and 2 women; in the sighted group (SP) there were 2 men and 3 women. There were 5 people who use Braille and half of the participants had already visited the Bayeux Tapestry Museum in the past. The average age of the participants is of 51.42 ± 16.64 years old. The details of the BPB and SP groups are shown in Table 1.

Table 1. Age distribution (years old) between groups of participants.

Visual perception	Min.	Max.	Average	SD	Number
Blind and partially blind people	24.00	71.00	51.29	17.42	7
Sighted people	29.00	69.00	51.60	13.59	5

The evaluations took place under 3 conditions:

- Condition A: Playback of audio description (V1) in front of the tapestry, no tactile support.
- Condition B: Playback of audio description (V2), with swell paper diagrams support
- Condition C: Playback of audio description (V1) with high relief support.

In this project, the audio descriptions of the Tapestry (V1 and V2) are Inclusive Co-created Audio Descriptions (ICAD) - co-created by groups of blind, partially-blind and sighted people [2]. The ICAD is composed of two descriptions: a brief description and a detailed description. The specificity of the brief description is that the scene is described from the point of view of a partially blind person.

The detailed description is co-created with the questions asked by BPB persons and answered by sighted persons (SP). This collective work is echoing that of the embroiderers. The detailed descriptions follow the direction of the narrative, from left to right. An example of ICAD is given in [17].

Two versions of the ICAD were created. In version 1 (V1) the ICAD only includes description of the artworks. Version 2 (V2), was based on V1 but incorporates guided touch of the swell paper supports used in condition B. These swell paper supports, focus on key elements of the scene in the tapestry. The representation of these elements is simplified to represent objects discernible with fingers with "comfort" spaces that separate the elements [17]. For condition B, version 2 of the ICAD described the scene more broadly, but also incorporated guidance for the tactile experience, and description of that tactile experience.

In condition C, the high relief details the entire scene. Version 1 of the ICAD was used in Condition A and Condition C, with no tactile description.

After each condition, participants completed a questionnaire, which included fixed-response questions using a 5-point Likert scale (including enjoyment, interest), and free text responses which provided participants with the opportunity to elaborate on their experiences. Given the size of the sample, no inference tests were run on the numerical data, and so any reported differences are only suggestive.

Figure 1. Three scenes from the Bayeux Tapestry (scenes 23, 39, 55) on the left column, relief representations (middle column) and swell paper representations (right column) of the same scenes.

3. Results

Results indicated that the audio description alone (condition 1) was found interesting, allowing focus on the scene presented in front of the participants. On the Likert scale with a rating out of 5 (1=not at all, 2=a bit, 3=neutral, 4=fairly, 5=a lot) presented in the table 2, participants showed high satisfaction with all conditions. Very small differences were observed, with all conditions (median= 5/5) with a lower minimum value for conditions A and C (range = [2,5]), whereas condition B has a smaller range ([4,5]).

Table 2. Likert scale statements results for conditions A, B and C.

Conditions	**A Median [min,max]**	**B Median [min,max]**	**C Median [min,max]**
How enjoyable was the experience?	5 [2,5]	5 [4,5]	5 [2,5]
How interesting was the experience?	5 [4,5]	5 [4,5]	5 [2,5]
How understandable was the tactile experience?	5 [2,5]	5 [2,5]	4 [2,5]
Has the experience enriched your feelings about the Bayeux Tapestry?	-	5 [2,5]	5 [3,5]
Are you satisfied with the amount of information provided by the scene?	-	5 [3,5]	4 [2,5]

Exploring participants' level of interest, again, scores are all near the upper limit, suggesting a very high level of interest across all conditions (median=5/5). Here, conditions A and B have the same range (range= [4,5]) and is slightly higher than condition C (range= [2,5]). All of the experiences were rated as very understandable. With condition A and B with a median of 5/5 and a range of [2, 5], with a very small reduction in understanding for condition C (median=4/5, range= [2,5]).

To the question of which condition, they preferred, three participants (2 BPB and 1 sighted person) mentioned that audio description alone (condition A) would suffice but a tactile model would be a plus because it would make certain elements represented tactilely more prominent. The rest of the participants preferred the combination of audio description and a tactile support.

Multimodality (Audio and Touch) is considered an enriching experience (Condition B (median= 5/5, range= [3,5]) and Condition C (median= 5/5, range= [2,5]). When asked how audio description and tactile exploration affect the experience, participants' responses revealed that they are sensitive to possible mismatches between what is represented and what is being listened to. For condition C, the audio description mentions the colours and the sighted participants are disturbed because the high reliefs have no colour (Fig. 1 middle column). For the blind and partially blind participants, if audio description does not describe what is being touched at the time of description, they would search for the described item without audio guidance. This can also be deduced through the lower results of participants' satisfaction for the amount of information presented (condition C: median= 4/5, range =[2,5], and condition B: median=5/5, range= [3,5]), where in the tactile representation of condition B the information is vastly simplified and reduced, and the audio description with tactile guide proposes better guidance for users, compared to the high relief of condition C with no guidance from the audio description. Participants, in general, would like to be more guided to touch it. They prefer to listen and touch at the same time.

When asked how visitors prefer to experience the Bayeux Tapestry, from a distance or in front of the Tapestry, some blind and partially blind participants remarked that it was not useful to come to the Museum to only listen to an audio description that could be posted online. The tactile support can therefore bring added value to the museum experience of visitors. From a practical point of view, participants reported a preference for Condition B, where the tactile experience was integrated with the audio experience. From an aesthetic point of view, high relief (Condition C) is preferred because it enhances the elements depicted and it is pleasant to the touch, but the imposing size can be intimidating.

As shown in table 3, for the question "What do you think about the level of detail?" on the Likert scale (1=not enough detail, 2=little detail, 3=enough detail, 4=a little too much detail, 5=too much detail), participants found sufficient representation of detail for all conditions with condition A having the smallest range (median = 3/5 : "enough detail", range = [3, 4]).

Table 3. Results for conditions B and C on the amount of detail presented for the participants.

Conditions	A Median [min,max]	B Median [min,max]	C Median [min,max]
What do you think about the level of detail?	3 [3,4]	3 [2,5]	3 [2,5]

Audio descriptions (condition A) are considered to be about the right length, although some participants suggested it was too long. The high relief (condition C) has some details not always indicated with the audio description that were pointed out by several participants.

Overall, some of the observations that emerge from the evaluation are the following:

- Synchronisation of audio-touch guidance with touch exploration is primordial;
- Providing more detailed descriptions of important elements in the scene (e.g. colours) should be on demand;
- Protruding elements should be easily discernible by different textures or relief effects;
- A simplified version of the tactile information should be available; however, the scene should also be presented in full;
- The choice of audio and tactile support or audio only should be available to all.

4. Conclusion

Through this article, contextual information was presented to better frame inclusion of BPB people through their museum experience, especially according to French laws, but also internationally. To that extent, a pilot evaluation was conducted to investigate multisensory experience of BPB people and SP through touch and audio, in the museum of the Bayeux Tapestry. 12 participants experienced three different conditions with audio (ICAD) and tactile representations (swell paper and high relief representation) of 3 scenes from the Bayeux Tapestry. The results showed that participants found interesting every condition. However, from the feedback of the participants some points still need to be worked on, especially how multisensory presentations can be created. From the observations, technologies should look into the personalization of a museum experience according to the visitor and, as such, support adjustable representations.

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References

[1] Convention on the Rights of Persons with Disabilities. 2006. Available from: https://social.desa.un.org/issues/disability/crpd/convention-on-the-rights-of-persons-with-disabilities-crpd?page=2.

[2] Romeo K, Thompson H, Chottin M. Inclusive Multimodal Discovery of Cultural Heritage: Listen and Touch. In: Miesenberger, K., Kouroupetroglou, G., Mavrou, K., Manduchi, R., Covarrubias Rodriguez, M., Penáz, P. (eds) Computers Helping People with Special Needs. ICCHP-AAATE 2022. Lecture Notes in Computer Science, vol 13341. Springer, Cham. https://doi.org/10.1007/978-3-031-08648-9_32.

[3] Romeo K, Chottin M, Ancet P, Pissaloux E. Access to artworks and its mediation by and for visually impaired persons. In: ICCHP 2018, 16th Int. Conf. Computers Helping People with Special Needs, Linz, Austria, July 11-13, 2018, Springer, p233-236. https://doi.org/10.1007/978-3-319-94274-2_32.

[4] Eardley AF, Thompson H, Fineman A, Hutchinson R, Bywood L, Cock M. Devisualizing the Museum: From Access to Inclusion. Journal of Museum Education 2022;47(2): 150-165, doi: 10.1080/ 10598650.2022.2077067.

[5] Reichhart F, Lomo A. L'offre culturelle française à l'épreuve de la cécité: étude de cas de l'accessibilité au musée. Canadian Journal of Disability Studies 2019;8(6), 6–23, doi: 10.15353/cjds.v8i6.577.

[6] Miguet D. Autour de la sensorialité dans les musées. Publics et Musées 1998 ;(13), 177-182, doi : 10.3406/pumus.1998.1313.

[7] Gilbert C, Sanchez J. L'accessibilité des musées de France. Musées et collections publiques de France 1997;(214).

[8] Gilbert C. Les Musées ouvrent leurs portes à tous les publics. Ed. Espace, Juin 1999(161) REVUE-ESPACES | Les musées ouvrent leurs portes à tous les publics (tourisme-espaces.com).

[9] Chenu R. Musées et handicap : les freins de l'accessibilité. Une enquête auprès de 127 musées, Culture & Musées 2018;3, doi : 10.4000/culturemusees.2140.

[10] Dhrif R. L'Accès aux Musées chez les Déficients Visuels : Entre Variété de l'Offre et Complexité des Besoins. Educational Science Master IIST, Université Paris 13, 2018.

[11] Marchetti M, Menillo M, Saudan M. Musées et accessibilité : de la sélection de l'information à la médiation, quelles approches pour les publics en situation de handicap visuel ? Mémoire Master Sc. Inf. HEG Genève 2016. Marchetti_Mennillo_ Saudan_MemoireRecherche_FINAL_15-01-16 (core.ac.uk).

[12] Direction des Musées de France. Des Musées pour tous, Manuel d'accessibilité physique et sensorielle des musées. Paris : Direction des Musées de France, 1992.

[13] Hutchinson R, Eardley AF. Inclusive museum audio guides: 'guided looking' through audio description enhances memorability of artworks for sighted audiences. Museum Management and Curatorship 2021;36(4):427-446, . doi: 10.1080/ 09647775.2021.1891563.

[14] Gay SL, Pissaloux E, Romeo K, Truong NT. F2T: A Novel Force-Feedback Haptic Architecture Delivering 2D Data to Visually Impaired People. IEEE Access 2021;9, p. 94901-94911, doi: 10.1109/ACCESS.2021.3091441.

[15] Bayeux Museum - Musée en Normandie.

[16] Michel Bris, Recommandations pour la transcription de documents, INSHEA https://www.inshea.fr/sites/default/files/SDADVrecommandations_transcription.pdf

[17] Example of ICAD. Description_scene_23.pdf. https://drive.google.com/file/d/1-aOGfv69xruY91b5vrgFsM5RmdK4U3ZH/view?usp=sharing.

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AT Outcomes

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Head Gesture Interface for Mouse Stick Users by AAGI

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Abstract. We developed a gesture interface (AAGI) for individuals with motor dysfunction who cannot use standard interface switches. These users have cerebral palsy, quadriplegia, or traumatic brain injury and experience involuntary movement, spasticity, and so on. In this paper, we describe a disabled user who utilizes a mouth stick for laptop PC input in daily life. Our objective is to lower the burden on his body by using gestures. To this end, we developed a "home position" for the head that enables gestures to coexist with the mouse stick usage. The results of basic experiments with five healthy participants indicate that our system has reached the level where it can be applied to actual disabled persons. Finally, we applied the system to a user with cerebral palsy asked him to perform web browsing.

Keywords. Gesture interface, support for the disabled, mouth stick, AAC, human sensing

1. Introduction

Individuals with severe motor dysfunction are unable to use existing computer interfaces due to spasticity, involuntary movements, and the like. The interfaces these individuals can use, if any, are limited to customized switch interfaces, which makes it difficult to operate a computer with any degree of ease.

To solve this problem, we have developed a switch gesture interface that utilizes a commercially available RGB-D camera. The system software recognizes gestures from 2D and 3D images, so it can be more easily customized to each user compared to a hardware system. The software is also easier to apply both daily and in the long term. The 3D images can specify gestures by using shape information, thus enabling application to more varied environments and types of gesture than when only 2D images are used.

As our aim is to apply this system to a variety of disability types, we gathered data on the types of gestures that severely quadriplegic individuals want to use in an interface. The data included both moving RGB images and depth (range) images. A total of 1745 gestures were collected from 81 individuals with motor dysfunction and the voluntary movements were classified on the basis of body part. We then incorporated the classification results into a gesture interface called the *Augmentative and Alternative Gesture Interface (AAGI)* [1–3] consisting of **seven recognition modules based on**

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body part (*Head, Eye, Mouth/Tongue, Shoulder, Finger, Knee, Foot*) and **two recognition modules independent of body part** (*Front object and Slight movement*). Since each user will want to utilize a different part of the system, each is able to select the module that best suits his/her needs.

Our system is currently being applied to over 30 users with nine recognition modules for daily use. In this paper, we describe a user with cerebral palsy who has involuntary movements and can only move his head voluntarily. Although he can use a PC by manipulating a mouse stick, this is quite taxing on his body (Fig. 1). Our objective is therefore to lower the burden on his body by using gestures, specifically, by enabling the use of the mouse stick and head gestures simultaneously.

Figure 1. Mouse stick user.

We briefly go over similar studies that utilize facial movements for PC operation, assuming that they can coexist with mouse stick operation. First, there are prior studies in which a 9-axis sensor is attached to the head and the mouse cursor is controlled by head movements [4]. However, it is difficult to utilize in conjunction with a mouse stick because it also uses mouth and tongue movements. In addition, the burden of hardware attachment is significant. Another method features an RGB-D camera and utilizes the position of the nose and the opening and closing of the mouth [5]. The purpose is to move the cursor at the nose position and execute a mouse click by opening and closing the mouth. The disadvantage here is that if the mouse stick is in the mouth, the click is not available. Finally, there is also a method that uses an RGB camera to identify the four directions of head orientation and link the transitions to mouse operations [6]. The output destination of this method is mouse operation. It also uses mouth opening and closing, which makes it difficult to use in conjunction with the mouse stick.

Basically, none of these three methods have been studied in conjunction with mouse sticks, and no prior research has reported techniques designed to be used with the mouse stick. Our goal is thus to create a head gesture interface that can be used in conjunction with a mouse stick.

2. Home position for mouth stick user

When using the head gesture, we place an RGB-D camera behind the PC monitor and the PC constantly calculates the direction of the user's face, enabling up to four switch inputs by turning the face in four directions (up, down, left, right). However, when the user performs a mouse stick action, he or she cannot speak and must keep the head constantly moving. It is inherently impossible to use the head gesture and the mouse stick for input operations simultaneously (**Figure 1**).

To circumvent this, we came up with a "home position" for the head so that gestures can coexist simultaneously with the mouse stick. The home position is the reference position for head gestures while looking at the PC. When users manipulate the mouse stick for keyboard input, they move closer to the PC monitor, which makes capturing the face orientation meaningless. When they finish the keyboard input, they return to the home position where the monitor is viewed from the front. We therefore disable all face orientation input during keyboard input and then enable gesture input from the point when the user returns to the home position. However, since the user we examine here has cerebral palsy, the position and orientation of his face is slightly different each time, even when returning to the home position. We therefore came up with a technique for updating the reference home position each time the mouse-stick operation is completed and the user returns to the home position. This allows him to use head gestures even when his head position is inconsistent. To ensure high accuracy, the home position is calculated from both the depth and the RGB images.

3. Experiment

3.1. Basic experiment with healthy participants

We conducted two basic experiments with five healthy participants to evaluate our approach. In the first experiment, we tested whether basic operations could be performed with Windows Explorer, which is a common software used on PCs (**Figure 2**).

First, we assigned Tab, ↓, Alt + ←, and Enter to the up, down, left, and right movements of the head, respectively. We then investigated whether a series of basic operations (e.g., moving folders, renaming files, and opening files) could be seamlessly performed with both gestures and the mouse stick.

In the second experiment, we examined the task of browsing news sites on a Web browser (Google Chrome). We assigned Tab, Enter, Page Down, and Ctrl + W to the right, left, down, and up movements of the head, respectively and investigated whether basic browsing operations (e.g., selecting news stories and scrolling up or down the page) could be performed using only gestures.

In both experiments, the five participants were first told what actions they could perform with the gestures and asked to practice the task operation twice with the AAGI. We then had them perform the task.

The results of Experiment 1 showed that the number of times a mouse stick action was misrecognized as a gesture was zero in a total of five tasks performed by five subjects. This confirms that introducing the home position enables the gesture interface to coexist with general mouse stick operation. A minimum of 81 gesture operations were required to perform all tasks in Experiment 1, and the actual number of gestures by participants (including recognition errors) averaged 1.16 times as many. In Experiment 2, the average number of gestures was 1.06 times higher. In both experiments, the total number of gestures performed by the participants was 168. Of these, misidentifications occurred ten times (10/168 = 6.0%) and detection omissions occurred just once (3/168 = 1.8%). As these promising results occurred after just two practice sessions, we believe our system has reached a level where it can be applied to real people with disabilities.

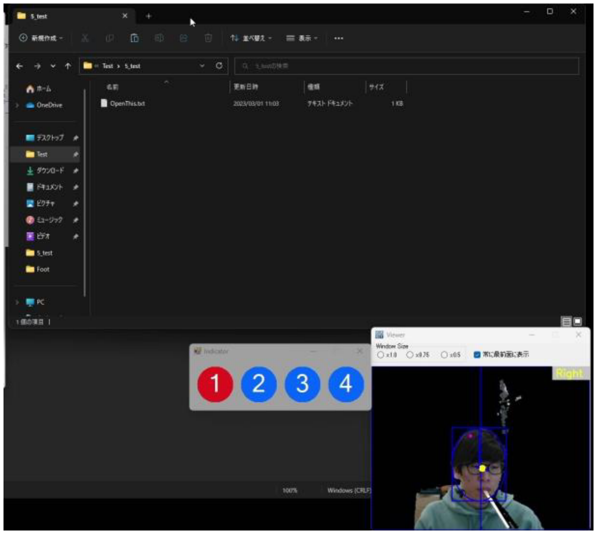

Figure 2. Operation for Windows Explorer by head gestures.

3.2. Application to real user for web browsing

We assigned an easy task (basically, the same one as in the second experiment) to the real user for web browsing. Tab, Enter, Page Down, and Ctrl + W were assigned to the right, left, down, and up movements of the head. These are Google Chrome shortcut keys that allow users to select, open links, scroll up or down the page, and close the current tab. The user selected a news story, scrolled through the page twice, and closed the tab using only gestures (Fig. 3 - 4). He repeated this three times in succession. The number of gestures required to complete this task is 20. He tried this task after three practices.

Table 1 compares the results of the real user with those of the three healthy subjects (average). The user took 57 seconds to complete the entire task. Seventeen gestures were actually performed by the user and over-detection occurred four times. When over-detection occurred, he ignored it and proceeded with the task. These three times advanced the task and one time had no effect on the progress of the task. There was no lack of detection. The time required per gesture was 3.35 seconds. For reference, the same task was performed with the three healthy subjects. The results took 2.57 seconds per gesture, and neither over-detection nor lack of detection occurred.

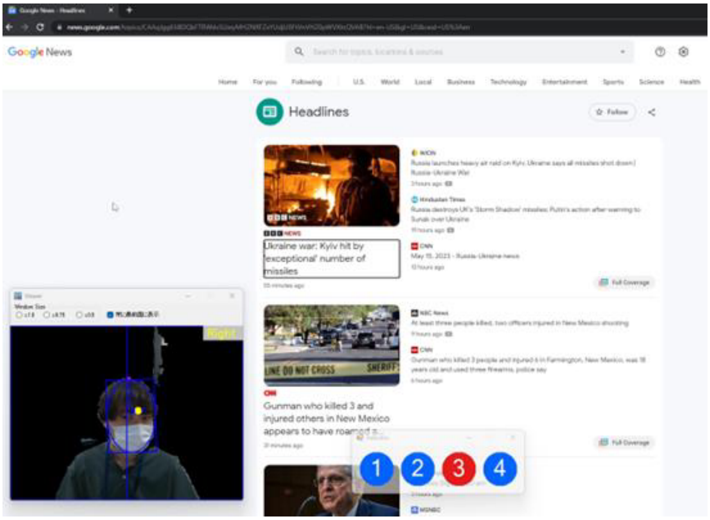

Figure 3. Operation for web browsing by head gestures.

Figure 4. Application to real user.

Table 1. Comparison of web browsing results.

	Real user	Three healthy subjects (avg.)
No. of gestures	17	20
Missed detection	0	0
Over-detection	4	0
Time/gesture (s)	3.35	2.57

The subject was a patient with cerebral palsy and had involuntary movements, which are what led to the over-detection. The involuntary movements had the impact on the detections for the right and down directions. The impact can be reduced by assigning shortcuts such as Tab and Page Down to directions where mistakes are likely to occur. In addition, the user's face shifted downward over time. This shifted the home position and presumably contributed to the decreasing accuracy over time.

4. Conclusion

In this work, we developed a system for use in our AAGI gesture interface in which mouse stick operation and gestures can coexist thanks to the introduction of a home position. The results of basic experiments with five healthy participants indicated that our system has reached the level of adaptability to real users. We therefore applied the system to a subject with cerebral palsy asked him to perform a web browsing task.

In future work, we will introduce our system to a greater number of real users with disabilities to investigate whether the actual user operation time is decreased and whether the burden on the body is reduced.

References

[1] Yoda I, Itoh K, Nakayama T. Collection and Classification of Gestures from People with Severe Motor Dysfunction for Developing Modular Gesture Interface. In: Antona M, Stephanidis C, editors. Universal Access in Human-Computer Interaction. Access to Interaction. UAHCI 2015. Lecture Notes in Computer Science, vol 9176. Cham: Springer; 2015. p. 58-68, doi: 10.1007/978-3-319-20681-3_6

[2] Yoda I, Itoh K, Nakayama T. Modular Gesture Interface for People with Severe Motor Dysfunction: Foot Recognition. Stud Health Technol Inform. 2017;242:725-732.

[3] AIST. Augmentative and Alternative Gesture Interface [Internet] Available from: http://gesture-interface.jp/en/

[4] Sahadat MN, Alreja A, Srikrishnan P, Ghovanloo M. A multimodal human computer interface combining head movement, speech and tongue motion for people with severe disabilities. 2015 IEEE Biomedical Circuits and Systems Conference (BioCAS), Atlanta, GA. 2015. p. 1–4, doi: 10.1109/BioCAS.2015.7348317.

[5] Bian Z-P, Hou J, Chau L-P, Magnenat-Thalmann N. Facial Position and Expression-Based Human–Computer Interface for Persons with Tetraplegia. IEEE Journal of Biomedical and Health Informatics. 2015 may;20(3): 915–924, doi: 10.1109/JBHI.2015.2412125.

[6] Song Y, Luo Y, Lin J. Detection of Movements of Head and Mouth to Provide Computer Access for Disabled. 2011 International Conference on Technologies and Applications of Artificial Intelligence, Chung Li, Taiwan. 2011. p. 223–226, doi: 10.1109/TAAI.2011.46.

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STAACS^3 : Simulation Tool for AAC with Single-Switch Scanning

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Abstract. Communication for people with motor impairments is a difficult, yet necessary, task in daily activities. To do so, soft keyboards, digital counterpart of physical keyboards, are used. Depending on their features, several designs can be considered, however their thoughtful evaluation in real-life is not feasible. Therefore, it becomes necessary to filter the possible configurations wisely, taking advantage of simulation tools. This paper presents STAACS^3, a Simulation Tool for AAC with Single-Switch scanning, that allows to model and simulate the performance of any type of scanning keyboard regardless of its keys configuration, scanning strategy or prediction systems.

Keywords. Augmentative and Alternative Communication, Soft keyboards, Single-switch scanning, Simulation

1. Introduction

Nowadays, written communication via email, social networks or discussion forums is one of the main uses of digital tools (PC, Smartphone, tablets, etc.). Digital text entry has become a main activity in our daily lives. In case of motor impairment, users can use a so-called ”soft keyboard”, i.e. a digital representation of the physical keyboard. These soft keyboards are used with a pointing device adapted to the user’s motor skills. For people with very poor motor skills, it is also possible to replace the pointing device with an automatic scrolling system where the cursor moves from key to key at regular intervals, usually from left to right and from top to bottom on the keyboard. The user selects a character by pressing a single-switch when the cursor is on the desired key. A large diversity of keyboards configurations can be imagined answering user needs. In order to evaluate the proposed keyboards during the design phase, and before assessing their relevance and usability by end users during an evaluation phase, simulation tools are a relevant solution. In this paper, we propose a Simulation Tool for AAC with Single-Switch Scanning (STAACS^3) that allows to model and simulate the performance of any type of scanning keyboard whatever a) its keys configuration, b) the scanning strategy used, c) the prediction systems used. Moreover, the simulation can easily be adapted to

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any language by modifying the text corpora used for the prediction systems and for the simulation. Finally, in order to be able to simulate all types of keyboards, we have also modified the calculation of the scan step per character (SPC). This allows us to take into account systems that use two different scan interval.

2. AAC with single-switch scanning

As aforementioned, a large number of virtual keyboards are available to AAC users, depending of their configurations. These configurations mainly differ by the scanning mode that is used. The use of language prediction systems (word or character) also has a significant impact on the different keyboards offered. This section describes the features that can be found in current virtual keyboards.

2.1. Scanning mode

Virtual keyboards offer multiple scanning modes that can be used, such as linear, row/column, half-and-half and n-ary. Figure 1 illustrates these scanning modes.

The **linear** scanning mode can be considered as the most basic approach. In this mode, the cursor systematically scans each key on the keyboard, following a left-to-right and top-to-bottom progression (Figure 1a). The selection of the desired character required only one validation [1]. However, when the keyboard follows an alphabetic order, the typing is very slow. Indeed, the maximum number of scan steps for an alphabetically sorted keyboard is *L*, where *L* is the length of the alphabet. To overcome this limitation,

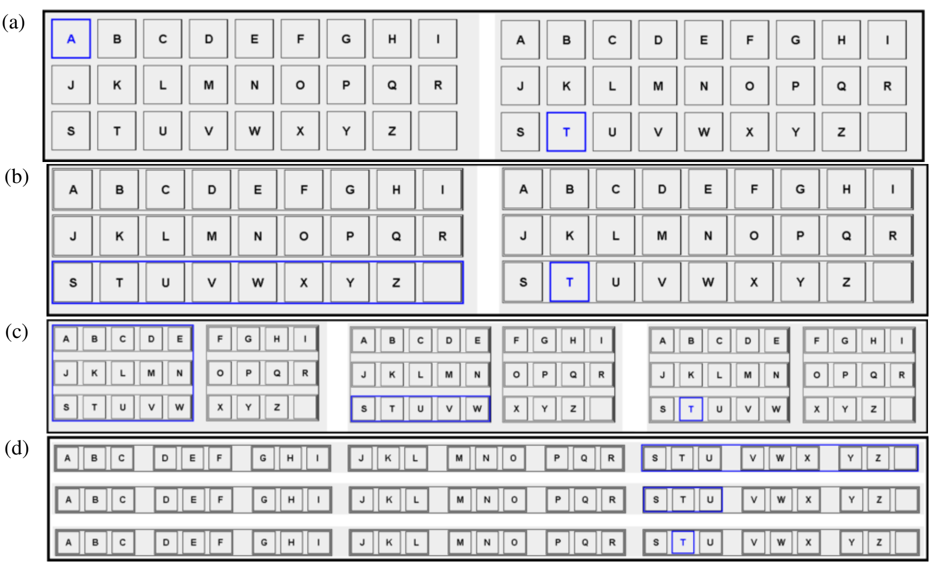

Figure 1.: Illustrations of scanning mode: (a) linear, (b) row/column, (c) half-and-half and (d) n-ary. For each scanning mode, the main steps required to select the letter ”T” are presented. These views are generated by the simulation tool presented in this paper.

keyboard with a linear scanning mode present a frequency-based organization : the most frequent letters in the considered language are presented first [1]. Another solution is to re-organise dynamically the letters ordering during text input, as explained in section 2.2.

The scanning mode that is commonly used is the **row/column** (R/C) scanning [2, 3,4]. In this scanning mode, the cursor highlights each row successively until the user validates the desired row (left of Figure 1b). When a row is selected, the cursor scans the keys (columns) of this row (right of Figure 1b). The desired letter is selected when the user validates the associated key by activating its switch. The method required two validations for one letter but the maximum number of scan steps for an alphabetically sorted keyboard is 8 [5]. Even if the number of user action is higher, the R/C scanning is faster than linear scanning [1]. Depending on the user's ability, the opposite scanning (i.e. column/row scanning) is possible.

The **half-and-half** scanning (H/H) method [6] is similar to the R/C but adds an additional first scan between two parts of the keyboard, traditionally the left and right side (left of Figure 1d). In this case, we add an additional load to the motor aspect but we divide the numbers of scan steps by two.

In ***N*-ary** search [7], at each step, the keyboard is divided into N parts. Two partition strategies can be considered: dividing the keyboard into parts with an equal number of letters or dividing the keyboard based on probability considerations. In this case, each part can contain different numbers of letters. Let's consider as an illustration the first strategy and the selection of the "t" with a ternary search keyboard ($N = 3$). At the first step (top of Figure 1d), the keyboard is divided into 3 groups and the user selects the part that contains the desired letter. At the second step (middle of Figure 1d), the selected group is again divided into 3 groups and the user will also select the group that contains the "t". These steps are reproduced until the selection of the desired letter (bottom of Figure 1d). This type of scanning is the one that requires the most keystrokes to select one character [7]: $\#steps = \lceil log_N L \rceil$, where L is the size of the alphabet and N is the number of groups.

2.2. *Linguistic prediction*

In order to enhance the text entry speed, some keyboards are augmented by character or word prediction modules.

Character prediction considers the last entered letters to predict the following one, usually by using a standard N-gram language model [8] or a lexical tree [9]. By using character prediction, we can expect to reduce the number of scan steps. Indeed, the most probable following characters are put closer to be beginning of scanning bloc. Thus theoretically improving input speed by avoiding some scan steps. However, this implies that the layout is dynamic and prevents the user from memorizing the character layout.

Word prediction modules offer a list of the most probable words based on either the input of previously typed words (prediction) or the letters already entered in the current word (completion). The most basic approach involves browsing a lexicon using a lexicographic tree organization [10]. However, these techniques may encounter difficulties when dealing with Out of Vocabulary Words (OOV), resulting in potential confusion. More advanced prediction modules rely on statistical language models. They estimate the frequency of occurrence of a word according to the previous words and characters already entered in the current word. Some models offer a user adaptation, based on user's writing or even an adaption to the current theme of the input text. Word prediction enables the user to save input of certain characters by selecting a prediction by activating the switch. Moreover, this can be used by some users to reduce their spelling error. In addition to the prediction technique used, parameterisation is an important factor that enables the system to adapt to the user motor or cognitive abilities as well as its preferences (for instance factors such as the number of displayed predicted words and their positions on the layout, allowing for personalized adjustments). All of these parameter variations (scanning modes and linguistic predictions) and their combinations lead to a large number of possible scanning keyboards, not to mention the various letter organisation on the layout. Conducting experimental tests for all of these configurations, that fit most of the time very specific user needs, is not practical. Therefore, it is common practice to use simulation to reduce the design space before conducting experiments with real users.

2.3. Design space

In summary, in this paper we have considered the following parameters: (i) scanning mode, (ii) character/word layout per block where variations were made in the number of characters (and/or words) per block, (iii) the use (or not) of character prediction, with the possibility of dynamic rearrangement either for the entire keyboard or within each block and (iv) the use (or not) of word prediction. We are therefore interested in the Representation, Interaction and Linguistic dimensions of the DESSK framework [11], that formalize the design space of AAC and virtual keyboards. The combinations between these different parameters studied lead to a wide range of configurations that can be obtained by varying these parameters. It is not possible to test all these combinations in uses studies. For this reason, it is important to be able to evaluate the theoretical contribution of these solutions by means of a simulator.

3. Related works on scanning keyboards simulation

Several works have already proposed to simulate virtual keyboards. They propose to estimate the behaviour of AAC users on these devices using different metrics. Some are related to the text input speed such as character per minute (CPM) [7] or text entry rate (TER) [12], and others are related to cognitive/motor workload (such as keystroke saving and switch saving [5]). Nevertheless, these metrics are ”relative” [13], and do not allow a fair comparison between different keyboard layouts. Hence, MacKenzie also proposed a new metric: the scan steps per character (SPC) [6]: it is the average number of scan steps required to write a character on the simulated keyboard.

Regardless of the simulator, the obtained results correspond to a theoretical estimation of the maximum aid that can be expected from a considered AAC system. These simulations are based on the assumption that the user has an ideal behaviour: the user promptly selects the character or prediction and enters the message without any spelling errors. The calculation of the SPC metric in [13] adds an complementary degree of theorizing. Indeed, it is not based on the writing of real texts, but on the input of isolated words whose influence on the final SPC is mitigated by their frequency of occurrence in a reference corpus. Additionally, it should be noted that the simulator does not have the capability to simulate a keyboard with character prediction. Moreover, with just the general SPC we can't calculate the word per minute (WPM) [14] for keyboards with different scanning interval (SI) for row and column. This formula considers only a single SI, which means we cannot apply the formula for keyboards like one in [4], and thus a direct comparison between the results of the simulation and the user study is not feasible.

4. STAACS^3

In order to address the limitations of MacKenzie's simulator, we propose in this paper a Simulation Tool for AAC with Single-Switch Scanning (STAACS^3) [2]. To facilitate the usage of STAACS^3, text input systems are described in a simple XML format that allows to define the keys layout, the characters' arrangement, the scanning strategy, and the way to use the results of the prediction algorithms (words and/or characters).

Metric The results are given in the form of a CSV file, with the number of scan steps per word. The SPC value is also computed, following [13], on these data. However, the SPC does not allow to compute the theoretical WPM if the SI is different for row and column. In STAACS^3, log files include SPC_{row} and SPC_{column}, representing the SPC values for rows and columns, respectively, so that theoretical WPMs can be calculated as close as possible to reality. In this case, we therefore consider the following formula to compute the WPM:

$$WPM = \frac{1000 \times 60}{5 \times (SPC_{column} \times SI_{column} + SPC_{row} \times SI_{row})} \quad (1)$$

Language adaptation STAACS^3 has been implemented to allow easy adaptation to different languages by simply modifying the test corpus and the prediction module. For example, to apply the simulator in French we have changed the prediction module to Predict4All [3] implemented in Life Companion [4]. We have also changed the test corpus to a corpus composed with the 2000 most frequent french words from [15] associated with their frequency of occurrence. According to the criteria of [16] this corpus is representative to the French language.

Character prediction In addition to the word prediction already offered by Mackenzie, STAACS^3 allows the integration of character prediction. This allows dynamic characters rearrangement, which can be global for the keyboard or within each block. This option of STAACS^3 allows to compare different keyboards with dynamic character rearrangement.

Visualisation Finally, STAACS^3 provides a graphical user interface that allows the user to visualise the keyboard layout and test its behaviour before simulating its theoretical performance. This allows the designer to check that the XML description corresponds to his intention. The images in figure 1 were generated with the proposed simulator.

[2] STAACS^3 is open-source: https://github.com/MathieuRaynal/keyboardSimulator
[3] https://github.com/mthebaud/predict4all
[4] https://lifecompanionaac.org/

5. Results and discussion

5.1. Results

STAACS^3 allows a wide range of keyboard configurations to be simulated based on variations in the parameter combinations mentioned in the section 2.3. The values considered for these parameters are given in Table 1. N-ary search can be reasonably declinable with N between 2 and 4 [7]. Keyboard layouts can take the form of a diagonal matrix (Figure 1a in [13] or a series of 1 to 5 lines balanced in terms of the number of keys (example with 4 lines in Figure 1a). All their designs are adaptable with an alphabetical or probabilistic order (i.e. letters are ordered according to their frequency in the desired language). Character prediction gives the possibility of dynamic rearrangement either globally for the whole keyboard or within each line. Finally, with word prediction, we can propose keyboards with 1 to 9 suggested words, either into the letter grid or as a list at the cardinal point (i.e. to bottom, top, left or right of the keyboard). The combination of their values leads to the wide range of scanning keyboards, not all of which are relevant.

Parameter name	Values		Count
Scanning mode	linear, R/C, H/H, N-ary [2-4]		6
Layout	diagonal matrix	alphabetical order	12
		probabilistic order	
	line [1-5]	alphabetical order	
		probabilistic order	
Character prediction	no		3
	yes	local dynamic rearrangement	
		global dynamic rearrangement	
Word prediction	no		46
	yes	position (inside, on the side)	
		number of predictions [1-9]	

Table 1.: Non-exhaustive list of parameter's values.

In Table 2 we present some keyboard simulations (with an SI of 750ms) to show the different possible analysis with STAACS^3.

To begin with, we reproduced the performance of MacKenzie's simulator by simulating keyboards (Figure 1a, b and c in [13]) from [4,5]. These simulations are carried out under the same conditions as in [13] i.e. with BNC-1 and Phrases corpus[16] and we obtain exactly the same SPC results.

Schadle et al. [17] showed that character prediction improves the average number of scanning steps by about 90% for a linear scan with a keyboard of 64 keys. With the simulator, we evaluated the contribution of character prediction with a keyboard of 27 keys (i.e. the 26 letters of the Latin alphabet and space). We obtain an SPC of about 3 scan step with prediction and 10 without. Similarly, STAACS^3 allows us to compare and order scanning modes such as between RC and N-ary [7] or between linear and RC [17].

Finally, thanks to the addition of SPC_{row} and SPC_{column}, we can compare the result of the simulation with the performance in the user study of a keyboard with two SI. The simulation of the keyboard from [4] was reproduced, on Phrases corpus, with the same

Name	Scanning mode	Word prediction	Character prediction	Layout	SPC	**WPM**
a	linear	no	no	Figure 1a	10.23	**1.56**
b	linear	no	yes	Figure 1a	3.36	**4.76**
c	R/C	no	no	Figure 1b	7.49	**2.14**
d	H/H	no	no	Figure 1c	6.83	**2.34**
e	N-ary	no	no	Figure 1d	6.39	**2.50**

Table 2.: Some scanning keyboards simulations' results, obtained with STAACS[3].

conditions as in user study (SI_{row}=250 ms and SI_{column}=750ms) to calculate the wpm. We obtain 5.75 wpm (SPC_{row}=2.001 and SPC_{column}=2.34). In [4], the wpm range from 4.4 to 6.6, and up to 7.4 wpm with a faster user.

5.2. Discussion

We can see that simulation gives a good idea of potential performance of a user with a given keyboard configuration. Indeed, the simulation allows to obtain results close to a study with users. This previous result proves that simulating keyboards is a good way of filtering out different ideas, but it doesn't substitute for a user study especially with motor disabled users. Indeed, STAACS[3] returns an single result where a user study shows the range of possible performances. Thus, several explanations can be highlighted.

First, it is interesting to note that the data simulated by STAACS[3] corresponds to optimal theoretical results: the user selects the character or the prediction as soon as possible and the message is entered without spelling errors. All these things are not systematically encountered when observing the behavior of real users, particularly with motor disabled users. Therefore, we will consider future experiments with real users, in order to collect as much data as possible on human behaviour during text input in order to model such behaviour and incorporate it into the simulation.

Furthermore, for the time being, we are only simulating word input, apart from the fact that it does not fully exploit word prediction, it also does not represent a real interaction with a scanning keyboard as text input by real users might. Finally, in this version of STAACS[3] we do not yet integrate accents or punctuation although they are important, especially in French. This constitutes an important bias because we only considered 27 keys (without word prediction keys), against 64 in the case of a full French keyboard [17].

6. Conclusion

In this paper we present STAACS[3], a scanning keyboard simulator that allows to evaluate several configurations with an easy adaptation to different languages. We investigated the wide range of scanning keyboards (at least 8000) that can be simulated with STAACS[3], and the usefulness and limits of the simulator.

In future works, we will consider future experiments with real users, in order to create a model of typing time that takes into account a theoretical model of human behavior. In future work, we will consider experiments with real users to create a predictive model that takes into account human behaviour. This model will then be integrated into

STAACS^3 to improve the relevance of the proposed results and to get even closer to the results obtained by users.

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References

[1] Venkatagiri H. Efficient keyboard layouts for sequential access in augmentative and alternative communication. Augmentative and Alternative Communication. 1999;15(2):126-34.
[2] Felzer T, MacKenzie IS, Beckerle P, Rinderknecht S. Qanti: a software tool for quick ambiguous non-standard text input. In: Computers Helping People with Special Needs: 12th International Conference, ICCHP 2010, Vienna, Austria, July14-16, 2010, Proceedings, Part II 12. Springer; 2010. p. 128-35.
[3] Sandnes FE. Can Automatic Abbreviation Expansion Improve the Text Entry Rates of Norwegian Text with Compound Words? In: Proceedings of the 8th International Conference on Software Development and Technologies for Enhancing Accessibility and Fighting Info-exclusion; 2018. p. 1-7.
[4] Koester HH, Levine SP. Learning and performance of able-bodied individuals using scanning systems with and without word prediction. Assistive Technology. 1994;6(1):42-53.
[5] Lesher G, Moulton B, Higginbotham DJ. Techniques for augmenting scanning communication. Augmentative and Alternative Communication. 1998;14(2):81-101.
[6] Sandnes FE, Eika E, Medola FO. Multi-switch scanning keyboards: A theoretical study of simultaneous parallel scans with QWERTY layout. In: Universal Access in Human-Computer Interaction. Methods, Technologies, and Users: 12th International Conference, UAHCI 2018, Held as Part of HCI International 2018, Las Vegas, NV, USA, July 15-20, 2018, Proceedings, Part I 12. Springer; 2018. p. 287-98.
[7] Poláček O, M'ikovec Z, Slav'ik P. Predictive scanning keyboard operated by hissing. In: Proceedings of the 2nd IASTED International Conference Assistive Technologies. Citeseer; 2012. p. 862-9.
[8] Wandmacher T, Antoine JY, Poirier F, Départe JP. Sibylle, an assistive communication system adapting to the context and its user. ACM Transactions on Accessible Computing (TACCESS). 2008;1(1):1-30.
[9] Raynal M, MacKenzie IS, Merlin B. Semantic keyboard: Fast movements between keys of a soft keyboard. In: Computers Helping People with Special Needs: 14th International Conference, ICCHP 2014, Paris, France, July 9-11, 2014, Proceedings, Part II 14. Springer; 2014. p. 195-202.
[10] Badr G, Raynal M. WordTree: results of a word prediction system presented thanks to a tree. In: Universal Access in Human-Computer Interaction. Applications and Services: 5th International Conference, UAHCI 2009, Held as Part of HCI International 2009. Springer; 2009. p. 463-71.
[11] Raynal M, Badr G, MacKenzie IS. DESSK: description space for soft keyboards. In: Human-Computer Interaction. Technological Innovation: Thematic Area, HCI 2022, Held as Part of the 24th HCI International Conference, HCII 2022. Springer; 2022. p. 109-25.
[12] Mankowski R, Simpson RC, Koester HH. Validating a model of row–column scanning. Disability and Rehabilitation: Assistive Technology. 2013;8(4):321-9.
[13] MacKenzie IS. Modeling text input for single-switch scanning. In: Computers Helping People with Special Needs: 13th International Conference, ICCHP 2012, Linz, Austria, July 11-13, 2012, Proceedings, Part II 13. Springer; 2012. p. 423-30.
[14] Mackenzie IS, Felzer T. SAK: Scanning ambiguous keyboard for efficient one-key text entry. ACM Transactions on Computer-Human Interaction (TOCHI). 2010;17(3):1-39.
[15] Ben Khelil C, Rayar F, Antoine JY, Hoiry L, Raynal M, Halftermeyer A. What you need is what you get: adapting word prediction of Augmentative and Alternative Communication aids to youth language. In: 25th HCI International Conference, HCII 2023. Springer; 2023. .
[16] MacKenzie IS, Soukoreff RW. Phrase sets for evaluating text entry techniques. In: CHI'03 extended abstracts on Human factors in computing systems; 2003. p. 754-5.
[17] Schadle I, Le Pevedic B, Antoine JY, Franck P. SibyLettre: Système de prédiction de lettre pour l'aide à la saisie de texte. In: TALN 2001 Recital 2001 (Tours, 2-5 juillet 2001); 2001. .

Universal Design in Education (UDE) Across the Entire Lifecycle

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Inclusion4EU: Co-Designing a Framework for Inclusive Software Design and Development

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Abstract. Digital technology is now pervasive, however, not all groups have uniformly benefitted from technological changes and some groups have been left behind or digitally excluded. Comprehensive data from the 2017 Current Population Survey shows that older people and persons with disabilities still lag behind in computer and internet access. Furthermore unique ethical, privacy and safety implications exist for the use of technology for older persons and people with disabilities and careful reflection is required to incorporate these aspects, which are not always part of a traditional software lifecycle. In this paper we present the Inclusion4EU project that aims to co-design a new framework, guidelines and checklists for inclusive software design and development with end-users from excluded categories, academics with expertise in human-computer interaction and industry practitioners from software engineering.

Keywords. Inclusive Software Design and Development, Co-Design, Software Engineering, Older Adults, Persons with Disabilities

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1. Introduction

Inclusive or accessible design is a process where the needs of specific groups of people such as older adults or persons with disabilities are specifically considered in technology products and services. The practice is gaining recognition in tertiary and third-level Computer Science curricula. However, we know from experience that scant university courses involve students working with persons from diverse backgrounds including older adults or those with disabilities in order to design and development software that supports their needs. Many Computer Science lecturers do not have the requisite training to facilitate collaborative design and development sessions involving these stakeholders. Computer Science lecturers require upskilling in the multi-disciplinary area of co-design – the act of creating with stakeholders to ensure the results meet their needs. We argue that inclusive software design in a crucial component of Computer Science students' education. From an industry standpoint, the degree of stakeholder involvement in the software design and development process is largely based on the tools, time, and resources available on any given project. Software design and development teams have to weigh the benefits of co-design, working collaboratively with diverse sets of stakeholders and finding ways to communicate meaningfully against the costs of its administration. However, this lack of meaningful stakeholder involvement can result digital exclusion - that is where a section of the population have continuing unequal access and capacity to use technology which in turn can lead to significant ethical, legal and financial deficiencies.

An estimated 135 million people in Europe live with a disability [1]. With population ageing and the rising prevalence of chronic health conditions due to non-communicable diseases and injuries, this number is set to increase. Comprehensive data from the 2017 Current Population Survey shows that older people and persons with disabilities still lag behind in computer and internet access [2]. The EU vision for digital transformation (via the European Declaration on Digital Rights and Principles [3]), encompasses digital sovereignty, inclusion, equality, sustainability, improving quality of life, and respect of people' rights and aspirations. Digital inclusion is also underpinned by legislation especially the EU Web Accessibility Directive of 2016 [4] and accessibility has been included as a transversal competence in the EU e-Competence Framework for ICT Professionals [5]. Tertiary and third-level education and industry need to respond to embrace active inclusion in their curricula and teaching materials and development practices.

To address digital exclusion in software design and development, a group of European Universities have developed a consortium, Inclusion4EU, funded under the Erasmus+ Strategic Partnership programme. The aim of Inclusion4EU is co-create a framework, guidelines and checklists for inclusive software design and development with co-design teams formed of academics with expertise in inclusive design, software designers and developers, and persons from excluded categories including older adults and persons with physical and cognitive disabilities. The project is focused on the exploration of ways in which inclusive human-centered design can be incorporated into the software development process and looking at ways to develop teaching materials to enable students and subsequent industry practitioners to gain a wider appreciation of the software design process through authentic partnerships with end-users. Our planned project activities include:

1. Reports on good and bad practices in software design and development, researched and created by pan-European partners;

2. A survey of European institutions about their current practices and future needs for teaching inclusive software design;
3. Co-design sessions including participants from across Europe to create a shared European understanding around the needs, capabilities and preferences of older adults and people with disabilities for inclusive technology;
4. The publication of a co-created framework for inclusive software design and development which will include design patterns, guidelines and checklists to maximize technology inclusion;
5. The creation of a European Community of Practice on inclusive software design and development align that will strongly with European Digital Inclusion initiatives.

This paper focuses on project activity 3 (co-design sessions) and will describe our planned approach to co-create a framework, guidelines and checklists for inclusive software design and development with co-design teams formed of academics, software designers and developers, and persons from digitally excluded categories.

2. Background

2.1. Digital Exclusion

Digital technology is now very much at the center of how public, economic and social life functions. It has transformed how we work, communicate, consume, learn, entertain and access information and public services. However the spread of access and use is uneven and many people remain digitally excluded [6]. Those who are excluded can be limited or unable to participate fully in society. Some groups are particularly affected, with a concentration of certain demographics within the digitally excluded. Studies show that overall non-users are increasingly older, less educated, more likely to be unemployed, disabled, and socially isolated [7]. Older people have consistently made up the largest proportion of internet non-users, and patterns of internet use by age is replicated when looking at digital skills [8]. Roulstone describes the Internet as 'inherently unfriendly' to people with many kinds of disabilities, with barriers to access and usage varying by the type and extent of disability [9]. Ofcom data from the UK in 2022 revealed that 56% of adult internet non-users were disabled. The same report showed that 47.7% of the non-user population responders have a long-standing illness, disability or infirmity [10].

2.2. Co-Design

Co-design is a methodology where the user actively and authentically participates in the process as an active co-designer [11]. The collaboration between the researcher and the co-designer goes further than the practice where the user is invited to participate in the processes of gathering and evaluating requirements, it is through this collaboration that they give value to the product or service by creating more meaningful experiences for the users [12]. The wide recognition of the role of co-design in improving the design of products has resulted in several studies investigating collaboration between researchers, stakeholders, and co-designers, primarily in medical and technology use. Participatory design approaches such as co-design are particularly important for the creation of inclusive technologies as a way for developers to understand the lived experiences of those that they are designing for.

3. Methods

The objectives of the co-design activities in the Inclusion4EU project are to: create a shared understanding of the existing software design and development process and propose how the process can be more inclusive; explore end users' experiences in best practices in inclusive technology; explore end users' current challenges and pain points with regard to existing technology; gain a deep understanding of the requirements and preferences of end users with regards to technology; co-create a framework, guidelines and checklists for inclusive software design and development; train academics and industry professionals with practical experience and knowledge of designing and running co-design sessions for inclusive design. In order to achieve these aims we will run co-design sessions where participants will include end-users from marginalized groups, academics and software engineers.

3.1. Requirements gathering

Semi-structured interviews are currently being conducted involving three groups of stakeholders – end users (older adults, persons with physical disabilities, and persons with intellectual disabilities), academics with experience in inclusive design and software industry practitioners. The interviews with stakeholders are examining the role technology plays in their lives, the types of technologies that users interact with, as well articulating their needs and preferences for possible technological solutions to support their independent living, examples of technologies that they consider to be well designed, and challenges and barriers that they face when using technologies.

Interviews with academics are aimed at understanding methods for inclusive designing including the co-design process and the role it can play in moving beyond participation by focusing more on co-production which is a key aim of our research.

Interviews with industry practitioners are focused on end-to-end software lifecycles in industry and whether and how inclusion is facilitated as part of those processes. For example, we are asking software designers and developers about inclusion criteria as part of a user analysis phase, whether and how they follow accessibility guidelines (e.g. WCAG [13]) as part of information architecture analysis in the planning phase, and if and how diverse end users are part of the software evaluation phase.

Following thematic analysis of the interview data, we aim to design and conduct a series of co-design workshops to interactively explore the themes arising from the interviews.

3.2. Co-Design

The next phase of our research is to run a series of co-design sessions where we will bring together the three groups of stakeholders to collect rich data and shared insights into experiences of all stakeholders, create topics for discussion and an open forum for knowledge exchange where all participants are considered equal experts. We believe it is important not only to gain insights from the end users but also for them to work with academics and industry professionals to co-create the final framework, guidelines and checklists for inclusive design so that their voices are firmly embedded in the resulting output.

Throughout the co-design sessions, methodologies such as personas, scenarios and storyboards will be used to explain technology and design concepts in lay terms to participants. The same participants will be involved in the co-design workshops as took part in the interviews phase.

From organizing and running the co-design sessions, we will collect a knowledge based of practical findings about running the sessions. Using this knowledge base we can create useful and open resources for academics and industry professionals. We will create an instructional guide for academics with practical advice on how to incorporate co-design activities into their teaching. Secondly the knowledge base will allow us to produce guidance for industry practitioners on how to incorporate co-design into industry practice for software design and development.

4. Conclusions

The impacts of a truly inclusive software design and development approach are many-fold: for older persons and persons with disabilities, their needs are considered, they are given a voice and empowered as part of an inclusive software design and development process, and gain design skills as part of the co-creation process. For Computer Science lecturers, they gain new experience in participatory processes and develop new skills in designing and delivering new curricula. For Computer Science students, they benefit from innovative pedagogical approaches that allow them to work with stakeholders, develop technology while building empathy with end users and gaining an insight into lived experiences. For industry professionals, they benefit from best practices in inclusive software design and the resulting software they build is usable by as many groups of end users as possible. The inclusion4EU project aims to co-create such a framework for inclusive software design and development and to develop open resources that can help students and subsequent graduates to reduce blind spots in order to produce more useable and accessible technology products and services.

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References

[1] WHO Factsheets, Disability: https://www.who.int/europe/news-room/fact-sheets/item/disability#:~:text=In%20Member%20States%20of%20the,Europe%20live%20with%20a%20disability.

[2] Scanlan M. Reassessing the disability divide: unequal access as the world is pushed online. Univers Access Inf Soc. 2022;21(3):725-735. doi: 10.1007/s10209-021-00803-5.
[3] European Declaration on Digital Rights and Principles. Available from: https://digital-strategy.ec.europa.eu/en/library/european-declaration-digital-rights-and-principles, 2022
[4] The Web Accessibility Directive (Directive (EU) 2016/2102). Available from: https://digital-strategy.ec.europa.eu/en/policies/web-accessibility#:~:text=The%20Web%20Accessibility%20Directive%20(Directive,mobile%20apps%20of%20public%20services.
[5] EU e-Competence Framework for ICT Professionals. Available from: https://itprofessionalism.org/
[6] Schejter A, Ben H, Orit R, Tirosh, N. Re-theorizing the "digital divide": Identifying dimensions of social exclusion in contemporary media technologies. In FACE Conference: European Media Policy 2015; New Contexts, New Approaches, 2015-04-09 - 2015-04-10.
[7] Helsper E, Reisdorf, BC. The emergence of a "digital underclass" in Great Britain and Sweden: changing reasons for digital exclusion New Media & Society; 2006; ISSN 1461-4448
[8] Office for National Statistics. 'Internet Users in the UK' 2018; Available from: https://www.ons.gov.uk/businessindustryandtrade/itandinternetindustry/datasets/internetusers
[9] Roulstone A. Disability and technology: An interdisciplinary and international approach. Basingstoke, UK: Palgrave Macmillan, 2016
[10] Ofcom, Digital exclusion A review of Ofcom's research on digital exclusion among adults in the UK, 2022. Available from: https://www.ofcom.org.uk/__data/assets/pdf_file/0022/234364/digital-exclusion-review-2022.pdf
[11] Steen M, Manschot M., and De Koning N. Benefits of co-design in service design projects. International Journal of Design, 2011; 5(2), 53-60.
[12] Phillips A, Morgan G. "Co-production within health and social care - The implications for Wales?", Quality in Ageing and Older Adults, Pier Professional Ltd, 2014; 15(1), 10–20.
[13] W3C Web Content Accessibility Guidelines (WCAG). Available from: https://www.w3.org/WAI/standards-guidelines/wcag/

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Universal Design in Education (UDE) Across the Life Course: Applying a Systems Framework to Create an Inclusive Experience for All

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Abstract. The UN Convention on the Rights of Persons with Disabilities (UNCRPD) promotes the realisation of the right of persons with disabilities to education through Article 24 - Education. Universal Design in Education (UDE) fosters a whole systems approach so that the physical and digital environments, the educational services, and the teaching and learning can be easily accessed, understood and used, by the widest range of learners and by all key stakeholders, in a more inclusive environment. The whole systems approach incorporates the entire educational environment, as well as the recognition of the capacity for all learners (including persons with disabilities) to learn, and environments which are fully accessible and inclusive. This paper discusses methods whereby a systems approach can be applied to various aspects of education across the life continuum. It further advocates the inclusion of Universal Design as subject matter in curricula and assessment, to ensure a broader and more widespread adoption across the educational spectrum.

Keywords. Universal Design, Education, Universal Design in Education

1. Introduction

Universal Design is often defined as "the design and composition of an environment so that it can be accessed, understood and used to the greatest extent possible by all people, regardless of their age, size, ability or disability" [1].

This includes the built and digital environments, products, services and systems. Universal Design is not a special requirement for the benefit of a minority of the population. It is a fundamental condition of good design.

Universal Design and inclusion are key to achieving the right to education and training as enshrined in the United Nations Convention on the Rights of Persons with Disabilities (CRPD), contains a reference to the concept of quality inclusive education and training, which clearly articulates the importance of Universal Design as the preferred approach to create an inclusive society [2].

Universal Design in Education (UDE) promotes a whole systems approach so that the physical and digital environments, the educational services, and the teaching and

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learning can be easily accessed, understood and used, by the widest range of learners and by all key stakeholders, in a more inclusive environment. This approach further advocates the inclusion of Universal Design as subject matter in curricula and assessment, to ensure a broader and more widespread adoption across the educational spectrum. A key focus of a Universal Design approach is to prioritise accessibility and usability for people with the most diverse capabilities, characteristics and preferences, to the greatest extent possible, from the earliest possible design stage and throughout all phases in the life of products and services, and their interoperability with assistive technology.

To achieve a complete and inclusive educational and social environment, practitioners need an emotional response to fully engage with and understand the barriers that exist and the enablers that are needed to bring about the necessary change: "our response must be emotional – we must feel the need for change and challenge our own values, beliefs, and assumptions" [3].

Based on experiences and projects in Ireland, this paper outlines methods whereby a systems approach can be applied to various aspects of education across the life continuum. This paper will discuss the importance of applying a Universal Design approach to ensuring that the design and composition of environments (both digital and physical), as well as underlying policies, are as inclusive as possible. A range of applications at the Macro, Meso and Micro levels across education will be described, as well as practical guidance on how to expedite the paradigm shift needed to make inclusive education a reality for all stakeholders, including those with disabilities.

2. Educational Policy in Ireland

A key feature of the national educational policy landscape for education and training in Ireland is the ambition for all learners to learn in the company of their peers in a fully integrated and inclusive way and within the same educational and training facilities and campuses, underpinned by the provision of graduated supports. This ambition is reflected in policy documents across the educational continuum, from early childhood education [4, 5], to primary [6], secondary [7], higher education [8, 9] and in further education and training [10].

The pursuit of equality and inclusion has been a concern of Irish education policy since the 1966 "Investment in Education" report. The Vision in the current statement of strategy of the Department of Education (2021-2023) highlights inclusive education as a fundamental principle of the Irish education and training system [11]. It states, "We must redouble our efforts to tackle educational inequality and ensure no child loses out in our education system, including those who have been additionally disadvantaged during the Covid-19 pandemic. This must come not only from increasing resources for students at risk of disadvantage, but by ensuring that the education system is conscious of the needs of all students." This vision is further elaborated in Goal Two entitled "Ensure equity of opportunity in education and that all students are supported to fulfil their potential". This goal, supported by a series of key actions recognises that: "Equity of opportunity and inclusivity must be fundamental principles in our education system. Our aim is to develop a system that welcomes and meaningfully engages all students, including those with special educational needs and students at risk of educational disadvantage." [11]

The Department of Further and Higher Education, Research, Innovation and Science, in its National Access Plan - A Strategic Action Plan for Equity of Access, Participation and Success in Higher Education 2022-2028, places equity, diversity and inclusion at the heart of its objectives [12]. It notes “That the higher education student body entering, participating and completing higher education, at all levels reflects the diversity and social mix of Ireland’s population.” and “That our higher education institutions are inclusive environments which support and foster student success and outcomes, equity and diversity and are responsive to the needs of students and wider communities.” This National Access Plan frames these ambitions in the context of Universal Design by seeking to ensure that “every student has a positive student experience supported by the principles of Universal Design and inclusive approaches to teaching and learning” [12].

3. A ‘Whole Systems’ approach to transforming education and training

Article 24 of the UNCRPD contains the first explicit legal enunciation of the right to inclusive education and it imposes wide-ranging duties on States Parties to the Convention [2, 13]. The UNCRPD Committee’s General Comment No. Four provides a framework, through which to consider the transformation required to realise inclusive education [14]. This is a “whole systems approach” which embeds “the necessary changes in institutional culture, policies and practices”. The whole systems approach incorporates the:

- “whole educational environment” - across all levels and all areas of educational institutions and including the local community or wider public
- “whole person” – in which “the capacity of every person to learn, and high expectations are established for all learners, including learners with disabilities” is recognised, and
- “learning-friendly environments” – which are fully accessible and “where everyone feels safe, supported, stimulated and able to express themselves”.

The UNCRPD Committee further elaborates particular aspects of the system that must be transformed, made inclusive and more accessible to all learners. These include “buildings, information and communications tools, the curriculum, educational materials, teaching methods, assessments and language and support services” [14]. Other aspects of the environment include school transportation, water and sanitation facilities (including hygiene and toilet facilities), school cafeterias and recreational spaces.

Universal Design for Learning (UDL) is one of the core elements of Universal Design in Education, and as such is a core component of the ‘whole systems’ approach described here. “UDL is a set of principles for curriculum development that give all individuals equal opportunities to learn, including Students with Disabilities. UDL aims to improve the educational experience of all students by introducing more flexible methods of teaching, assessment and service provision to cater for the diversity of learners in our classrooms” [15].

Within many educational systems, a paradigm shift is needed to achieve UDE. This paradigm shift necessitates moving beyond minimal compliance with accessibility standards, which provide basic access to facilities, products, and services for persons with disabilities, to a Universal Design approach. A Universal Design approach enables independence and social participation for all through continual improvement in all contexts [16].

This systems approach recognises the multiple layers within the human ecological framework that affect human development. A human ecological perspective uses a systemic and holistic framework that accounts for multiple factors at multiple levels and the interrelations between them. Within the educational ecosystem these are:

- Macro level – establishing directives, legislative acts, developing standards, promoting awareness and ensuring the diffusion of Universal Design and its adoption at national and regional educational levels.
- Meso level – institution level – covering governance, policies and procedures as well as linking families and the community-based initiatives, which is now known to be critical for growing and sustaining innovative learning.
- Micro level – individual needs and abilities catered for through teaching practices; classroom design and layout; technologies including assistive technologies; learning resources, supports and spaces; shifting the focus of education from institutional to individual learning, re-orientating the education towards the user; user involvement in the co-design of their own education; and embedding Universal Design as subject matter in curricula and assessment.

This whole systems framework based on a human ecological systems perspective proposes a transformation of the whole of the education and training ecosystem. By continuing to adopt and implement a Universal Design approach, the whole of the education and training system can be made more inclusive [17].

4. The 'Whole Systems' Approach applied

Before embarking on a brief description of some practical projects which demonstrate a 'whole systems' approach to Universal Design in Education, it is necessary to briefly digress in order to outline the structure of the Irish education system. Typically, pupils begin their educational journey at the age of three, by attending pre-schools, or 'Early Learning and Care Settings'. These are known colloquially as 'play schools'. Following this, children progress to Primary school, which consists of 8 years of study, and comprises Junior and Senior infants, as well as first-to-sixth classes. On conclusion of Primary education, children proceed to Secondary school. Here, two cycles of education take place. The first, known as the Junior Cycle, encompasses the first three years, and concludes with a state-run examination known as the Junior Certificate. A Transition Year (TY) then follows this. This Transition Year affords students the time and space to explore educational and other avenues, which are not examined. Secondary school concludes with a two year cycle (known as the Senior Cycle), and which culminates with the state-run examination known as the Leaving Certificate. Following conclusion of Secondary School, students may progress to third-level education, or engage in Further Education, which focusses on vocational training.

We now present brief descriptions of projects taking place at the various educational stages just described, and which are exemplars of incorporating the Macro, Meso, and Micro viewpoints previously discussed.

4.1. Early Learning and Care Settings

The Access and Inclusion Model (AIM) was established in 2016. "The goal of AIM is to create a more inclusive environment in pre-schools, so all children, regardless of ability, can benefit from quality early learning and care" [17]. A key facet of how this model operates is that it provides universal supports to pre-school settings without the need for a diagnosis of disability. This model of supports is "a child-centred model, involving seven levels of progressive support, moving from universal to targeted, based on the needs of the child and the Early Learning and Care setting" [18].

A key output of the AIM project is the Universal Design Guidelines for Early Learning and Care Settings" (UDG4ELCS) [18]. The guidelines set out the key Universal Design considerations and design guidance for Early Learning and Care settings in Ireland. They apply to both new-build and retrofit projects, and provide a flexible framework to ensure that settings are accessible, understandable and easy to use for all children, staff, families and visitors. Ongoing work seeks to follow up the publication of the UDG4ELCS to promote its understanding and adoption by Early Learning and Care (ELC) and School-Age Childcare (SAC) educators/practitioners, as well as by built environment professionals involved in the design, planning and construction of ELC and SAC settings.

4.2. Universal Design in Primary Level

The Power of Design (POD) Programme was established as a pilot in 2015 as a collaboration between Junior Achievement Ireland (JAI)[2] and Dublin City Council.[3] It grew into a national programme in 2019 at which point the collaboration was expanded to include the Centre for Excellence in Universal Design.[4] The POD programme incorporates content relating to Universal Design. "The Power of Design uses a learning by doing methodology to demonstrate to primary and second level students the positive impact of design on social, cultural and economic life" [19]. This programme is a self-contained workshop delivered by volunteer mentors. It introduces 12-year-old students in primary classrooms to Universal Design as well as to the facilitating teachers and the professional volunteer mentors involved.

4.3. Universal Design in Secondary Level

The BIG IDEA education programme "…aims to put creative thinking at the centre of Ireland's second-level education system" [20]. It introduces a creative design ethos based on social themes for Transition Year (TY) students; the purpose of The BIG IDEA is to empower students through inquiry-based learning, developing critical thinking through socially conscious, human centred projects that will connect them with their peers, industry, their community and their world.

During early development of the BIG IDEA, a project in 2020 explored the feasibility for use of the Universal Design Curriculum[5] produced by the National Disability Authority (NDA) and Centre for Excellence in Universal Design (CEUD). The project informed the development of the initial BIG Idea trial that ran in spring of 2021, involving 500 students and 100 mentors. The successful trial feedback called for the inclusion of more Universal Design content in the programme. The percentage of Universal Design was increased in The BIG IDEA programme that ran in spring 2022 across all counties in Ireland involving 2000 students and 400 participating mentors.

[2] https://jai.ie/
[3] https://dublincity.ie
[4] https://universaldesign.ie
[5] Available on request from info@ceud.ie

Impact review and feedback on the successful Big Idea programme has identified an opportunity to further embed Universal Design through collaboration on the development of additional materials. The project partners developed a set of curriculum materials to support learning. This step-by-step practice for design methods can be utilised in the Big Idea programme called the "Creativity Card Kit. The Big Idea programme is showing strong growth and plans to expand exponentially.

4.4. Universal Design at Third Level

To reflect the differences between third-level education and the Primary and Secondary levels which precede it, the examples given here are geared more towards policy rather than practice.

The importance of including Universal Design in learning content should not be understated. For students, in wide-ranging disciplines, to acquire knowledge of the concepts of Universal Design is something which can inform their future careers. However, it is not enough that content relating to Universal Design is included solely as learning content. Rather, it should form the basis for assessment and/or examination. It is notable that in this regard, Engineers Ireland[6] has incorporated Universal Design into its most recent accreditation criteria. Specifically, relevant content can be found in Program Area Four where it states: "Students should have an understanding of the application of Universal Design as the design and composition of an environment so that it can be accessed, understood and used to the greatest extent possible by all people regardless of their age, size, ability or disability. An environment (or any building, product, or service in that environment) should be designed to meet the needs of all people who wish to use it" [21] This ensures that programmes which wish to be accredited by Engineers Ireland must show evidence of the inclusion of Universal Design across their content and assessment. It represents a significant step forward in recognising it as an intrinsic part of the learning and assessment undertaken by students.

Quality Qualifications Ireland (QQI) has incorporated Universal Design into its accreditation criteria for Architectural Technologist NFQ (National Framework Qualification) Level 7 – Knowledge: Design principles, techniques and methods. It requires that students "Demonstrate an understanding of the application of technical design principles, techniques and methods to address factors including but not limited to user needs, environmental impact, **Universal Design**, safety, appearance, life cycle, conservation and refurbishment" [22]. This approach may offer learning to inform future adoption of Universal Design criteria in the accreditation processes for other relevant qualifications.

5. Conclusion

Universal Design is the "highest expression of a person-centred planning philosophy which, 'to the greatest extent possible' acknowledges the real world complexity and points to a process, not to a size idealised 'one size fits all' solution" [23]. As noted previously, the right to education for persons with disabilities is enshrined in Article 24 of the UNCRPD [2]. As stated above, a Universal Design systems approach recognises the multiple layers within the human ecological framework that affect human

[6] A professional body for the engineering profession in Ireland.

development; as applied at the macro, meso, and micro levels which comprise educational systems. Following this approach will enable a greater and more diverse population to engage in active citizenship, employment and leisure activities, and to do so in a manner which reflects a greater degree of both respect and dignity.

References

[1] Government of Ireland. Disability Act [Internet]. 2005 [cited 2023 May 26]. Available from: http://www.irishstatutebook.ie/eli/2005/act/14/enacted/en/html

[2] United Nations. Convention on the Rights of Persons with Disabilities (CRPD) [Internet]. 2006 [cited 2023 May 26]. Available from: https://www.un.org/development/desa/disabilities/convention-on-the-rights-of-persons-with-disabilities.html

[3] Craddock G, Doran C, McNutt L, editors. Transforming Our World Through Design, Diversity and Education: Proceedings of Universal Design and Higher Education in Transformation Congress 2018. IOS Press; 2018 Oct 18.

[4] Department of Children, Equality, Disability, Integration and Youth. The Access and Inclusion Model [Internet]. 2016 [cited 2023 May 29). Available from: https://aim.gov.ie

[5] Department of Children, Equality, Disability, Integration and Youth . Better Outcomes, Brighter Futures: The National Policy Framework for Children and Young People, 2014-2020 [Internet]. 2019 [cited 2023 May 26]. Available from: https://www.gov.ie/en/publication/775847-better-outcomes-brighter-futures

[6] Department of Education. Inclusive Education, 2 [Internet]. 2019 [cited 2023 May 26]. Available from: https://www.gov.ie/en/policy-information/9bf5d3-inclusive-education

[7] National Council for Special Education. Inclusive Education Framework A guide for schools on the inclusion of pupils with special educational needs [Internet]. 2011 [cited 2023 May 26]. Available from: https://ncse.ie/wp-content/uploads/2014/10/InclusiveEducationFramework_InteractiveVersion.pdf

[8] Department of Further and Higher Education. Research, Innovation and Science. Programme for Access to Higher Education [Internet]. 2017 [cited 2023 May 26]. Available from: https://hea.ie/policy/access-policy/path

[9] Higher Education Authority. National Access Plan: A Strategic Action Plan for Equity of Access, Participation and Success in Higher Education 2022-2028 [Internet]. 2022 [cited 2023 May 26]. Available from: https://hea.ie/policy/access-policy/national-access-plan-2022-2028/

[10] Solas. The FET Professional Learning & Development: Statement of Strategy 2020-2024," 2020 [Internet]. 2020 [cited 2023 May 26]. Available from: https://www.solas.ie/f/70398/x/1e2e117467/solas-professional-dev-strategy.pdf

[11] Department of Education. National Strategy for Higher Education to 2030 [Internet]. 2019 [cited 2023 May 26]. Available from: https://www.gov.ie/en/publication/072a65-national-strategy-for-higher-education-to-2030

[12] Department of Further and Higher Education, Research, Innovation and Science. National Access Plan A, Strategic Action Plan for Equity of Access, Participation and Successin Higher Education 2022-2028 [Internet]. 2022 [cited 2023 May 23]. Available from: https://hea.ie/assets/uploads/2022/09/National-Access-Plan-2022-2028-FINAL.pdf

[13] Broderick A. The Right to Inclusive Education: Article 24 of the UN Convention on the Rights of Persons with Disabilities and the Irish Experience. In: Mullally S, de Londras F, editors. Irish Yearbook of International Law 13. London, United Kingdom: Bloomsbury Publishing, 2020.

[14] Committee on the Rights of Persons with Disabilities. General comment No. 4 on Article 24 - the right to inclusive education [Internet]. 2016 [cited 2023 May 26]. Available from: https://www.ohchr.org/en/documents/general-comments-and-recommendations/general-comment-no-4-article-24-right-inclusive

[15] AHEAD. Universal Design for Learning [Internet]. 2017 [cited 2023 May 26]. Available from: https://ahead.ie/udl

[16] Craddock G, McNutt L. Rethinking the Educational Ecosystem - A Universal Design Approach [Internet]. In: Mooney B., Editor. Ireland's Yearbook of Education 2019 2020. Education Matters; 2020. Available from https://irelandseducationyearbook.ie/irelands-yearbook-of-education-2019-2020

[17] Government of Ireland. Aim Resources [Internet]. 2023 [cited 2023 May 26]. Available from: https://aim.gov.ie/homepage/resources

[18] Junior Achievement Ireland (JAI). The Power of Design - Inspiring Students to Shape their Own Future [Internet]. 2019 [cited 2023 May 23]. Available from: https://jai.ie/the-power-of-design-inspiring-students-to-shape-their-own-future

[19] The Big Idea. The Big Idea [Internet]. 2023 [cited 2023 May 26]. Available from: https://thebigidea.ie/
[20] Engineers Ireland. Accreditation Criteria 2021 [Internet]. 2021 [cited 2023 May 26]. Available from: https://www.engineersireland.ie/listings/resource/519
[21] Quality and Qualifications Ireland (QQI). Architectural Technology Awards Standards [Internet]. 2020 [cited 2023 May 26]. Available from: https://www.qqi.ie/sites/default/files/media/file-uploads/Architectural%20Technology%20Awards%20Standards.pdf
[22] Bencini GM, Garofolo I, Arenghi A. Implementing Universal Design and the ICF in Higher Education: Towards a Model That Achieves Quality Higher Education for All. In: Proceedings of Universal Design and Higher Education in Transformation Congress; 2018; Dublin Ireland. Amsterdam: IOS Press; 2018.
[23] Department of Education. Department of Education Statement of Strategy 2021-2023 [Internet]. 2021 [cited 2023 May 26]. Available from: https://www.gov.ie/en/publication/56137-department-of-education-statement-of-strategy-2021-2023/

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Analysing Italian Inclusive Education Practices in Relation to Universal Design for Learning Principles

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Abstract. This study aims to investigate how teaching practices in the Italian inclusive education system align with the principles of Universal Design for Learning (UDL), which is aimed at providing access to education for all students, including those with disabilities. In line with Article 2 of the Convention on the Rights of Persons with Disabilities (CRPD), which requires states to promote Universal Design (UD) in all aspects of life, including education, this research examines the extent to which the Italian education system meets this requirement. The study involved teachers who participated in a course on inclusive education. The research was conducted in three phases, including the introduction of UDL, identification of teachers' perceptions and initial reactions to UDL, compilation of a questionnaire related to UDL checkpoints, and a focus group discussion on teachers' attitudes towards UDL and the use of information and communication technologies (ICTs) in the classroom. The analysis focused on the first UDL principle, "Provide Multiple Means of Representation," which emphasizes the need to present information in an accessible way to learners with disabilities. The findings revealed that despite not having previous training on UDL, teachers in the Italian inclusive education system use ICTs in their daily teaching practices to make knowledge accessible, which is in line with the UDL principles. However, the study also highlighted a lack of awareness and reflection on the use of ICTs in teaching, suggesting the need for specific training to enhance inclusive practices. This study contributes to the ongoing dialogue on inclusive education in Italy and highlights the importance of promoting UD principles in education to ensure that all learners, regardless of their abilities, have equal access to education. Furthermore, it underscores the significance of providing adequate training and support to teachers to facilitate inclusive practices and improve learning outcomes for all students..

Keywords. Higher education, universal design, inclusion, Italian educational system

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1. Introduction

Inclusive education in Italy started more than 45 years ago with the aim of creating schools open to all students in which to offer quality education and instruction. These ideas and the aims to provide equitable and accessible educational opportunities to all students, regardless of their abilities, has been embraced internationally [1]. The CRPD [2] highlighted the importance of promoting Universal Design in art. 4 general obligations.

In education, Universal Design for Learning (UDL) [3] is an approach to inclusive education that focuses on providing multiple means of representation, expression, and engagement to ensure that all learners can access and participate in educational activities accompanying them in a process that increases their self-regulation in learning. Italy has made significant strides towards building a more inclusive education system, but it is essential to examine the extent to which UDL principles are being implemented in teaching practices.

Our research interest is linked to initial teacher training as it becomes a space and moment to promote the acquisition of pedagogical, didactic and technology competences aimed at overcoming barriers to learning for all students.

This study aimed to investigate the extent to which teaching practices in the Italian inclusive education system align with UDL principles, specifically the first principle of "Provide Multiple Means of Representation". In particular, we've questioned: "How teaching practices coming from the Italian inclusive education system, match up with UDL principles?"

2. Methodology

This investigation takes the form of a case study focused on a specialized course for support teachers, which is part of a broader research framework involving several Italian universities.

2.1. The research sample

The study engaged 120 teachers, sample, who participated in a specialization course on inclusive education, at master level. Consequently, the sample consists of individuals with specific teacher training or who have successfully completed an open competition exam and have chosen to specialize in school inclusion processes.

Table 1. Sample distribution.

Gender	F	86%
	M	14%
Age Range	20-29	9,6%
	30-39	47,8%
	40-49	26,1%
	+50	16,5%
Role	Teacher	85,3%
	Educational assistant	3,5%
	Other	11,2%

The sample is characterized by a significant representation of females, aligning with national teacher statistics, and comprises individuals already employed in schools on fixed-term contracts.

2.2. Methods

The research was conducted in three phases:

(1) Training on UDL.
(2) Compilation of a questionnaire related to UDL checkpoints.
(3) Focus group discussion on teachers' attitudes towards UDL.

Training on UDL

During the specialization course, participants received three hours of dedicated training on Universal Design for Learning (UDL), complemented by online study materials and resources. After one month, a second three-hour meeting was conducted, where participants collaborated in groups to discuss their work experiences and re-evaluate them through the lens of UDL. The final hour was dedicated to group presentations and feedback from instructors.

Completion of a questionnaire related to UDL checkpoints.

A questionnaire was developed based on the graphic organizer provided by CAST [4]. Participants were asked to provide a brief description of a teaching activity they had conducted and self-assess the extent to which they considered each UDL checkpoint during the activity's design, using a scale from 1 (never) to 4 (always). Additionally, for each checkpoint, participants were required to indicate the actions they had taken to implement it. This step allowed researchers to assess the relevance of the actions in relation to the checkpoints, serving as a control to verify the accuracy of self-assessment regarding the presented design. The questionnaire was administered through Moodle. While our courses are mandatory, we utilize Moodle for organizing supplementary activities, sharing materials, facilitating communication, and more. The self-assessment data were quantitatively analysed to provide a percentage-based description of participants' perceptions. Regarding the provided examples, a qualitative analysis was conducted by categorizing responses into two groups: "relevant" and "not relevant" to the checkpoints.

Focus group discussion on teachers' attitudes towards UDL:

Finally, a focus group discussion was arranged with 30 teachers during their practical training on Information and Communication Technology (ICT). The purpose was to explore the extent to which they had internalized UDL and consciously applied it in their teaching practice. The data generated from the discussion were analysed using content analysis [4].

3. Results

What follows is the presentation of the self-assessment and self-perception.

The results that emerge from the three guidelines of the first principle return a very positive perception and self-assessment. From the comparison with the examples that each student has represented emerges a discrepancy of values as shown below:

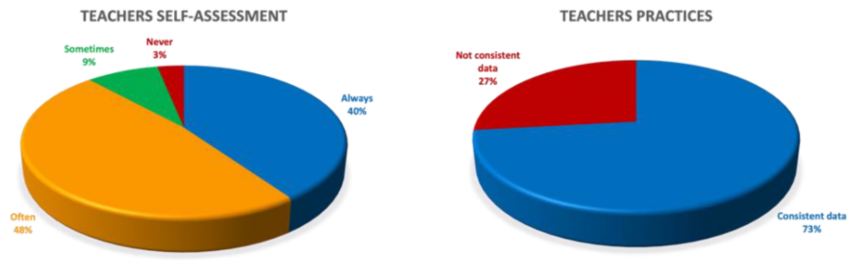

Figure 1: Provide options for perception (Guideline 1).

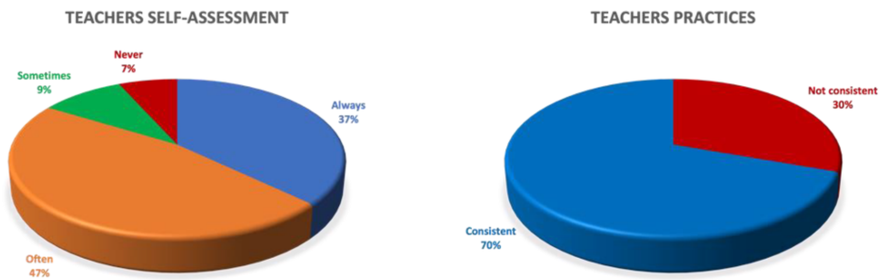

Figure 2: Provide options for language, mathematical expressions, and symbols (Guideline 2).

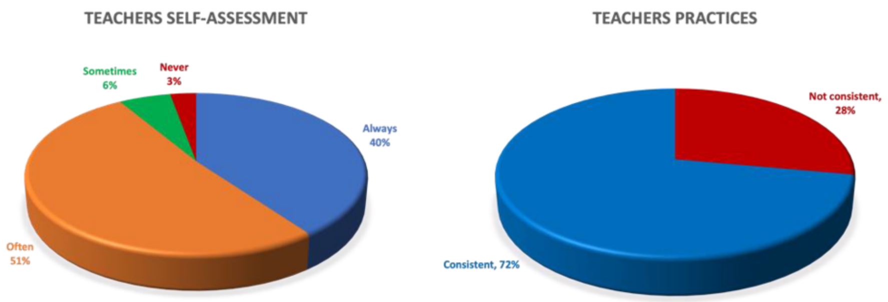

Figure 3: Provide options for comprehension (Guideline 3).

Despite this discordance, over 70% of the students gave examples that match the checkpoints.

Regarding the focus group, a very positive attitude towards UDL and its application emerged.

The analysis of the interventions revealed two categories of answers, on the one hand many teachers reported applying UDL criteria in their daily practice, even without being aware of it.

> "*I have noticed many aspects, in the guidelines, that in my experience as a teacher I had not taken into account... there is much to learn.*" (Teacher 15)[2]
>
> "*I found myself using the UDL, without being so conscious*" (teacher 7)

The second category of answers concerns the less experienced participants in the course also highlighted the need for a more comprehensive didactic training during their initial education, as they felt they lacked the necessary skills. This required extra effort on their part during the specialization course and led them to identify UDL as a valuable support tool.

> "*To me, as a teacher with little experience, UDL is an excellent help for teachers*" (Teacher 12)
>
> "*The UDL is a formidable tool for the teacher, it allows you to pay attention to what you do and that you could do, is a guide and a reminder, can act both as a check list and logbook*" (Teacher 6)

Therefore, we can say that thanks to a design that takes into account the heterogeneity of the classroom and the tools for promoting integration and school inclusion implemented in the Italian context, there is a teaching approach that aligns with the principles of UDL.

4. Conclusions

From this preliminary study it emerges that, in response to our initial question, there is a concordance between what is done in Italian schools and the principles of the UDL. This makes us think that the principles of universality and inclusive educational design belong to the culture of the Italian school that has been able to make commendable progress in promoting inclusion and catering to the diverse needs of students. The emphasis on recognizing the uniqueness of each student and fostering collaborative learning has created an inclusive educational environment. However, there are still areas that require attention and improvement [6].

One significant aspect is the need for guidelines, such as Universal Design for Learning (UDL), to assist less experienced teachers in curriculum design. Providing these teachers with practical frameworks like UDL can enhance their ability to meet the needs of diverse learners effectively.

Furthermore, there is a need to enhance the didactic competences of general education teachers during their initial training. Equipping teachers with the necessary skills and knowledge to address the diverse needs of students from the beginning of their careers can greatly contribute to inclusive education.

While the Italian education system has embraced inclusivity long time ago [7], there may be challenges in finding and utilizing resources effectively. The creative use of available resources is vital, but it is essential to address the difficulties teachers may face in accessing appropriate resources to support inclusive practices.

The implementation of UDL has proven beneficial in activating metacognitive processes related to the use of technology in teaching practices. By employing UDL

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[2] Translated by the authors

principles, teachers are encouraged to reflect on their instructional strategies and adapt their approaches to meet the needs of individual students effectively.

In the light of these considerations, it would be desirable to implement UDL research by opening up different paths:

- the different universal design models applied in education and training in order to identify affinities with the Italian pedagogical teaching tradition
- teachers specific training on universal design
- comparison between UDL and didactic, as pedagogical, teaching, educational and organizational mediators processes

In conclusion, overall, the Italian education system has made impressive strides towards inclusion, and the critical adoption of UDL principles aligns well with the existing culture of inclusivity. By addressing the needs of less experienced teachers, enhancing initial training, improving resource accessibility, and leveraging UDL, the Italian education system can further strengthen its inclusive practices and continue to provide quality education for all students.

References

[1] UNESCO. The Salamanca Statement and Framework for Action on Special Needs Education. [Internet] 1994 [cited 2023 June 21]. Available from: https://unesdoc.unesco.org/ark:/48223/pf0000098427
[2] United Nations. Convention on the Rights of Persons with Disabilities. [Internet] 2006 [cited 2023 June 21]. Available from: https://www.un.org/disabilities/documents/convention/convoptprot-e.pdf
[3] Meyer A, Rose DH, Gordon D. Universal design for learning: Theory and practice. CAST Professional Publishing; 2014.
[4] Luo A. Content Analysis Guide, Methods & Examples. Scribbr. [Internet] 2022 [cited 2023 June 21]. Available from: https://www.scribbr.com/methodology/content-analysis/
[5] Wakefield, MA. Universal design for learning guidelines version 2.2, graphic organizer [Internet] 2018 [cited 2023 June 21]. Available from: https://udlguidelines.cast.org/binaries/content/assets/udlguidelines/udlg-v2-2/udlg_graphicorganizer_v2-2_numbers-no.pdf
[6] Mura A. Diversità e inclusione. Prospettive di cittadinanza tra processi storico-culturali e questioni aperte, Milano, FrancoAngeli; 2016.
[7] de Anna L. Pedagogia speciale. Integrazione e inclusione, Carocci, Rome; 2014.

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I'm in Tales MOOC on Tangible User Interfaces and the UDL Model: A Case Study Design

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Abstract. This paper presents the design and implementation of a Massive Open Online Course (MOOC) developed on Universal Design for Learning (UDL) principles within the I'm in Tales Erasmus Project, focused on Tangible User Interfaces (TUIs) and their potential in enhancing storytelling for inclusive education. The MOOC aims to equip educators with the knowledge and skills necessary to design and implement TUIs in educational settings, promoting their understanding of TUIs as tools for creating accessible and engaging storytelling experiences for all learners. The course follows a self-paced and independent learning approach, incorporating active, contextual, social, and reflective learning methods. Preliminary evaluation results are discussed, and further evaluation methods are planned to assess the MOOC's impact on educators' understanding of TUIs and their potential for inclusive education. The use case presented illustrates the practical application of TUIs in universally designed learning experiences. The study concludes that the MOOC provides a valuable resource for educators and learners interested in TUIs and their role in enhancing inclusive education.

Keywords. MOOC, tangible interfaces, UDL, inclusive education.

1. Introduction

This study describes the design and the implementation of a MOOC on the adoption of innovative technologies such as Tangible User Interfaces (TUIs) using the UDL principles. The MOOC is going to be co-created within an Erasmus+ project, I'm in Tales, involving partners from different European countries and educational systems.

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TUIs are becoming increasingly popular in educational settings as they provide an engaging and interactive approach to learning [1][2]. This paper describes the development and first delivery, within the I'm in Tales Erasmus Project, of a Massive Open Online Course (MOOC) [4] aimed at introducing educators to the basics of TUIs and their potential in enhancing storytelling for inclusive education. The MOOC includes theoretical and practical elements [5], which enable learners to familiarize themselves with the process of selecting, designing, and implementing TUIs for storytelling in education. The MOOC also promotes educators' competences in acknowledging and identifying TUI as a tool for creating accessible and engaging storytelling for all learners, including those with disabilities. The use case presented aims to demonstrate the application of TUIs in universally designed learning experiences.

The use of technology in education has evolved over the years, with the development of TUIs providing new opportunities for enhancing learning experiences. TUIs allow learners to interact with digital content in a tangible and physical way, which can enhance engagement and understanding. This MOOC aims to introduce learners to the basics of TUIs and their potential in enhancing storytelling for inclusive education. The MOOC includes both theoretical and practical elements, which enable learners to gain the knowledge and skills required to select, design, and implement TUIs for storytelling in education. The MOOC also promotes educators' competences in identifying TUI as a tool for creating accessible and engaging storytelling for all learners, including those with disabilities.

In recent years, TUIs have gained significant attention in educational settings due to their ability to provide an engaging and interactive approach to learning [1][2]. These interfaces enable learners to interact with digital content in a tangible and physical manner, which has the potential to enhance engagement, understanding, and inclusivity in education. This scientific paper focuses on the development and initial delivery of a Massive Open Online Course (MOOC) within the I'm in Tales Erasmus Project, specifically designed to introduce educators to the fundamentals of TUIs and their role in enhancing storytelling for inclusive education [4].

The MOOC serves as a comprehensive learning platform that incorporates both theoretical and practical elements [5]. It offers educators the opportunity to familiarize themselves with the process of selecting, designing, and implementing TUIs for storytelling in educational contexts. By integrating theoretical knowledge with hands-on activities, the MOOC enables learners to develop the necessary skills and competences in utilizing TUIs effectively.

A key aspect addressed by the MOOC is the promotion of educators' competences in acknowledging and identifying TUIs as a valuable tool for creating accessible and engaging storytelling experiences for all learners, including those with disabilities. Inclusive education aims to provide equal opportunities for diverse learners, and TUIs offer a medium through which educators can cater to individual needs and preferences. By incorporating TUIs into storytelling practices, educators can create immersive and interactive learning environments that foster creativity, critical thinking, and collaboration.

The I'm In Tales MOOC showcases a use case that exemplifies the application of TUIs in universally designed learning (UDL) experiences. Universal design principles focus on creating learning environments that are accessible and beneficial to all learners, regardless of their abilities or learning styles. Through the use of TUIs, educators can adapt storytelling techniques to meet the diverse needs of their students, ensuring that every learner can actively participate and engage with the content.

2. Methods

The implementation of this course utilizes the methodology of a Massive Open Online Course (MOOC), providing learners with the flexibility to engage in self-paced and independent learning. The pedagogical approaches and methodology to be employed in this MOOC start from UDL and will involve methodologies promoting [3]: (a) active learning in an online environment, (b) contextual learning, (c) social learning and (d) reflective learning [3].

Active learning is fostered through a variety of activities and content developed using techniques such as discovery learning, project-based learning, and collaborative learning. These approaches encourage learners to actively engage in the course material, stimulate creativity, enhance decision-making skills, and promote problem-solving abilities. The organization of modules is structured around real education or classroom projects, providing learners with an authentic learning experience that culminates in the completion of a final product. Practical and technical guidance is provided through multiple means, including guidelines, readings, and instructional videos.

Contextual learning is facilitated by tailoring "project-based inquiries" to align with learners' individual contexts and backgrounds within their local or national educational settings. The activities and problem-based learning scenarios are designed to help learners identify the relevance and significance of their engagement in the course, highlighting how the knowledge and skills acquired can address challenges encountered in their own classrooms. The incorporation of appropriate case studies further enhances the simulation of real-world scenarios.

Social learning is promoted by integrating online collaborative tools and social media platforms within the modules. Interactive and collaborative activities encourage various forms of interaction, including learner-to-learner, content-to-learner, and technology-to-learner interactions. Learners are encouraged to participate in peer review processes and provide feedback to their peers, fostering a sense of community and collaboration within the course.

Reflective learning is an integral component of the course, aligning with the importance of reflective practice in early childhood education. Participants (learners) are actively engaged in reflective practice activities that encompass their own learning experiences as well as the learning experiences of their students during the development and implementation of TUI storytelling activities. The modules are connected to the participants' real classroom environments, allowing them to apply the concepts and techniques learned in the course. Online diaries/journals and "reflection moments" through the use of personal videos serve as tools to facilitate reflective thinking and documentation of insights and observations.

By employing these pedagogical approaches and methodologies, the course aims to create a dynamic and interactive learning environment that supports active engagement, relevance, social interaction, and reflective thinking. Through a combination of theoretical knowledge, practical application, collaborative activities, and opportunities for self-reflection, participants are provided with a comprehensive learning experience that equips them with the skills and competences necessary for incorporating TUIs effectively into their educational practices.

2.1. I'm in Tales MOOC Design

With these premises, the involved partners have designed the structure of the MOOC with the aim of training general and special education teachers to implement a methodology based on the tangible user interfaces (TUI) paradigm. To achieve this goal, the following steps has been followed for the MOOC development:

- Definition of the training approach and curriculum design
- Creation of content for different modules
- Localization in the languages of various partners and pilot sites
- Validation

Upon enrolling in the course, learners will be asked to provide feedback regarding how the MOOC has equipped them with the essential knowledge and skills to design and implement tangible user interfaces (TUIs) in their respective educational environments. Their reports will offer insights into the course's effectiveness in empowering educators to perceive TUIs as valuable tools for creating inclusive and captivating storytelling experiences for all learners, including those with disabilities.

3. Preliminary Results

As first step it has been defined a MOOC syllabus with the competence framework as reported in the table below:

Table 1. I'm in Tales MOOC Competence framework

Area 1: storytelling methodology	**Knowledge**	**Skills**	**Attitudes**
Competences related to the design and development of storytelling experiences and activities for all learners In the following aspects: - Basic principles of **engaging storytelling** - **Digital Storytelling** - Learners as **co-creators**	**Storytelling:** **A1.K1.** To be aware of the basics of storytelling methodology for young learners	**Storytelling:** **A1.S1**. To develop storytelling activities that engage all learners	**Storytelling:** **A1.A1.** To reflect on learners' competences and needs in relation to engagement in storytelling
	Digital Storytelling: **A1.K2.** To be familiar of the basic principles of digitalisation of storytelling activities (why and how are they different from other forms)	**Digital Storytelling:** **A1.S2**. To digitally transform storytelling activities that engage all learners and encourage participation and role-play with technological means	**Digital Storytelling:** **A1.A2.** To acknowledge the added value of digital storytelling in terms of pedagogy as well as accessibility
	Co-design: **A1.K3.** To be familiar with the main elements for engaging children as co-designers and active participants in storytelling	**Co-design:** **A1.S3.** To design storytelling activities in collaboration with students including adaptations for children with disabilities.	**Co-design:** **A1.A3.** To value co-creation and co-design of storytelling activities with learners and colleagues.
Area 2: Disability & Inclusion	**Knowledge**	**Skills**	**Attitudes**
	Barriers:	**Barriers**:	**Barriers**:

Competences related to understanding disability in terms of barriers and importance of designing inclusive learning environments In the following aspects: - Identifying and responding to **barriers** - Fostering **Inclusive Education** - Universal Design - **Learning for all** - Integrating **technology** into learning	**A2.K1.** To be aware of the physical, digital, societal and other barriers to participation for all learners and especially learners with disabilities.	**A2.S1.** To seek and reduce barriers to learning and participation in all aspects of the curriculum and lesson design	**A2.A1.** To value sharing with colleagues ideas, experiences and obstacles on responding to the needs of learners with disabilities
	Inclusive Education: A2.K2. To be aware of the basics of inclusive education as a whole school approach for all learners	**Inclusive Education: A2.S2.** To design learning and play activities that promote all learners' development, education, collaboration and participation	**Inclusive Education: A2.A2.** To support and share the right for inclusive education for all children in school settings
	UDL: A2.K3. To be aware of the Universal Design for Learning Framework	**UDL: A2.S3.** To implement the Universal Design for Learning Guidelines with the use of technology in learning design	**UDL: A2.A3.** To seek to raise awareness about inclusive learning design within one's setting
	Technology: A2.K4. To be aware of the importance and the benefits of the use of technology for all learners and especially learners with disabilities	**Technology: A2.S4.** To integrate the use of technology in all aspects of the curriculum and learning process design.	**Technology: A2.A4.** To be motivated to foster all learners' active use of technology in classroom
Area 3: TUI technology for education and storytelling	**Knowledge**	**Skills**	**Attitudes**
Competences related to understanding and using TUI technology and be able to integrate it in playful storytelling and learning activities In the following aspects: - Familiarizing with **TUI technologies** - Integrating **TUI in educational activities** - Integrating **TUI in storytelling**	**TUI: A3.K1.** To be aware of the basics of TUI technologies	**TUI: A3.S1.** To manage set up, maintenance, upgrades and safety of TUI technologies by young learners	**TUI: A3.A1.** To recognize the limitations of TUI technology resources and seek continuous improvement
	TUI in Education: A3.K2. To be familiar with the principles and the uses of TUI technologies in education	**TUI in Education: A3.S2.** To design TUI technology enhanced learning activities for all learners	**TUI in Education: A3.A2.** To acknowledge the added value of TUI technologies in education
	TUI in Storytelling: A3.K3. To identify the main components of integrating TUI elements in storytelling activities	**TUI in Storytelling: A3.S3.** To integrate TUI technologies in storytelling activities for all learners	**TUI in Storytelling: A3.A3:** To acknowledge the added value of TUI technologies in storytelling
Area 4: Evaluation	**Knowledge**	**Skills**	**Attitudes**

Competences related to selection and development of flexible and accessible evaluation activities to monitor and assess all learners' progress and participation though constructive feedback In the following aspects: - Developing **alternative and on-going evaluation approaches and tools that foster a pedagogy of documentation** - Integrating **TUI in evaluation methods**	**Alternative evaluation/Pedagogy of documentation: A4.K1.** To identify the main characteristics of alternative and accessible evaluation as part of a pedagogy of documentation **TUI Evaluation methods: A4.K2.** To identify which elements of TUI can be implemented in evaluation and feedback as part of a pedagogy of documentation	**Alternative evaluation/Pedagogy of documentation: A4.S1.** To provide alternative methods of evaluation of learning, language, motor and sensory learning, development and performance of all learners. **TUI Evaluation methods: A4.S2.** To develop evaluation tools including TUI technologies for all learners	**Alternative evaluation/Pedagogy of documentation: A4.A1.** To seek for self-improvement by reflecting on all learners' progress and participation **TUI Evaluation methods: A4.A2.** To value the added value of TUI technologies in learners' evaluation activities

Under this framework there have been designed the learning objectives addressing each and every defined area. This led to a MOOC with four modules:

- Module 1 - Storytelling: Storytelling methodology, Introduction to digital storytelling, Digital storytelling: I'm in Tales practice
- Module 2 - Inclusive Pedagogies and Technology: Challenges to storytelling: identifying barriers to learning process, Inclusive education and UDL, Accessibility and technology, Evaluation of learning experience,
- Module 3 - TUI Interfaces in Education and Storytelling: Introduction to TUIs, Introduction to TUIs for storytelling, TUIs for storytelling in practice
- Module 4 - I'm in Tales TUI experiences: I'm in Tales Use cases

4. Limitations and future work

The findings of this study are yet to come and are expected to highlight the critical importance of adopting the Universal Design for Learning (UDL) model in the design and implementation of online courses, such as the I'm in Tales MOOC focusing on Tangible User Interfaces (TUIs). Preliminary evaluations of the MOOC and its implementation tools were conducted by the partners of the I'm in Tales project [4]. However, these evaluations served as an initial assessment, and further steps involve deploying an active evaluation method to demonstrate the transformative impact of the MOOC on educators' understanding of TUIs and their potential in enhancing storytelling for inclusive education.

Learners who enroll in the course will be requested to provide feedback on how the MOOC equipped them with the necessary knowledge and skills to design and implement TUIs in their own educational settings. Their reports will shed light on the effectiveness of the course in empowering educators to recognize TUIs as a valuable tool for creating accessible and engaging storytelling experiences for all learners, including those with disabilities.

The use case presented within the MOOC is expected to be particularly valuable in demonstrating the practical application of TUIs in the context of Universal Design for Learning (UDL) experiences. Through this use case, participants will witness firsthand how TUIs can be incorporated to facilitate inclusive education. By showcasing real-life scenarios and their successful implementation, the MOOC aims to provide concrete evidence of the benefits and potential impact of TUIs on enhancing inclusive education.

The study will employ a combination of quantitative and qualitative data collection methods to gain a comprehensive understanding of the MOOC's effectiveness and impact. Quantitative data will be gathered through surveys and analytics tools, providing insights into participants' appreciation of the course content and their engagement rates. On the other hand, qualitative data will be obtained through surveys and interviews conducted with both learners and educators, allowing for a deeper exploration of the course's quality, relevance, and effectiveness in meeting their educational needs.

The analysis of both quantitative and qualitative data will provide valuable insights into the effectiveness of the MOOC in promoting understanding and competence in the use of TUIs for inclusive education. These results will contribute to the growing body of evidence supporting the role of online courses in enhancing educators' awareness and skills related to TUIs and their potential impact on creating inclusive learning environments.

Overall, the anticipated results of this study will demonstrate the significance of the UDL model in designing and implementing online courses, such as the I'm in Tales MOOC, and provide evidence of the MOOC's efficacy in educating educators and learners about TUIs and their potential in enhancing inclusive education. The findings will contribute to the advancement of inclusive educational practices and highlight the transformative potential of TUIs in fostering accessibility, engagement, and meaningful learning experiences for all learners.

5. Conclusions

In conclusion, the evolution of technology in education has opened up new avenues for enhancing learning experiences, and TUIs have emerged as a promising tool in this regard. This MOOC serves as a platform for educators to gain a comprehensive understanding of TUIs and their potential in enhancing storytelling for inclusive education. By equipping educators with the knowledge and skills required to incorporate TUIs effectively, the MOOC empowers them to create engaging, accessible, and inclusive learning environments for all learners. Through the integration of theoretical foundations, practical application, and a focus on universally designed learning experiences, this MOOC aims to inspire educators to embrace TUIs as a means to transform education and foster meaningful learning outcomes. The use case provides a practical example of how TUIs can be integrated into UDL experiences, demonstrating the potential of TUIs in enhancing engagement and understanding for all learners[9].

Acknowledgments

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References

[1] Shaer O, Hornecker E. Tangible user interfaces: past, present, and future directions. Foundations and Trends® in Human–Computer Interaction, 2010;3(1–2):4-137, http://dx.doi.org/10.1561/1100000026
[2] Almeida J, Baloian N. Tangible user interfaces in education. Computers & Education, 2015;81:381-392.
[3] Picciano AG. Theories and frameworks for online education: Seeking an integrated model. Online Learning, 2017;21(3):166-190. doi: 10.24059/olj.v21i3.1225
[4] I'm in Tales Erasmus Project. MOOC: Tangible User Interfaces for Storytelling in Inclusive Education. 2021. Retrieved from https://www.imintales.eu/
[5] Siemens G. Massive Open Online Courses: Innovation in education? In: McGreal R, Kinuthia W, Marshall S, editors. Open Educational Resources: Innovation, Research and Practice. Commonwealth of Learning and Athabasca University. 2013; p. 5-16.
[6] Ciampa K. Learning in a Tangible World: The Intersection of Tangible User Interfaces and Education. Journal of Educational Technology Development and Exchange, 2014;7(1):1-14.
[7] Siemens G. Connectivism: A learning theory for the digital age. International Journal of Instructional Technology and Distance Learning. 2005;2(1):3-10.
[8] Bellotti F, Berta R, De Gloria A, Lavagnino E. A gamified approach for improving participation in a MOOC for teachers. Computers & Education. 2014;78:142-152.
[9] Kuhn J, Brodersen C, Seeberg I. Applying Universal Design for Learning (UDL) principles in a MOOC. Journal of Educational Technology Development and Exchange. 2018;11(1):1-14.

Assistive Technology and Inclusive Early Childhood Education

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Development of Orientation and Mobility Training System for Visually Impaired Children Using VR

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Abstract. Visually impaired children do Orientation and Mobility(O&M) training to acquire the abilities to walk alone with white cane. The abilities to walk alone are to discriminate sound sources, localize sound sources, recognizer sound motion or echoes, and form a mental map. A mental map is a map formed in the brain, and visually impaired people create a map mainly from sound information. Walking without sight is dangerous, so many assistants are needed during O&M training. However, due to the shortage of O&M specialists, the time which visually impaired children do O&M training is becoming shorter. Therefore, we developed an O&M training system on a map created in a Virtual Reality (VR) space to eliminate the danger and alarm which visually impaired children feel during O&M training, and to enable safe and secure O&M training with fewer assistants.

Keywords. Orientation and Mobility training, VR, VI children

1. Introduction

Visually impaired children do Orientation and Mobility(O&M) training to acquire the abilities to walk alone with white cane. The abilities to walk alone are to discriminate sound sources, localize sound sources, recognizer sound motion or echoes, and form a mental map. Furthermore, in Japan, they practice walking using braille blocks installed on roads.

Walking without sight is dangerous, so many assistants are needed during O&M training. However, in Japan, due to the shortage of O&M specialists, the time which visually impaired children do O&M training is becoming shorter. Therefore, we developed an O&M training system on a map created in a Virtual Reality (VR) space to eliminate the danger and alarm which visually impaired children feel during O&M training, and to enable safe and secure O&M training with fewer assistants. We have constructed a walking practice system for visually impaired children that uses a map created in a VR space and a swivel chair to move around [1,2]. Users of the system using swivel chair bounce their legs up and down and rotates the chair while they are seated in the chair. It is safe, but there are a lot of differences from the actual walking experience. We aim to construct a new system using omnidirectional treadmill which enables users

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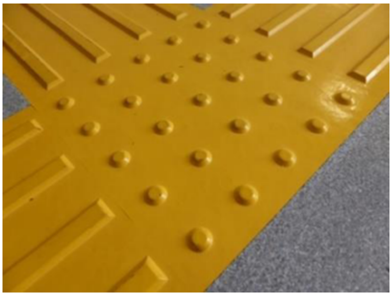
to move around in VR space by walking on an enclosure that enables blind children to practice walking safely.

2. Walking environment for the visually impaired in Japan

2.1. Visually impaired walking alone

In Japan, facilities for the visually impaired to walk alone are widely installed. Braille blocks are installed not only in public transportation facilities such as train stations, but also on sidewalks, allowing the visually impaired to walk alone with a white cane. There are two types of Braille blocks: guide blocks (**Figure 1**(a)) and warning blocks (**Figure 1**(b)). Guiding blocks indicate the direction of the path, and warning blocks warn the visually impaired of hazards such as stairs and intersections. They use Braille blocks by tracing them with a white cane or stepping on them with their feet. Furthermore, in Japan, as shown in **Figure 2**, traffic lights are equipped with a device that emits a sound to indicate that the light has turned green.

(a) Guide block



(b) Caution block

Figure 1. System overview

Figure 2. Traffic lights with sound guidance

2.2. Orientation and Mobility training for visually impaired children

In Japan, visually impaired children do Orientation and Mobility training at schools for the blind. They practice guided walking and walking along walls without support. When walking with a white cane, they practice using the cane to judge changes in the road surface, the presence or absence of sidewalk amenities, and to walk along Braille blocks and curbs. They are also trained to walk on the streets that are necessary for their daily lives and to use public transportation.

3. System

This system is designed to train creating mental map by walking on a map consisting of sound sources and braille blocks created in VR space. An overview of the system is shown in Figure 3.

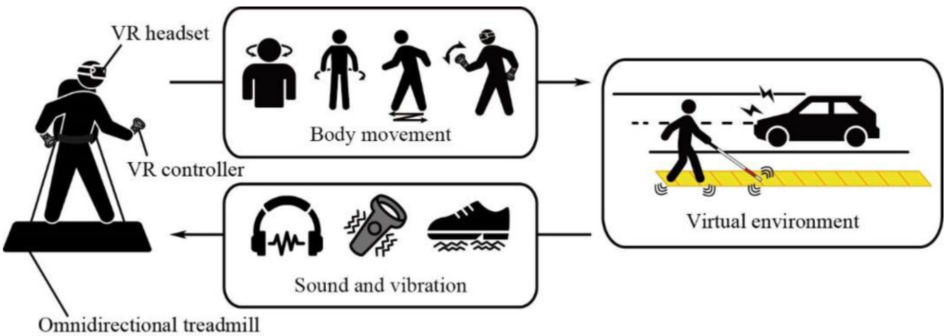


Figure 3. System overview

3.1. Hardware

The Meta Quest2 VR headset (Meta Platforms, Inc.) [3] was used to capture head and hand movements. Head motion is captured in three degrees of freedom using a head-mounted display and hand motion is captured in six degrees of freedom using a controller. Furthermore, the omni-directional treadmill KAT WALK mini S (KAT VR), shown in Figure 4, was used to acquire body orientation and gait information. An omni-directional treadmill is a device that enables movement in a VR space by detecting walking motion on it using multiple sensors such as pressure sensors and infrared sensors. The communication method of each device with the PC is shown in Figure 5. KAT WALK mini S is connected to a PC via USB. The Meta Quest2, a standalone VR headset, was connected using Air Link, a function that allows it to be used as a PCVR by using Wi-Fi.

Figure 4. KAT WALK mini S

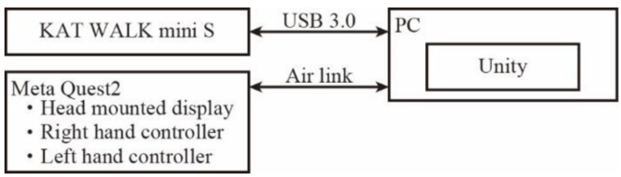


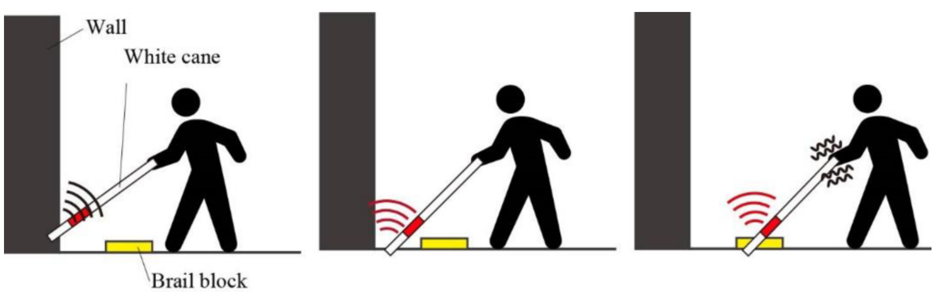
Figure 5. Connecting method

3.2. Software

Unity (Unity Technologies Inc.), a game development engine, was used to create the map in the VR space. Steam Audio (Valve Corporation), a 3D audio SDK, was used to stereo localize the sound sources in VR space. The XR Interaction Toolkit and OpenXR Plugin, Unity's native XR toolkit, were used to capture the movements of Meta Quest2.

3.3. Reproduction of the white cane

This system uses sound and controller vibration to reproduce a white cane (**Figure 6**).



(a) Collide with wall **(b) Collide with ground** **(c) Collide with brail block**

Figure 6. Reproduction of the white cane

When the white cane collides with an object such as a building in VR space, a sound is emitted from the point of collision to indicate the collision with the object and its position. By changing the sound between the building and the ground, the user is shown what the white cane is colliding with. When the white cane collides with a Braille block, the controller vibrates with the sound to indicate the position of the Braille block. When the user steps on a warning block, the base plate of the KAT WALK mini S vibrates to indicate that the user has stepped on the warning block.

3.4. Reproduction of echo localization and sound insulation effects

Echolocation is the ability to detect the distance, direction, and magnitude of an object by the reverberation of sound. The visually impaired tap the ground with a white cane to actively emit sound and perform reverberant localization. It is also possible to detect the presence of an obstacle by the change in sound pressure caused by the obstacle blocking the sound, i.e. the sound attenuation effect.

4. Experiment

4.1. Experiment Overview

We conducted an experiment to evaluate whether the hardware can be used by children, and whether they can actually walk without visual information and form a mental map. Scene from the experiment is shown as **Figure 7**.

Figure 7. Scene from the experiment

4.2. Subjects

As a preliminary step to the experiment with visually impaired children, an experiment was conducted with three normal children. Information about the subjects is shown in Table 1.

Table 1. Information about the subjects

Subjects	Sex	Age	Height [cm]	Weight [kg]
A	Male	8	122	25
B	Male	10	130	25
C	Male	11	127	27

4.3. Experimental procedure

In this experiment, they walked the map three times. In the first time, the participants practiced walking on a treadmill with visual information. In the second time, after explaining the use of the white cane, they practiced walking with visual information in order to confirm the feedback about the white cane. Finally, they walked without visual information and confirmed whether they could walk to the goal with only sound information and the white cane.

4.4. Map

The map used in this experiment is shown in **Figure 8**. This map includes the sounds of children playing in a park, noise of moving car, traffic light sounds, and voice guidance indicating the location of building entrances. The red line on the map is the route used in the experiment, and the distance is about 100 meters in the VR space.

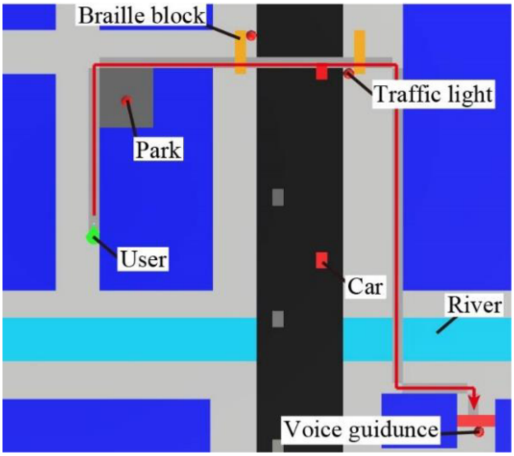


Figure 8. Map used in the experiment

5. Results

All subjects were able to finish the goal without visual information. The time required for each subject is shown in **Table 2**. When walking without visual information, some subjects lost their direction of travel, so we guided by voice.

Table 2. Result of the experiment

Subjects	Time [sec]		
	1st time	2nd time	3rd time
A	310	330	522
B	491	305	327
C	N/A	257	268

The following is a list of comments received after experiment.

- Sometimes, no matter how hard subjects move their feet, they can't move forward.
- The body is facing oblique to the direction of travel.
- Subjects get stuck in a wall in the VR space and lose their orientation.

About the first problem, since we do not know the cause of the problem, we need more subjects to cooperate with us to study the walking method. In addition, it is necessary to verbalize the walking method for the visually impaired because they will need to use the device without visual information when they actually use it. About the second problem, because the harness for fixing the body is heavy, when it is bent, the direction of the body and the direction of the harness become misaligned. About the 3rd problem, we eliminated the possibility of the user falling into a wall in the VR space. We are considering the creation of a device that vibrates on the shoulder of the side that collided with the wall to indicate which side collided with the wall in relation to the direction of travel.

6. Conclusion

Although many problems were found in the prototype system, we were able to confirm that the children could walk to the goal without visual information. In the future, we plan to develop a feedback device for when the child collides with a wall and a force presentation device for a white walking cane.

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References

[1] Seki R, Shimomura Y, Asakawa N, Takasugi K. Proceedings of the 29th JSPE Graduation Research; 2022 Mar 15-17; Tokyo Japan, p. 64-65.
[2] Shimomura Y, Seki R, Wada H, Asakawa N. Proceedings of the 22nd APIEMS; 2022; Taichung Taiwan
[3] MetaQuest2 [Internet]. Available from: http://www.meta.com/jp/quest/products/quest-2/
[4] KAT VR JP KAT WALK mini S [Internet]. Available from: https://katvr.jp/product_katwalk_minis.php
[5] Unity [Internet]. Available from: https://unity.com
[6] Steam Audio [Internet]. Available from: https://valvesoftware.github.io/steam-audio/

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The Design and Implementation of Technology-Based Inclusive Classroom Activities in Inclusive Early Childhood Education and Care: A Pilot Study in Four European Countries

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Abstract. Access to inclusive and qualitative education on an equal basis is a clear right of every child, even from the very beginning in Early Childhood Education and Care (ECEC). However, inclusive education is often not possible without access to appropriate (assistive) technologies. Notwithstanding the opportunities of technology to enhance inclusion of all children, it is still limitedly integrated by educators and teachers into their curriculum. Therefore, the SKATE project aims in gearing innovative technology as resource for inclusive education. This study describes and evaluates the preparation, the design, the implementation, and the effects of technology-based classroom activities in inclusive ECEC. The classroom activities are developed and implemented by school teams of 14 preschools spread over four European (EU) countries. A total of 50 school team members participated in a SKATE Learning Programme. This resulted in more than 20 technology-based inclusive class activities, created by school teams together with technology experts. Across the four countries, approximately 330 pre-schoolers, with and without special educational needs (SEN), participated. At this moment, 13 school team members from four EU countries and 45 parents from two EU countries evaluated the technology-based inclusive classroom activities. Nearly all teachers agreed that the activity promoted the inclusion of all children. Teachers reported that most of the children enjoyed the activity. This was confirmed in the evaluation by the parents. Most parents had the impression that the activity was meaningful, joyful and inclusive for all children.

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Keywords. Inclusion, Early Childhood Education and Care, Assistive Technology, Information and Communication Technology, technology-based inclusive classroom activities

1. Introduction

Access to inclusive and qualitative education on an equal basis is a matter of all levels of education, i.e., from the very beginning in Early Childhood Education and Care (ECEC) [1]. However, inclusive education is often not possible without access to appropriate (assistive) technologies [2]. Moreover, the UN Convention on the Rights of Persons with Disabilities states that the use of (new) technologies, including Information and Communication Technologies (ICT) and Assistive Technologies (AT), should be promoted [1]. In literature various opportunities and benefits of implementing ICT and AT in ECEC (e.g., developing problem-solving thinking, supporting collaborative learning, equal play and social interaction, enabling participation, developing expressive and receptive communication skills and language, increasing independence) are described, but also various barriers (e.g., access to technology, attitudes towards technology, concerns about the negative impact of technology, digital competencies of the school team/educators, lack of knowledge of existing technologies and on the use of AT, financial barriers, absence of ICT and AT policies) [2-6] .

Inclusive education involves improving the quality of education for all children. It not only consists of removing barriers, but also in creating an enabling environment for quality in ECEC, at all levels. This is demonstrated in the Ecosystem Model of Inclusive Early Childhood Education [7]. The model can be served as a framework for planning and implementing technology-based inclusive classroom activities and identifies five dimensions: 1) Outcomes of inclusion (e.g., child belongingness), 2) Processes for enabling child's participation (e.g., involvement in daily activities), 3) Structural factors within ECEC environment (e.g., accessible environment, qualified staff, collaboration with families), 4) Structural factors outside the ECEC setting (e.g., collaboration with support services) and 5) Structural factors at a national level of policy and practice (e.g., right-based approaches).

Notwithstanding the opportunities of technology to enhance inclusion of all children, we still see limited actions by educators and teachers to integrate ICT and AT into their curriculum [8]. Therefore, the SKATE project aims in gearing innovative technology as resource for inclusive education. The SKATE project also aims to encourage and support educators and teachers in the use of technologies (ICT and AT) with the aim of increasing the quality of inclusive ECEC for all children, and for children with special educational needs (SEN). (SKATE project: Skills & Knowledge on Assistive Technology in Early Childhood Inclusive Education (Erasmus+KA201, No. 2020-1-BE02-KA201-074810, https://skateerasmus.be)).

To achieve these objectives, among others, the SKATE Learning Programme has been developed. (https://skateerasmus.be/learning_programme/) This was done in several collaborative workshop sessions with experts (researchers, teachers, supporting teachers, occupational therapists, speech therapists) from the four involved European (EU) countries. The programme consists of 4 modules: 1) Inclusive education and early childhood education, 2) Using ICT with early learners, 3) Using AT with early learners and 4) Creating digital inclusive education in early education settings. Depending on the existing competences of teachers and their training needs, it can be opted to offer the entire programme or part of it. In addition, the Learning Programme was conducted in the four European countries: Belgium, Cyprus, Italy, and The Republic of North Macedonia. It served as the starting point for developing technology-based inclusive classroom activities in cocreation with school teams and technology experts.

2. Aim

The aim of this pilot study was to describe and evaluate the preparation, the design, the implementation, and the effects of technology-based classroom activities in inclusive ECEC. The classroom activities were developed and implemented by school teams of 14 preschools spread over four European countries.

3. Method

The pilot study was structured in several phases consisting of preparation, design, implementation, and evaluation of technology-based inclusive classroom activities. These phases were carried out in each of the four European countries.

In the preparation phase, each country informed the ECEC settings within its own region about the study. Inclusion criteria for participation were the presence of at least one pre-schooler with special educational needs in the class group and participation of the involved school team into the SKATE Learning Programme. If the ECEC setting decided to participate in the study, the involved school team was informed about the study design (preparation, design, implementation, and evaluation of technology-based classroom activities), and invited to participate in the SKATE Learning Programme on inclusive education and (assistive) technology.

During the design phase, school teams, with the guidance of technology experts, designed an inclusive classroom activity using ICT and AT. The aim of this activity was to enhance the participation of all children, and in particular the participation and inclusion of the child with special educational needs. In doing so, the school teams made use of two templates: 1) a Use Case Template, for describing the profile of the child identified as a child with special educational needs and 2) an Activity Template, which support the development of the technology-based inclusive classroom activity. In the Use Case Template, teachers noted the strengths and capabilities of the child with SEN, the official diagnosis or disability, the child's goals in the classroom, the current use of (assistive) technology if any, and the support already provided by the school. For all cases pseudonyms have been used and no personal data other than the disability has been provided by teachers. The Activity Template was meant to guide teachers in planning the inclusive classroom activity. Teachers thus reflected on the main objectives of the lesson; the sequential steps of the activity and how these steps can be differentiated through Universal Design For Learning (UDL) and (assistive) technology, the organisation of the classroom, the persons involved (e.g., school team members, paramedics, parents, peers) and their role and tasks.

School teams themselves selected the (assistive) technology and the activity, which could be thematic or within a regular activity carried out using (assistive) technology with a specific focus on inclusion. Next, the inclusive classroom activity was implemented with all relevant stakeholders, e.g., teacher(s), (special) educator(s), paramedic(s), parent(s), and peers.

At the evaluation phase, the involved school team and parents were asked to complete a survey to evaluate the inclusive classroom activity, each from their own perspective. School teams evaluated the design and implementation of the activity, as well as the effects for classroom practice and their young learners. Parents of children with and without special educational needs were asked for their opinions on the technology-based inclusive activity and effects for their child. Preschool children, because of their young age, were not surveyed directly. The level of enthusiasm of the pre-schoolers during the classroom activity is reflected in the responses of the school team and parent(s).

In each country, local standards on ethical approval were respected and informed consents were obtained from all individual participants before data collection. Data collection was anonymous. The data obtained were analysed and processed according to the General Data Protection Regulation (GDPR). The data collection was conducted at the local level (per country) in the local languages. Then the data were translated to English and anonymous analysed (in QuestionPro) all together for the four EU countries.

4. Results

4.1. Preparation phase: SKATE Learning Programme

A total of 50 school team members (teachers, care teachers, (special) educators, pedagogical coordinators, paramedics, directors) participated in a SKATE Learning Programme across the four European countries. The English Learning Programme, developed by the project team in consultation with other stakeholders in previous stages of the project, was then localised and adapted based on the needs of the participating schools. These were identified through the Entelis self-assessment framework for schools [9].

In Belgium, two Learning Programmes were conducted, one for the school support team and one for five school teams (teachers, care teachers, pedagogical coordinators, directors). The Learning Programme for the support team consisted of two face-to-face sessions of each three hours. The first session (7 attendees) was an introduction to Inclusive Education and technology (ICT and AT) and the second session (15 attendees) was a hands-on session to get to know, and try out, (assistive) technologies. The Learning Programme for school teams consisted of one online session and three face-to-face sessions. The first online session (2h, 5 attendees) focussed on Inclusive Education and Early Childhood Education. The second (3h, 7 attendees) and third (3h, 4 attendees) sessions focused respectively on the use of ICT and AT with young learners. Both were hands-on sessions in which the attendees experienced different (assistive) technologies. The last session (3h, 10 attendees) was about creating digital inclusive ECEC and designing technology-based inclusive classroom activities Attendance per session fluctuated based on the needs of the support team and school teams and unforeseen circumstances such as illness.

The Cypriot Learning Programme was conducted face-to-face with an online platform for self-study (Google Classroom) for six ECEC teachers. The Learning Programme consisted of four sessions of three hours of face-to-face meetings each. Preparation and self-study time was configured by each participant according to own pace and availability. The trainers were three SKATE researchers and an ECEC teacher/collaborator expert in Inclusive Education. The competences, learning outcomes and activities of the Learning Programme were based on the starting proficiency level of the attendees. The first session was about Inclusive Education. The second session focussed on AT. During the third session the teachers learned to design technology-based classroom activities and the last session was about whole school approach, collaborations, and an implementation plan for the use of technology to enhance inclusion of children with special educational needs in classroom activities. In Italy, the local Learning Programme was conducted face-to-face during six sessions of each two hours. A total of 12 teachers, educators and special educators followed the training given by two special educators and an informatic engineer. All four modules were covered but the focus was on using AT with early learners. The North-Macedonian Learning Programme was conducted face-to-face during four sessions of each five hours. Five teachers, one special educator and one social worker attended the Learning Programme given by two SKATE researchers. All four modules were covered during the Learning Programme.

4.2. Design phase: developing technology-based classroom activities

Over the four countries, school teams together with technology experts designed a total of 21 technology-based inclusive class activities, using the Activity Template. Each activity was focused on the inclusion of at least one child with special educational needs. The Use Case Template was completed for each child and was used both to meet the child's needs and to maximise the child's abilities and skills in the activity.

4.3. Implementation of the technology-based classroom activities

Across the four countries, approximately 330 pre-schoolers, with and without SEN, from 14 preschools were involved in the technology-based classroom activities.

Five Belgian preschools were involved and in each preschool the school team implemented one technology-based classroom activity. Approximately 100 children participated in the activities, of which six children with special educational needs. Technologies (ICT and AT) used during the classroom activities were: digital story sequencer, talking photo album, Osmo educational games system for iPad, C-pen, GoTalk, talking picto wall (Touch and Talk), and talking clothes pegs. In Cyprus six preschools were involved. In total, about 120 children, including seven children that have an official disability diagnosis and several other children that seem to face a few challenges but are not (yet) diagnosed/assessed, participated in six technology-based classroom activities. The following (assistive) technologies were used: talking photo album, BigKeys keyboard, BigTrack (trackball), CBoard, LED board, interactive whiteboard, and symbols (e.g., Widgit). In Italy, two preschools were involved and in total they implemented five technology-based classroom activities. Around 30 children, of which five children with special educational needs, participated in activities with (assistive) technologies such as a projector, sensors, a tablet, educational software and Augmentative and Alternative Communication (AAC) adapters. One North-Macedonian kindergarten has implemented five technology-based classroom activities. There were about 80 children of which five children with an official disability diagnosis involved in the classroom activities. Technologies (ICT and AT) used during the activities were: Bluetooth speaker, tablet, magnifying glass, and CBoard.

Some examples of technology-based classroom activities that took place in the different countries, are: story telling with sequencing and story structure by use of CBoard; recognition of alphabet letters and phonemes in small and capital letters by labelling pictures and copy typing (e.g., from small to capital letters) with the use of a BigKeys keyboard; the use of a digital story sequencer/talking photo album during the morning circle; the use of Osmo for all young learners in one of the learning corners; and learning different syllable by use of a C-pen.

4.4. Evaluation of the technology-based inclusive classroom activities

At this moment, as activities are still going in several schools, 13 school team members from four EU countries and 45 parents from two EU countries evaluated the technology-based inclusive classroom activities. Below we present the preliminary results of the evaluation surveys for both school team members and parents.

4.4.1. Evaluations from school team members (n = 13)

Regarding to the design phase, most school team members (further referred to as teachers) were positive about the usability (n = 9) and sufficiency (n = 7) of the design phase to prepare the technology-based classroom activities. To most teachers, the Use Case Template was clear (n = 7), but most of them neither agreed nor disagreed (n = 5) or could not answer (n = 4) on the helpfulness of this template. Regarding the Activity Template the opinions differed on the clearness and helpfulness of this template. However, most teachers (n = 11) agreed that there was sufficient support from the technology experts during the design phase and adequate involvement of the whole school team/colleagues (n = 8). On the other hand, the opinions about the involvement from parents during the development of the technology-based activities differed. Finally, almost all teachers (n = 11) agreed that the design phase focussed on inclusive classroom activities instead of activities with (assistive) technology for one child.

Concerning the implementation of the technology-based classroom activities, most teachers reported that the implementation went smoothly (n = 9) with involvement of the whole school team/colleagues (n = 8) and good collaboration with all involved stakeholders (n = 10). Although, opinions differed on the involvement of parents during the implementation of the technology-based classroom activities. On the other hand, most teachers (n = 7) felt that there was adequate support from technology experts during implementation. Regarding the time intensity of implementing the technology-based classroom activities, opinions are divided. Some teachers agreed that the implementation was time consuming (n = 4), others found the implementation not time consuming (n = 5) and some nor agreed, neither disagreed on the time consuming (n = 3) or did not answer this question (n = 1).

Finally, regarding the effects of the technology-based classroom activities for the classroom practice and young learners, the evaluations were positive. Most teachers agreed that the technology-based classroom activity was tailored to their young learners (n = 10), joyful for the young learners (n = 8), promoted the inclusion of all young learners (n = 11), and worth repeating (n = 9). A quote of one of the teachers: "Very rewarding tool [Osmo], we should dare to use this more in the classroom and not just individually."

4.4.2. Evaluations from parents (n = 45)

Based on the evaluation, most parents (n = 41) were informed about the technology-based classroom activity in which their child was involved in. But on the contrary, most parents (n = 28) weren't involved in designing this activity.

Regarding the effects of the technology-based classroom activity for their child and inclusion of all children during the activity, most parents were positive. According to most parents, the classroom activity in which their child was involved, was meaningful (n = 33), joyful for their child (n = 42) and promoting the inclusion of all children (n = 24). A quote of one of the parents: “We are very grateful and happy with this device [AAC]. Our son has really changed (positively) because of it.” Finally, regarding the transferability of the (assistive) technology used in the classroom activity to use at home, the opinions of the parents were a little bit less positive. Most parents neither agreed nor disagreed (n = 20) and disagreed (n = 11) on the usability of the (assistive) technology at home. Merely six parents indicated that they would use the (assistive) technology at home as well to enhance inclusive play of all children. The most common reason was the fact that the (assistive) technology is too expensive.

5. Conclusion & Discussion

The aim of this pilot study was to describe and evaluate the preparation, the design, the implementation, and the effects of technology-based classroom activities in inclusive ECEC. The classroom activities were developed and implemented by school teams of 14 preschools spread over four European countries: Belgium, Cyprus, Italy, and The Republic of North Macedonia. A total of 50 school team members (teachers, care teachers, (special) educators, pedagogical coordinators, paramedics, directors) participated in a SKATE Learning Programme. The Learning Programme was adapted to the local context and to the training needs of the school- and support teams (number of sessions, number of hours, content, face to face and/or online sessions). All participants had the opportunity to gain experience with (assistive) technology. They all were supported by the SKATE training team in developing their own technology-based classroom activity. Several kinds of (assistive) technologies were used to pursue a diversity of (inclusive) objectives. (Assistive) technologies for the implementation of the inclusive classroom activities were provided by the SKATE team of each country.

Across the four countries, approximately 330 pre-schoolers, with and without SEN, from 14 preschools were involved in the technology-based classroom activities. Only a limited number of teachers and parents completed the evaluation form. One reason is that, in some of the schools it was not a one-off activity, so it was not obvious to have the technology-based school activity already evaluated by a large number of teachers and parents, as the activities are still going in several schools.

Notwithstanding, the preliminary results are promising. Nearly all teachers agreed that the activity promoted the inclusion of all children, which was the main goal of the activity. Teachers reported that most of the children enjoyed the activity. This was confirmed in the evaluation by the parents. Most parents had the impression that the activity was meaningful, joyful and inclusive for all children. During the design and the implementation phase, there was a good collaboration with the involved stakeholders and with the technology experts as well. There is no consensus on the involvement of parents. Although they were informed, it’s not clear if they were always invited to be actively involved in the design process and implementation. This corresponds to the parents' evaluation, where most of the parents indicate that they were not involved.

Most of the teachers find the technology-based activity worth repeating, although time investment for implementation may be a factor here. As teachers were positive about the usability of the design phase and the support they got from technology experts, the opinions on the helpfulness of the Use Case and Activity Template were mixed. In this case, it would have been interested to ask teachers whether they would develop a new activity without help from the experts and whether the templates could be helpful to them then.

This study also raises some critical considerations. Conclusions are based on limited results. Although, based on observations by researchers in the schools for which evaluations were not yet completed, most technology-based activities appear to be positively received.

All participating schools were part of an inclusive school system, even though this is not officially introduced in the policies of the countries or had already support for the child with special educational needs. This may have influenced teachers' active engagement in the SKATE project.

The inclusion criteria for this study were broad, for example, no inclusion criterium was based on diagnosis. Inclusion was based on having one or more pre-schoolers with special educational needs per class group. The outcome should not be linked to a diagnosis, but rather assessed in the overall context of the pre-schoolers. Therefore, the profiles of the children were not included in this paper.

The pilot study did not focus on the use of one specific technology, but on all possible (assistive) technologies that may be applicable with young children. Technology is not the solution to inclusion, but a means of inclusion for children with special educational needs. The role of the teacher, parents, peers and others involved should not be underestimated. The fact that many different technologies were used in this study shows that school teams are really looking for what fits best for their young learners. It is therefore important that teachers are trained in the use of (assistive) technology with young children and given support to get started with this.

References

[1] United Nations. Convention on the Rights of Persons with Disabilities. 2007 ; Article 4 & 24. https://www.un.org/development/desa/disabilities/convention-on-the-rights-of-persons-with-disabilities/convention-on-the-rights-of-persons-with-disabilities-2.html.

[2] Hunt PF. Inclusive education: The case for early identification and early intervention in Assistive Technology. Assistive Technology. 2021;33(sup1):94-101, doi 10.1080/10400435.2021.1974122.

[3] Botelho FHF. Childhood and Assistive Technology: Growing with opportunity, developing with technology. Assist Technol. 2021 Dec 1;33(sup1):87-93, doi: 10.1080/10400435.2021.1971330.

[4] Blackwell CK, Lauricella AR, Wartella E. Factors influencing digital technology use in early childhood education. Computers and Education. 2014 Aug;77:82-90. doi: 10.1016/j.compedu.2014.04.013.

[5] Murcia K, Campbell C, Aranda G. Trends in Early Childhood Education Practice and Professional Learning with Digital Technologies. Pedagogika. 2018;68(3):249–64, doi 10.14712/23362189.2018.858

[6] Lyons CD, Tredwell CT. Steps to implementing technology in inclusive early childhood programs. Computers in the Schools. 2015;32(2):152–66, doi 10.1080/07380569.2015.1038976.

[7] Bartolo PA, Kyriazopoulou M, Björck-Åkesson E, Giné C. An adapted ecosystem model for inclusive early childhood education: A Qualitative Cross European study. International Journal of School & Educational Psychology. 2019;9(1):3–15. doi 10.1080/21683603.2019.1637311.

[8] Delien T, Daems J, Mavrou K, Desideri L, Lazarev K, Blagojevska G, Efstathiadou M, Eliadou A, Gherardini A, Priori F. Perspective of Educators and Parents of Four European Countries on Integrating (Assistive) Technology in Inclusive Early Childhood Education and Care Settings. In: Petz, A, Hoogerwerf EJ and Mavrou K, editors. Open Access Compendium "Assistive Technology, Accessibility and (e)Inclusion" Part II, ICCHP-AAATE; 2022. July 11-15; Linz: Association ICCHP, 2022. 1/2: p.205-211, doi 10.35011/icchp-aaate22-p2-26.

[9] The Entelis Consortium. Digital skills development and ICT in inclusive education: A self-assessment framework for schools. 2016 (v1.0). https://www.entelis.net/wp-content/uploads/2020/12/entelis_self_assessment_framework_for_schools_version_1.0_-_2016.pdf.

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Augmented Tactile Book: Design of a Multisensory Page Prototype

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Abstract. In the framework of the LTA project, focusing on leisure reading for children with visual impairment, we present a prototype of multisensory illustration that will be used as a model for future accessible tactile interactive books. This multisensory illustration is based on two approaches to illustrate the storytelling. The first approach consists in embodying the character's legs with the index and middle fingers in order for the user to imitate actions such as walking. The second approach is to offer interactions feedback according to the readers actions. The main goal of this multisensory illustration prototype is to test and evaluate a selection of interactions and their associated sensors. These interactions help visually impaired readers to identify the environment of the story. They also help to understand actions behind the verbs. Readers are engaged to produce actions such as touching and imitating with their fingers. These interactions are developed according to hypotheses based on the literature. This multisensory illustration prototype was tested with a panel of children. The results comfort the idea that these interactions are useful for them.

Keywords. multisensory illustration, visually impaired children, tactile book

1. Introduction

This research work focuses on the design of multisensory illustrations, its main objective is to propose new solutions fitting reading needs for children with visual impairments. [1] emphasises the importance of illustrations for vocabulary acquisition by young readers, so it is relevant that most children's book are illustrated. The images make it possible for readers to identify the environment of the story and thus to assign meaning to the words. They also allow readers to understand the concepts of actions behind verbs, especially thanks to the images that illustrate dynamic movements. For children with visual impairment, authors stress the importance of tactile illustrations as alternatives [1,2,3]. Such illustrations are composed of different textures including fabrics and various materials. They help visually impaired readers to identify characters and the narrative environment. These illustrations cannot be immediately recognised by touch as the visual illustrations are for sighted children. They need a mediation associating each tactile element (like a piece of fabrics) with its meaning. Then they help following the dynamics of the story, page after page. The problems are that: the mediation is performed by an adult or by an-

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other child (sighted), meaning a lack of autonomy from visually impaired readers. And also that these tactile illustrations are limited in information and interactions.

D. Valente [1,4] introduced the concept of embodiment using two fingers to enhance the interactions. Basically the child uses the hand to represent a character – index and middle fingers representing the legs, allowing to "imitate walk" within the tactile illustration. She [5] tested her concept with sighted and visually impaired children. Blindfolded, they were invited to read 3D tactile illustrations that stimulate their sensory-motor memory. For example, they had to climb the steps of a staircase with their fingers to understand the action of climbing the steps and identify the staircase.

The works presented in this paper continue the LTA project ("*Livres Tactiles Augmentés*", literally "Augmented Tactile Books") [2], which aims to encourage the readers to produce gestures. In the framework of this project, an augmented tactile book was produced by LDQR with the support of 2 research laboratories : CHArt (University Paris 8) and DIPHE (University Lyon 2). This book, entitled *"Kapi Kapitaine"*, was written by a French author of children's book. The recent emergence of tiny programmable electronic devices such as programmable micro-controllers and their vast ecosystem of sensors allowed to develop a new approach a new approach: in the LTA project, tiny sensors are embedded within the tactile illustrations themselves, and they are controlled by a programmed micro-controller to develop interactive illustrations. The sensors are located inside the page, while the micro-controller is hidden in the cover. The sensors detect the actions performed on the page by readers and offer them perceptible non visual feedback. They create a communication between readers and the book and therefore lower the need of mediation, allowing more autonomous reading.

The first objective of the works presented in this paper is to develop a multisensory illustration model to use for future augmented tactile books. Interactions should be accessible and useful to young readers with visual impairments. The majority of these interactions are coming from the LTA project. They can be divided into two groups: the active ones and the passive ones. Active interactions are actions produced by readers and interpreted by the illustration. Sensitive surfaces have been selected as the active interactions. They allow the illustration to locate the contact positions of the readers fingers. They also measure the pressure exerted by the fingers. Passive interactions are the non-visual feedback produced by illustration and perceived by readers. In this prototoype, sound and vibration feedback are tested. Passive interactions are associated with active interactions to help readers to interact with the multisensory illustration. This combination of interactions is our main solution for an autonomous and immersive reading session.

2. Hypotheses

Our main objective is to enhance readers immersion with the multisensory illustrations. An extensive literature about this kind of interactions, and the various sensors that are necessary to implement them, can be found.

We suppose that active interactions will engage the readers to produce actions. We think that applying the haptic scenarios from [1,4] using electronic sensors, associated with different kind of feedback, will help the readers to better understand the concepts behind verbs. The child user is proposed to embody the character's legs, using two fingers, and to imitate the actions described in the narration. We have selected two differ-

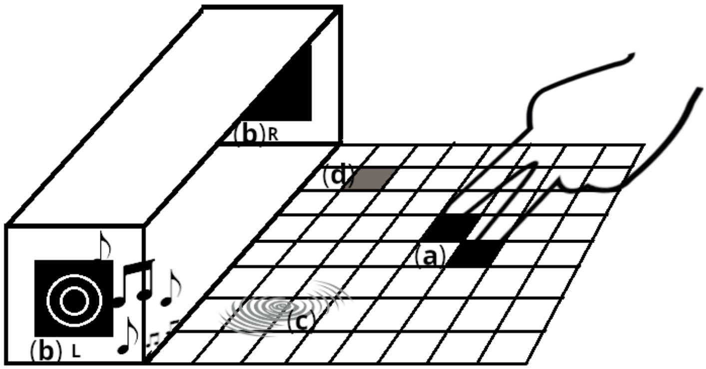

Figure 1. Prototype diagram with the following sensors: (a) matrix page that allows for locating finger positions and measuring exerted pressures, (b) two speakers R&L for the stereo sound, (c) vibratory devices and (d) capacitive surfaces

ent active interaction methods to detect the child's action on the page of the book. The first one is based on the capacitive effect, it allows to detect when the readers fingers is touching some of the elements located on the page. We can then deliver feedback when the readers touches the connected tactile textures from the multisensory illustrations like in [2]. It may be used to explain the meaning for each tactile element used to illustrate the story as a mediation. The second active interaction method is based on resistive effect. The resistive effect consists in measuring the pressure exerted on a surface by the fingers. We have been designing a matrix page which draws these ideas from [2,6] using resistive effect. This matrix page is able to locate the cell on which a pressure is exerted its surface. We assume that this matrix page may allow the readers to enhance the way they imitate different actions such as walking, running or jumping into the multisensory illustration itself. Providing appropriate sound feedback according to the fingers positions in the matrix page make the environment of the story more immersive, this is the role of passive interactions.

Passive interactions are therefore very important in this context. They are the main source to illustrate the story. In our prototype we use sound and vibratory perception. When it comes to accessible projects for visually impaired users, sound feedback is the main issue. [7] used different aspects of sounds feedback (sound effects), to immerse the readers in an accessible comic books. [8] show good results for the vocabulary memorisation with vocal reading. In our prototype we will use these aspects of sound feedback for an immersive reading. We will focus on another sound aspect which is the stereo. We think that using stereo which means using two speakers, one from the readers right side and the other from the readers left side will enhance the immersion. It will use the concept of space. Using stereo allows to moving sounds from the right to the left speakers and vice versa, in order to help readers to better understand dynamic movements. We assume that plyaing sounds from the left or the right side can be used ti help the readers to find hidden items. Vibrations, which commonly used in [9] and [10] also use the concept of stereo. This concept for vibrations means to describe a movements thanks to several vibratory devices. If we activate one after the other several vibrators a vibration will move through the multisensory illustration. We assume that this will also illustrate dynamic movements or an element of the story.

3. Method

For validating our hypotheses, we have been designing a storytelling together with a prototype of matrix page. The storytelling features a character to embody, and which will be associated with the multisensory illustration. The system consists of three parts (1) the story, (2) the matrix page prototype and (3) a tactile illustration in which some active elements are embedded. We need to test each interactions one by one, in order to observe how children are using them. The prototype reads the story and engages the readers to interact with it's sensors according to our scenario. A session takes about ten minutes.

3.1. The Story

The story tells about *"Teddy"*, a little bear who is looking for three ingredients, in order to make a honey cake for his birthday. To evaluate the matrix page prototype, we have been asking readers to embody *Teddy* with their fingers, imitating the action of walking on the tactile space, and to look for the different ingredients. To find the way, the user can hear some auditory clues giving directions. For instance the bees are making honey, so following the bees sound will lead to it. The two other ingredients, eggs and milk, are localised respectively with sounds of hen cackling and cows mooing. Each time an ingredient is found, *Teddy* carries it back home and then looks for another one. When all ingredients have been gathered, the narration ends with *Teddy* cooking the cake and blowing out the candles.

3.2. The Prototype

To detect pressure, we use a sheet of "Velostat" [6], allowing to modify the flowing electrical current according to the pressure exerted on its surface. The electrical current increases proportionally with pressure. The matrix is a flat canvas composed of two series of parallel conductive bands separated by a sheet of Velostat. The top and bottom series are arranged perpendicular to each other. This will give us the location of the finger. Each series is connected to analogue input pins of a micro-controller through a multiplexer.

An ESP32 micro-controller from *Adafruit* is used to develop this prototype. Stereo output is provided by a pair of loudspeakers, one located on the left of the setting, one located on the right. The speakers are connected to the system through two I2S amplifiers from *Adafruit*.

The controller's code was developed in *CircuitPython*, which includes specific sound libraries allowing for sound mixing, which is needed for our purpose. Then a time-based algorithm allows for detecting if and where the matrix is touched and in this case for measuring the pressure exerted by the fingers. In addition, some of the micro-controller's pins are available to be connected to parts of the tactile illustration. Some of the pins offer an option called "Touch", which is able the use of the capacitive effect.

3.3. The Tactile Illustration

The tactile illustration is made of different pieces of fabric sewn together. The items which *Teddy* is to look for, are made of conductive fabrics, so the system can recognise when the reader touches one of them with a finger, thanks to the capacitive effect. Tiny motorised vibratory devices are embedded in the illustration. Conductive fabrics and vibrators are directly connected to the controllers pin mentioned above (see **Figure 2**)

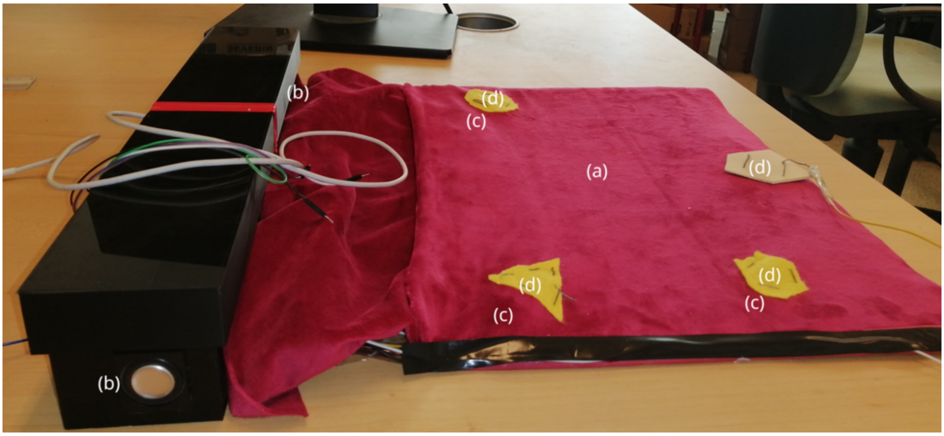

Figure 2. Picture of the multisensory illustration prototype. The prototype offers a storytelling and interactions thanks to: (a) the matrix page, (b) two speakers, (c) the vibratory sensors (they are within the page) and (d) the conductive fabrics

3.4. Scenario

The scenario is coded, as seen above in CircuitPython. Some narrative items are played first, then when an interaction is recognised, the code triggers audio and/or vibration feedback and switches the next part of the scenario. *e.g.* When the user simulates the action of walking on the tactile illustration, foot steps sound are triggered. When the conductive fabrics corresponding to an item to look for is touched appropriate feedback is triggers according to the scenario. The vibrators, activated one after the other, are used in this prototype to simulate the moves of bees.

3.5. Testing the Prototype

Our research targets young readers, with visual impairments, who are learning vocabulary. They must be aged between 6 to 11 years old. We had the opportunity to participate in an event called *Science Infuse*. The event took place at the *"City of Sciences and Industry"*, a famous science museum in Paris, from 24 to 30 April 2023. After approval by the ethical committee, we could evaluate our prototype with children visiting this event, under the responsibility of their legal tutors (mostly parents). After testing the prototype, the children were asked a short set of questions.

After informing them, together with their legal tutors, about their right to end the experiment anytime, to ask for deletion of the collected data, and about the way the experiment would be conducted as well as it's approximate duration. The children were seated in front of the prototype and blindfolded – to help them focus on their other senses. They had to listen to the narration, and they were asked to embody the character's legs with their middle and index finger.

The researcher observed children's interactions with the prototype to assign a value between 0, 1 and 2: 0 meaning that the subject did not understand how to interact with the system, implying that the targeted interaction was not useful; 1 meaning that the interaction had an impact but the child made mistakes; and 2 when the scenario helped the child to interact correctly, that is as expected. The set of questions following the experiment

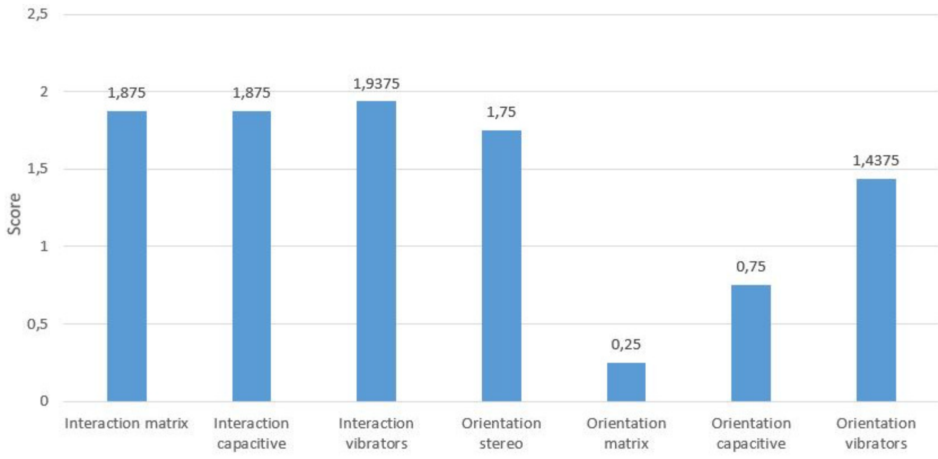

Figure 3. Scores corresponding to each interaction of the prototype tested with the children from the panel.

corresponded to the groups. The first correspond to drawing each child's profile, while maintaining their anonymity. Ages and genders may influence the outcomes. Another question of this group was about their reading habits and their familiarity with interactive toys. The second group of questions were evaluation how much of the story the children could memorise, thanks to the multisensory illustration. As they only listened to the story once. The third group of questions simply collected the children free feedback.

4. Results

A panel of 19 children (9 boys and 10 girls) tested the prototype. After the experiment, only collected data from 16 children were selected, consisting of 8 boys (aged 7-10 with an average age of about 8 years) and 8 girls (aged 7-11 with an average age of about 9 years). We selected results from children old enough to understand the experiment, and we targeted elementary school pupils.

The observation results show that vibrations seemed really effective (score of 1.875 out of 2). Children perceived that vibrations did help them to oriented within the tactile illustration improved the children orientation (score of 1.4375 out of 2). When they had located one vibrator, the children kept their fingers there in order to feel the vibrations. Then the vibration started to move (in fact another vibrator is activated) and, as the vibration feeling was perceived stronger when the finger were closer, the children felt they were following the bees (the vibration).

The capacitive surfaces and the matrix page have good results (score of 1.875 out of 2). Children imitated the "walk" action during the narration, thanks to sound feedback, associated with the steps. They were engaged in the production of this gesture, thanks to the matrix page. And the capacitive surfaces allowed feedback when they were touched. The children identified sound feedback with the capacitive surfaces. However, these active interactions did not help for the orientation (capacitive surfaces: score of 0.75 on 2, matrix page: score of 0.25 on 2).

The stereo sound show good results (score of 1.75 out of 2). The children were oriented thanks to the right and left speakers to imitate the walk towards the targeted items.

All these interaction results increase significantly with age. The majority of children have interactive toys and are used to read. This may explain their focus on the storytelling and their confidence in interacting with the prototype.

After the experiment, the researcher asks questions to write the impact of the prototype and the children comments. All the children seemed to focus on the narrative, they were engaged when interacting with the multisensory page. Some of them posted smiles, they all said they liked the selected interactions. Some of them were disturbed by vibrations, but find them easy to interact with. They all listened to the story once, when it comes to summarize it, the older and more engaged ones could provide a lot of details. It's worth noting that they all built their abstracts, thanks to the interactions they experienced through sensors. The majority mentioned they were *"walking"*, *"going toward animals"*, *"looking for ingredients"*, *"following bees with vibrations"*, etc. These answers are based on verbs and actions. These actions are produced thanks to the multisensory illustration. Then it seems this had an impact on the storytelling memorisation.

5. Discussion

The results sound very interesting, showing some improvements to be done in our setting, and allowing us to refine consistently our objectives. One strong limitation of this prototype is that it contains a unique multisensory illustration. Next step will be to build a book with multiple pages including various multisensory illustrations, designed for each part of the narrative. Turning the pages should help readers understand that they can interact differently with different multisensory illustration.

Testing this prototype in a public event, with random sighted children from the public (they had to come and to ask to try it) is a good start and allows for more participants than limiting to children with visual impairment. It allow also to improve our prototype before using it with blind children. The drawback is that it was not possible to organise a control group, and of course being blindfolded is not comparable to any visual impairment. In next step we will include children with visual impairment, not only to test, but showing them this and elaborating with them about the kind of books they want (including the kind of interaction but also the subjects and whatever they could mention).

6. Conclusion

The test results show positive use of the interactions based on sensors embedded in the page. They have engaged the production of gestures such as imitating walking, touching targeted objects, going toward sound sources and following the vibrations movements. They also support our hypothesis on the application of stereo for orientation.

We are currently working on next prototypes, allowing to introduce and evaluate new kind of interactions and features, and to support books with multiple pages. In addition, too new features are in development: a glove to allow to analyse finger gestures with a good accuracy; and a bracelet to allow the user to embody different characters of the book, with different feedback according to the selected character. To select a character the user will connect a tangible avatar to the bracelet.

Augmented tactile books can be used for leisure – promoting access to reading –, which would be already enough. They can also be useful for a large range of educative or therapeutic purposes, such has psychomotor exercises or reading sessions with children with autism for instance. We started a new project, entitled *LTA-Conception*, which goal is to make it possible for a range of professionals to create some contents fitting their needs. They do not have programming or electronic skills, but they do have ideas about how to use such augmented books for their practices. *LTA-Conception* consists in designing an authoring tool, usable by anyone, for creating augmented tactile books.

References

[1] Valente D. Haptic books for blind children : A design for all approach. Conference. In: The value of design research. Paris, France; 2015. Available from: https://ead.yasar.edu.tr/wp-content/uploads/2017/02/EAD11_Valente_Haptic-books.pdf.

[2] Archambault D, Negrerie S, Blain S. Design of Augmented Tactile Books for Blind Children. The journal on technology and persons with disabilities. 2022 May;10:219-31. Accepted: 2022-06-20T21:01:33Z Publisher: California State University, Northridge. Available from: http://dspace.calstate.edu/handle/10211.3/223476.

[3] Posch I. Crafting Stories: Smart and Electronic Textile Craftsmanship for Interactive Books. In: Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction. TEI '21. New York, NY, USA: Association for Computing Machinery; 2021. p. 1-12. Available from: https://doi.org/10.1145/3430524.3446076.

[4] Valente D, Palama A, Malsert J, Bolens G, Gentaz E. Adults' visual recognition of actions simulations by finger gestures (ASFGs) produced by sighted and blind individuals. PLOS ONE. 2019 Mar;14(3):e0214371. Publisher: Public Library of Science. Available from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0214371.

[5] Valente D, Palama A, Gentaz E. Exploring 3D miniatures with action simulations by finger gestures: Study of a new embodied design for blind and sighted children. PLOS ONE. 2021 Feb;16(2):e0245472. Publisher: Public Library of Science. Available from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0245472.

[6] Jeong E, Lee J, Kim D. Finger-gesture Recognition Glove using Velostat (ICCAS 2011). In: 2011 11th International Conference on Control, Automation and Systems; 2011. p. 206-10. ISSN: 2093-7121.

[7] Lee Y, Joh H, Yoo S, Oh U. AccessComics: an accessible digital comic book reader for people with visual impairments. In: Proceedings of the 18th International Web for All Conference. W4A '21. New York, NY, USA: Association for Computing Machinery; 2021. p. 1-11. Available from: https://doi.org/10.1145/3430263.3452425.

[8] Korat O, Shamir A. Direct and Indirect Teaching: Using e-Books for Supporting Vocabulary, Word Reading, and Story Comprehension for Young Children. Journal of Educational Computing Research. 2012 Mar;46(2):135-52. Publisher: SAGE Publications Inc. Available from: https://doi.org/10.2190/EC.46.2.b.

[9] Israr A, Zhao S, Schwalje K, Klatzky R, Lehman J. Feel Effects: Enriching Storytelling with Haptic Feedback. ACM Transactions on Applied Perception. 2014 Sep;11(3):11:1-11:17. Available from: https://doi.org/10.1145/2641570.

[10] Zhao S, Schwemler Z, Fritz A, Israr A. Stereo Haptics: Designing Haptic Interactions using Audio Tools. In: Proceedings of the TEI '16: Tenth International Conference on Tangible, Embedded, and Embodied Interaction. TEI '16. New York, NY, USA: Association for Computing Machinery; 2016. p. 778-81. Available from: https://doi.org/10.1145/2839462.2854120.

[11] Richard GT, Kafai YB. Responsive Make and Play: Youth Making Physically and Digitally Interactive and Wearable Game Controllers. In: Nijholt A, editor. More Playful User Interfaces: Interfaces that Invite Social and Physical Interaction. Gaming Media and Social Effects. Singapore: Springer; 2015. p. 71-93. Available from: https://doi.org/10.1007/978-981-287-546-4_4.

[12] Ono K, Iwamura S, Ogie A, Baba T, Haimes P. Textile++: low cost textile interface using the principle of resistive touch sensing. In: ACM SIGGRAPH 2017 Studio. SIGGRAPH '17. New York, NY, USA: Association for Computing Machinery; 2017. p. 1-2. Available from: https://doi.org/10.1145/3084863.3084868.

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'Touching' Stories: Towards the Development of Tangible User Interfaces Story-Building Authoring Tool for Inclusive Education

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Abstract. Tangible User Interfaces (hereafter, TUIs) are novel forms of human-computer interactions based on the physical manipulation of any kind of object/artifact. A great potential of TUIs technologies is the possibility to personalize objects and interaction between the user and the system. The high level of platform flexibility allows, for example, a multisensory approach, that is crucial for children that have sensory limitations and disabilities. This contribution aims at presenting and discussing the development of an authoring tool for creating TUI-supported activities for inclusive digital storytelling. The authoring tool is a product of collaboration and consultation with researchers and teachers involved in the ERASMUS+ project I'M IN TALES. A preliminary usability validation study using a mixed-method approach has been conducted involving 50 educators and assistive technology professionals. The results indicate an overall acceptance of the system. The feedback provided by the participants involved will be used for the future refinement of the tool.

Keywords. tangible user interfaces, education, inclusion, storytelling

1. Introduction

Technology in early education is a creative tool and not just a tool that supports current teaching methods. It can create creative thinkers, explorers, planners, analyzers, and collaborators.

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Technology also supports the development of children's skills, in learning, social interaction, play and collaboration [1]. While nowadays young children enjoy playing with digital means, they are also keen of engaging in real-world play activities. Balancing digital and real worlds are essential, and the use of digital technology in early age especially in the digital era is essential in early digital literacy development of children and empowerment for digital inclusion and participation [2]. In the education of children with disabilities and the promotion of inclusive education, technology holds an even more important position with different roles. The use of mainstream and assistive technologies has assumed, especially in recent years, a growing and fundamental role in schools, to eliminate and/or reduce, as much as possible, the impact of disability, impairment and difficulties in learning and education, and to sustain all learners' participation in creativity, learning and play.

1.1. Tangible User Interfaces in education

Tangible User Interfaces (hereafter, TUIs) are novel forms of human-computer interactions based on the physical manipulation of everyday objects [3].

TUIs are thus physical objects that can translate user actions into input events in the computer interface. The application of TUIs in education has shown its benefits and strengths in enhancing learning and effective educational experiences of pupils, thanks to the augmentation of learning environments [4]. In a nutshell, as shown in figure 1, in a TUI-based learning scenario the student interacts with augmented tangible objects obtaining digital feedback or interacting with other digital platforms in parallel with the traditional digital interactions (i.e., video, robot, audio speaker). Tangible User Interfaces represent a bridge between physical and digital environments. By touching and placing a physical object on a device able to recognize it the student can trigger an event (e.g., a sound, an image) on a digital device (e.g., smartphone, tablet). In this way, it is then possible for the student to learn abstract concepts through concrete representations. TUIs also support social interaction through collaboration, considering collaboration as an essential skill for social development and learning, helping children to develop communication skills [4].

One of the potential application fields of TUIs in education is storytelling and narration [4], where the interaction with tangibles could enhance the involvement of children in listening and creating stories [5]. When presenting a narration, both the digital features, such as sound or animation, and the haptic-initiated feedback represent an active and independent involvement of children in learning from narration contents [5]. A great potential of TUIs technologies is the possibility to personalize objects and interaction between the user and the system. The high level of platform flexibility allows, for example, a multisensory approach, that is crucial for children that have sensory limitations and disabilities.

However, as recently highlighted in a systematic review of the literature [5], translating the potential of TUIs into real educational practice is challenging due to the lack of accessible indications and best practice examples on how teachers can create and implement TUIs-based storytelling activities in their day-to-day activities to foster inclusive education. It is decisive to provide a methodological framework as a guide, not only to design inclusive learning through TUIs-enhanced storytelling, but also to evaluate TUIs application expected to sustain these practices, professionals, and practitioners in early years' education. Acknowledging the aforementioned needs, the I'M IN TALES project focuses on developing innovative methodologies for inclusive storytelling through technologies that are close to the way young learners experiment with and experience the worlds. More specifically, this contribution aims at presenting and discussing the first stakeholders' validation of an authoring tool for creating TUI-supported activities for digital storytelling (see Figure 1). The authoring tool allows the development of stories with audio and video feedbacks provided and created by the authors (i.e. teachers, caregivers, parents) that proceeds scene by scene by the selection of a target object.

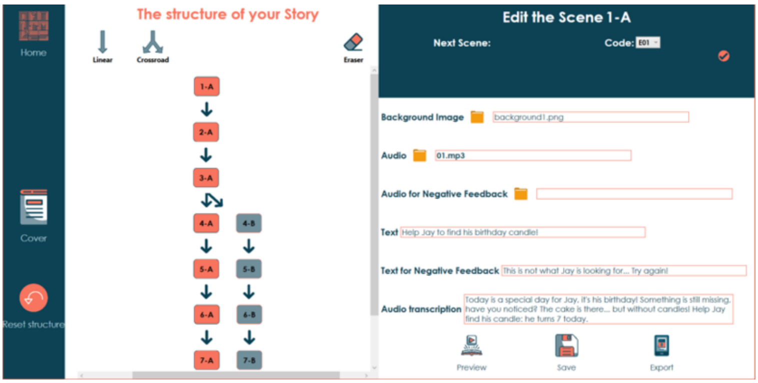

Figure 1. Screenshots of the I'M IN TALES Authoring tool.

2. Method

2.1. Development of the authoring tool

The authoring tool is a product of collaboration and consultation with researchers and teachers involved in the project. It was first developed based on feedback from teachers and educators from four European countries (Italy, Belgium, Cyprus, and Lithuania) who have been involved in living lab sessions involving storyboard building activities. Data collected from teachers have been thus analyzed and used to inform the design and development of the authoring tool (data not presented in this contribution).

2.2. First validation of the authoring tool

The scope of this contribution is to present the results of the first validation of the authoring tool developed as described in section 2.1. The validation took place in a series of open public events organized by the project's Consortium in which the authoring tool was shown to various stakeholders, mostly educators. During the public events, participants had the opportunity to work hands-on with the authoring tool and provide feedback through two usability scales (i.e., the System Usability Scale [6] and The Technology Acceptance Model Questionnaire [7]) as well as provide qualitative comments and particular suggestions for improvement. The System Usability Scale (SUS) is recognized as a reliable tool to assess usability of web-based and other applications. It includes 10 items and provides a global view of subjective assessments of usability [6]. Scores for each item are converted, summed up together and multiplied by a factor of 2,5 to result in a final usability score ranging from 0 to 100. Based on research, a SUS score above 68 would be considered above average and anything below 68 is below average [6]. The Technology Acceptance Model (TAM) questionnaire aims at quantifying the likelihood of technology acceptance. The original version of the TAM has 12 items, six assessing perceived usefulness (PU) and six assessing perceived ease of use (PEU) [7]. Because the SUS is already a measure of ease of use, for the scope of the current study we used only 5 items of the PU sub-scale of the TAM. The excluded item (i.e., job performance) was considered not pertinent to our study goals. Scores ranged from 1(Strongly disagree) to 5 (Strongly agree), with higher scores indicating higher perceived usefulness of the tested system.

3. Results

In total, 74 participated in hands-on demonstration sessions across three European countries: Italy, Cyprus, and Belgium. In Italy, participants included 30 professionals in the field of assistive technology and education. In Cyprus participants included 20 professionals in the field of early childhood education. In Belgium the sample included 24 professionals in the field of special education.

3.1. Usability assessment questionnaire

Valid responses to the usability questionnaires were collected from 50 respondents out of 57 participants who answered to the questionnaire. Questionnaires with missing responses in the SUS or the TAM were excluded from the analyses. Respondents included 42 females (84%) and six males (12%), while two respondents preferred not to disclose. On average, respondents were aged 40 years old (standard deviation [SD] = 9). The majority of the respondents (n = 41; 82%) reported to have never used a TUI before the hands-on session. Concerning perceived usability and ease of use as assessed with the SUS, the respondents overall provided positive feedback. On average, the SUS scored 68,02 (SD = 12,8).

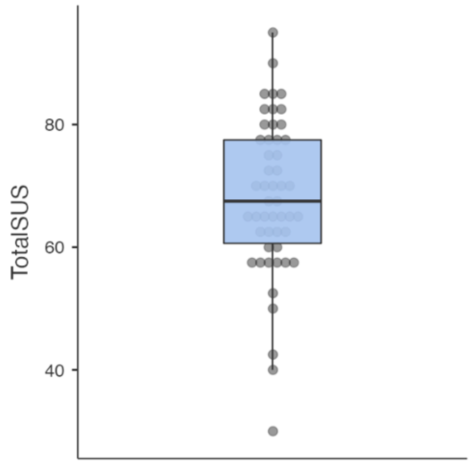

Figure 2. Distribution of SUS total scores across respondents (n = 50). The black line indicates the mean score [68,02 (SD = 12,8)].

As shown in figure 2, about half of the respondents (n = 26) provided scores below the acceptability threshold (M = 58,4), while the remaining (n = 24) provided scores well below the acceptability threshold (M = 78,4). Exploratory analyses showed a weak but significant negative association (r = -0.32; *p* = 0.02) between age and SUS total scores (figure 3), meaning that as age increases, perceived usability decreases.

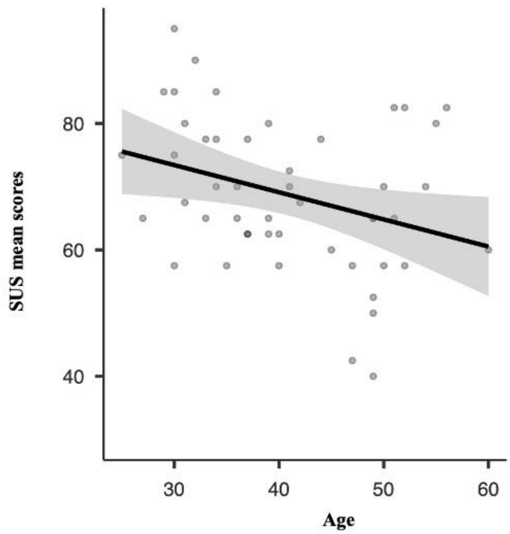

Figure 3. Scatterplot showing the association between SUS total scores and age of respondents.

3.2. Usability qualitative concerns

The qualitative comments and concerns raised by participants in the usability testing events as well as the consortium members have been mapped to Nielsen's 10 general principles [8] for interaction design, called "heuristics". In summary, overall comments were positive towards the usability of the system. Specific comments indicated that clearer visibility of the system is needed. Not all essential functions are clearly identified and in some cases the output of a function is not obvious in the editing mode. Error notifications would also be appreciated and consider that non-expert teachers/users would be largely the target population of the tool.

3.3. Perceived usefulness

Perceived usefulness as assessed with the TAM resulted overall acceptable, with an average score of 3,3 (SD = 0,8). No association was found between TAM (i.e., perceived usefulness) scores and age.

4. Conclusions

The first working concept of the I'M IN TALES authoring tool has produced positive feedback from the interested stakeholders. Further development of the system is however needed to make it easier to use and more intuitive. The next steps of the project will involve further iterations of usability evaluations and system's revision. Such activities will take place with the active involvement of students with and without disabilities along with their teachers.

References

[1] Pagliara SM. Use of Different Media and Technologies in the Inclusive Educational Didactics. In: Teaching Accessibility and Inclusion. Carocci Editore. 2016. p. 71-83.

[2] Hoogerwerf EJ, Mavrou K and Traina I (Eds.). The Role of Assistive Technology in Fostering Inclusive Education. Strategies and tools to support change. London & New York: Routledge. 2021.

[3] Shaer O, Hornecker E. Tangible user interfaces: past, present, and future directions. Foundations and Trends® in Human–Computer Interaction. 2010;3(1–2):4-137.

[4] Rodić LD, Granić A. Tangible interfaces in early years' education: a systematic review. Personal and Ubiquitous Computing, 2021;1-39.

[5] Somma F, Desideri L. A rapid review on Tangible User Interfaces-augmented storytelling in inclusive education. In: Proceedings of the Third Workshop on Technology Enhanced Learning Environments for Blended Education, June 10–11, 2022, Foggia, Italy. 2022.

[6] Brooke J. Sus: a "quick and dirty'usability. Usability evaluation in industry. 1996;189(3).

[7] Lewis JR. Comparison of Four TAM Item Formats: Effect of Response Option Labels and Order. Journal of Usability Studies. 2019;14(4).

[8] Nielsen J, Molich R. Heuristic evaluation of user interfaces, In: Proc. ACM CHI'90 Conf. (Seattle, WA, 1-5 April). 1990. p. 249-256.

AT and Children's Rights

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The Right to Assistive Technology and Accessible Instructional Materials for U.S. Students Does Not Consistently Translate into Predictable Access and Effective Use

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Abstract. Students in the United States have federally-established rights regarding access to assistive technology (AT) devices and services, yet those rights are not consistently upheld for a variety of reasons acknowledged in the literature. We conducted a interview-based study with 48 education professionals, family members and students to analyze the facilitators and barriers that influence AT access for students in the State of Delaware. Study results were consistent with the extant literature, and revealed numerous violations of student rights guaranteed under U.S. special education law. Some barriers were attitudinal, yet most arose from the inadequacy of infrastructures: professionals lacked training, funding was inadequate or difficult to access and, in most areas, there was no definitive guidance relative to the processes that should be followed and how decisions regarding AT-related decisions regarding devices and services should be documented. Elements revealed to facilitate AT access and use were the availability of resources — highly-qualified personnel, time, training, funds, and access to devices — and persistence among educators and family members in pursuing AT solutions for students.

Keywords. Assistive technology, students with disabilities, access, school, barriers, facilitators

1. Introduction

The United States has protected the rights of students with disabilities to access special education services since 1975, and special education law has undergone several

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reauthorizations since that time. Regarding assistive technology (AT) access, the law was amended in 1991 to include a definition of "assistive technology device" and "assistive technology service," both of which are entitlements under the law when warranted by student need. The legal definition of an AT device is: "any item, piece of equipment, or product system, whether acquired commercially off the shelf, modified, or customized, that is used to increase, maintain, or improve the functional capabilities of a child with a disability. The term does not include a medical device that is surgically implanted, or the replacement of such device." An AT service is defined as "any service that directly assists a child with a disability in the selection, acquisition, or use of an AT device , including:

a) The evaluation of the needs of a child with a disability, including a functional evaluation of the child in the child's customary environment;
b) Purchasing, leasing, or otherwise providing for the acquisition of AT devices by children with disabilities;
c) Selecting, designing, fitting, customizing, adapting, applying, maintaining, repairing, or replacing AT devices;
d) Coordinating and using other therapies, interventions, or services with AT devices, such as those associated with existing education and rehabilitation plans and programs;
e) Training or technical assistance for a child with a disability or, if appropriate, that child's family; and
f) Training or technical assistance for professionals (including individuals providing education or rehabilitation services), employers, or other individuals who provide services to, employ, or are otherwise substantially involved in the major life functions of that child."

These expansive definitions benefit students by reminding decision-making teams that students have a right to a broad range of equipment and a wide variety of services that influence AT assessment, acquisition, and ongoing use. With the reauthorization of the law in 1997 and the adoption of new regulations in 1999, schools were required to consider the need for AT for *every* child for whom a special education plan is developed. In the 2004 reauthorization of the law, student rights were extended to include the right to accessible instructional materials for students with a print disability. [1]

The literature abounds with examinations of factors that facilitate and limit access to AT. Among the barriers reported as limiting access are:

- limited educator training [2,3,4,5,6,7];
- lack of buy-in among stakeholders (educators, administrators, families and/or students [8,9];
- lack of time [4,7,10];
- lack of funding [3,4,10,11[;
- the rapid evolution of products on the market prevents educators from staying current [12];
- lack of ready access to AT for trial use and longer-term implementation [4,13];
- lack of an adequate evidence base supporting technology use among specific populations [10];

- overemphasis on technology applications for students with more complex disabilities [14]; and
- lack of support in technology implementation. [5,12,14]

Factors identified in the literature as facilitating access to and use of AT include: 1) pre-service and in-service training of education personnel [2,7,12,15,16]; 2) adequate deployment of AT [13]; 3) evidence that technology is providing a benefit to students [12,17]; and 4) educator confidence in the ability to make informed selection decisions and support technology use. [12]

2. Rationale

There is considerable stakeholder commitment to improving AT access for children in Delaware, a state in the mid-Atlantic region of the United States with a population of roughly one million people. Delaware has a decentralized education system that, while requiring public schools to follow federal and state law, affords localities considerable autonomy in how to implement those laws and related policies. The need for substantial revision in AT-related policies and practices was first documented in a report issued by the Delaware Department of Education. [18] In partnership with the Delaware Department of Education, the University of Delaware Center for Disabilities Studies (CDS) devised a plan to address some of the recommendations, yet this work was suspended due to pandemic-related challenges. In 2022, CDS secured support from the United States Department of Education enabling a comprehensive assessment of barriers to and facilitators of AT access and use and the subsequent development of infrastructures enabling more widespread utilization of AT. The first phase of this work involved interviews with educators, administrators and family members exploring their perspectives relative to a variety of issues identified in the literature as influencing assistive technology access.

3. Method

A protocol of issues to be explored with educators, families and students was devised by the project team and shared with stakeholders for social validation. Once the protocol was finalized, a flyer advertising the study was created with a QR code linked to an electronic recruitment form, an email, and a phone number to text or call for expressing interest in an interview. Following receipt of approval from a human subjects review board at the University of Delaware, the flyer was distributed online through collaborators associated with the Center for Disabilities Studies and also through the Delaware Department of Education. A researcher affiliated with the University of Delaware's Center for Research in Education and Social Policy conducted interviews via phone and remote meeting tools between November 2022 and March 2023. Interviews were recorded and transcribed verbatim to ensure accuracy of analysis. The research team read each interview transcript and developed descriptive codes based on the interview questions. These transcripts and codes were programmed into Dedoose for interview analysis. The team applied codes to the interviews and extracted excerpts associated with each code. They then used a three-step process to analyze the excerpts in order to produce memos for each code. These memos included assertions or themes that summarized findings for each code as well as multiple quotations that supported the assertions.

4. Results

Interviews were conducted with 45 participants, the majority (82%) of whom were professionals who worked in schools. The remaining participants were parents of students who needed or used AT and students themselves (17% parents, 2% students). The breakdown of professional respondents by role includes special education teachers (27%), speech-language pathologists (18%), special education coordinator (11%), general education teacher (7%), special education director (4%), AT specialist (4%), teacher of the visually impaired (4%), district administrator (2%), instructional coach (2%), and occupational therapist (2%).

The results reflect considerable similarity to factors reported in the literature. Regarding elements that facilitate access to assistive technology, respondents who work in the schools most frequently cited the opportunity to collaborate with others (e.g., speech-language pathologists, occupational therapists, AT specialists and tech support), opportunities for training and hands-on use, and their own persistence in breaking down barriers that stood in the way of device selection, acquisition and use. The greatest barriers noted by families and educators alike related to educators' lack of awareness, knowledge and experience with assistive technology. Most of the professionals interviewed perceived that their undergraduate and graduate education did not adequately prepare them to support AT access and use among the students they serve. Educators also noted as barriers their lack of confidence in selecting appropriate technology, in part due to their limited awareness of the current products in the marketplace, which certainly connects to overall knowledge and experiences. Families also expressed a desire for more training for their children and themselves. Access to funding, a device inventory for exploration and device deployment to students, and administrative support were also noted as vital for student AT access and use. Resistance to AT utilization was noted as a concern across respondent types. Resistance may arise from teachers who find learning and implementing AT to be overly burdensome and time-consuming. Resistance was also noted as arising from families and students who perceive that AT use will have a stigmatizing effect or that reliance on AT will hamper the development of independent skills in domains such as writing, reading or communication. Families reported that they often had to advocate vigorously in order to get AT supports approved for and implemented with their children.

5. Implications

The findings from this research suggest several remedies that must be implemented if students are to have the access to AT guaranteed them under U.S. law. Prominent among these is a need for more education regarding AT and more time dedicated to raising awareness, skill, and buy-in relative to AT implementation among educators, families and students. AT needs to be more readily available, both through device inventories but also through predictable funding mechanisms that support individualized access and use.

Also needed is greater clarification about the processes that teams should follow in considering, documenting and meeting AT needs; this would involve the promulgation of statewide guidance as well as modifications to the tools that are used to document that students are receiving the services and supports to which they are entitled under the law.

References

[1] Individuals with Disabilities Education Improvement Act Amendments of 2004 (IDEA 2004). 20 U.S.C. § 1400 et seq. (2004).

[2] Anderson SE, Putman RS. Special education teachers' experience, confidence, beliefs, and knowledge about integrating technology. J Special Education Technology. 2020 Mar;35(1):37-50. Available from: https://doi.org/10.1177/0162643419836409

[3] Atanga C, Jones BA, Krueger LE, Lu S. (2020). Teachers of students with learning disabilities: Assistive technology knowledge, perceptions, interests and barriers. J Special Education Technology. 2020 Dec;35(4):236-248. Available from: https://doi.org/10.1177/0162643419864858

[4] Chmiliar L. Perspectives on assistive technology: What teachers, health professionals, and speech and language pathologists have to say. Developmental Disabilities Bulletin. 2007;35(1&2): 1-17.

[5] Flanagan S, Bouck EG, Richardson J. Middle school special education teachers' perceptions and use of assistive technology in literacy instruction. Assistive Technology. 2013 Jan;25(1):24-30. Available from: https://doi.org/ 10.1080/10400435.2012.682697

[6] Lee Y, Vega LA. Perceived knowledge, attitudes, and challenges of AT use in special education. J Special Education Technology. 2005 Apr;20(2):60-63.

[7] Zapf SA, Scherer M., Baxter M., Rintala, DH. Validating a measure to assess factors that affect assistive technology use by students with disabilities in elementary and secondary education. Disability and Rehab: Assistive Tech. 2016 Jan;11(1):38-49. Available from: https://doi.org/10.3109/17483107.2015.1104559

[8] Copley J, Ziviani J. Barriers to the use of assistive technology for children with multiple disabilities. Occupational Therapy International. 2004 Dec;11(4):229-243.

[9] Evmenova AS, Regan KS, Schladant M, Hall TE, Buzhart J, Erickson KA, Ai J, Sudduth C, Jackson T. Stepping-up technology implementation—How does it happen? J Special Education Technology. 2023 Mar;38(1):61-74. Available from: https://doi.org/10.1177/01626434221074357

[10] Ghanouni P, Jarus T, Zwicker JG, Lucyshyn J. The use of technologies among individuals with autism spectrum disorders: Barriers and challenges. J Special Education Technology. 2020 Dec;35(4):286-294. Available from: https://doi.org/10.1177/0162643419888765

[11] Special Education Assistive Technology: A Report to the Legislature. Roseville, Minnesota: Minnesota Department of Education. 2018 Jan 22.

[12] Lamond B, Cunningham T. Understanding teacher perceptions of assistive technology. J Special Education Technology. 2020 June;35(2):97-108. Available from: https://doi.org/10.1177/0162643419841550

[13] Alsolami, AS. (2022). Teachers of special education and assistive technology: Teachers' perceptions of knowledge, competences and professional development. *SAGE Open*.2022Jan-Mar;12(1). Available from: https://doi.org/10.1177/21582440221079900

[14] Bouck EC, Long H. Assistive technology for students with disabilities: An updated snapshot. J Special Education Technology. 2021 December;36(4):249-257.

[15] Schaff DM. Assistive technology instruction in teacher professional development. J Special Education Technology. 2018 Sept;33(3):177-181.

[16] Thomas CM, Peeples KM, KennedyMJ, Decker M. Riding the special education technology wave: Policy, obstacles, recommendations, actionable ideas, and resources. Intervention in School and Clinic. 2019 May;54(5):295-303. Available from https://doi.org/10.1177/1053451218819201

[17] Boot FH, Owuor J, Dinsmore H, MacLachlan M. Access to assistive technology for people with intellectual disabilities: A systematic review to identify barriers and facilitators. J Intellectual Disability Research. 2018 Jul:62(10), 900-921. Available from: https://doi.org/10.1111/jir.12532

[18] Task Force on State Educational Technology. A Report to the 148th General Assembly on the State Educational Technology Plan in Response to Senate Concurrent Resolution #22. Dover, Delaware: Delaware Department of Education. 2016 Mar 30.

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Personalized Assistive Technologies for Motor-Impaired Students: A Case of Learning Process Mining

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Abstract. Motor disability includes the lack of sensation, movement, or coordination, and Assistive Technologies (AT) can help overcome these challenges. Motor-disabled students need different ATs and configurations depending on courses and individual needs, and some solutions can be expensive. Some affordable AT has roots in gaming but can also be used for other purposes. However, there is little research on how they can be combined to define a personalized setting. Therefore, we performed a literature review to identify challenges and solutions to support students with motor disabilities in using information systems. The result defines a framework for identifying personalized settings. The usability of the result was demonstrated by performing a self-experimentation study of the first author, who has a motor disability. The results show its utility while learning process mining using the Graphical User Interface (GUI) and code-based tools. We identified challenges in using different User Interface (UI) elements, which can be used as a guideline for designers of process mining tools as well as other information systems to support diversity.

Keywords. assistive technologies, motor disability, underrepresented groups, process mining

1. Introduction

There are more than one billion people who live with some form of disability (global population estimates, 2010), and equalizing the educational opportunities for students with disabilities is a recognized right to "develop their capabilities and skills to the maximum"[2]. This assistance requires developing and evaluating supporting services in different areas to enable equalization to enhance learning, working, and daily living, a.k.a. assistive technology (AT), in accordance with the UN standard rules on equalizing opportunities in education[3]. Some ATs are designed for accessible gaming but can also empower disabled people in other contexts. However, there is a dearth of research on how these technologies can enhance learning for students with motor disabilities in courses where Graphical User Interface (GUI) and code-based tools are used. Different sorts of disabil-

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[2]https://www.ohchr.org/sites/default/files/res3447.pdf
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ities are categorized based on different impairments [1]. Congenital diseases, illnesses, and physical trauma are only a few of the reasons for motor disabilities, but they all pose similar difficulties for users when they use a computer and the internet[2][3]. Barriers are often unnecessary and unintended by designers. Accessibility means avoiding such unnecessary barriers. Thus, the research questions are: 1) What challenges and solutions for motor-disabled students are identified in the literature? 2) How can personalized settings, which are based on the existing solutions, support students with functional motor disabilities to learn process mining, a sub-area of information systems? The first question is answered with a literature review (Section 2 and Section 3), which was then mapped as a framework to help motor-disabled students select solutions and configure settings. The second question is answered by self-experimentation (Section 4) as a motor-disabled student (the first author) with different User Interface (UI) elements. The results may also be used by designers of GUI and code-based tools. Section 5 concludes the paper and discusses the research directions.

2. Challenges

This section presents identified challenges from the literature. Three categories are defined for these challenges, i.e., Input challenges, Output challenges, and Documentation challenges [4]. The output challenge category includes the co-existence of other disabilities, which is outside the scope of this paper. Thus, we only include *Input challenges* and *Documentation challenges* categories for which we have identified 18 challenges, shown in Table 1. The *Input challenges* are categorized as several sub-categories, i.e., *accessible environment*, *fine motor control*, the *regular input devices*, and *severely hampered motor abilities*. The *regular input devices* sub-category is further split into two other sub-categories, i.e., *mouse* and *keyboard*. These sub-categories are explained as– The *accessible environment* concerns the accessibility to i) power switches (CH01), ii) keyboards (CH02), and iii) monitors (CH03) - due to lack of their proper positioning. The *fine motor control* includes challenges requiring minor adjustments in existing input devices for the motor-disabled person with reduced function in a finger, an arm, etc. It includes i) *accidental key strokes* (CH04) that causes clicking the wrong key due to lack of control, ii) *one-sided access* (CH05) that is the lack of function in one of the limbs, iii) *fine cursor movement* (CH06) that is the lack of ability to move the cursor to the intended point accurately, iv) *use of modifier keys* (CH07) that refers to the lack of ability to press two keys at once like ctrl+c, and v) *key pressed longer than intended* (CH08) that refers to lack of speed in clicking some keys to prevent repeated actions, e.g., pressing a dash (-) key longer means that it will produce a dashed-line. In a *regular input device* and within the *mouse* sub-category, we identified four challenges representing difficulty in performing some functions, i.e., *click function* (CH09), *cursor pointing* (CH10), *hold function* (CH11), and *scroll function* (CH12). In *regular input device* and within the *keyboard* sub-category, we identified two challenges, i.e., *reaching keys on keyboard* (CH13), and having *strength to press a key* (CH14). The *severely hampered motor abilities* includes *completely immobile upper limb with speech control* (CH15), which indicates the person can only use voice commands and cannot use other parts of the body. This category also includes *completely immobile upper limb without speech control* (CH16), which refers to persons that not only have limitations for the previous category but also cannot talk. The *Documentation Challenges* refers to challenges faced in reading a physical document.

Category			Challenge	Reference
Input Challenges	Accessible Environment		CH01. Power switches	[5][4]
			CH02. Keyboard Position	[5][6]
			CH03. Monitor Position	[5][6]
	Fine motor control		CH04. Accidental key Strokes	[5][4][7]
			CH05. One-sided access	[5][8]
			CH06. Fine cursor movement	[5] [9]
			CH07. Use of modifier keys	[5][10]
			CH08. Keys pressed longer than intended	[5][11]
	Regular Input devices	Mouse	CH09. Click function	[12][13]
			CH10. Cursor pointing	[14][15][16]
			CH11. Hold function	[17]
			CH12. Scroll function	[18]
		Keyboard	CH13. Reaching keys on keyboards	[5] [19]
			CH14. Strength to press a key	[4]
	Severely hampered motor abilities		CH15. Completely immobile upper limb with speech control	[5][18]
			CH16. Completely immobile upper limb without speech control	[20][21]
Documentation Challenges			CH17. Reading a physical document	[5][22]
			CH18. Accessing 'help' online	[5][23][24]

Table 1. Identified Challenges for persons with motor disability to use computer effectively. Categories are defined based on [5,19].

This category includes *reading a physical document* (CH17), *accessing 'help' online* (CH18).

3. Solutions

We identified 29 solutions in total, which are listed in Table 2. All solutions are documented in detail in GitHub[4]. As can be seen, the challenge in *accessible environment* category (CH01 to CH03) can be supported using the first two solutions, i.e., S01 and S02. The challenge in *fine motor control* (CH04 to CH08) can be addressed using S03 to S07. Here, S11 (JoyToKey program), which is a free software [45], can also support CH07 (use of modifier keys). The challenge in the *mouse* sub-category of *regular input device* (CH09 to CH12) can be addressed using S08 to S15. The challenge in the *keyboard* sub-category of *regular input device* (CH13 and CH14) can be addressed using S16 to S18. The challenge in *severely hampered motor abilities* (CH15 and CH16) can be addressed using S18 to S25. Here, S18 (virtual keyboard) also supports the keyboard sub-category, as explained before. The challenge in *documentation challenges* (CH17 and CH18) can be addressed using S26 to S29. These solutions are described below.

[4] https://github.com/Shubhra-1/AT4PM

			Challenges																	
ID	Solution name	References	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
S01	Switch interface unit	[4]	+																	
S02	Equipment that position facilities	[5]		+	+															
S03	Keyguard	[25]				+														
S04	Left- and right-handed keyboards	[5][26]					+													
S05	Mouth- or head stick for pointing	[27][28]						+												
S06	Sticky Keys	[29]							+											
S07	Disabling key repeat functions	[11][29]								+										
S08	External buttons	[30]							+		+		+	+						
S09	Trackballs	[16][15]										+		+						
S10	Joy Stick	[31]										+		+						
S11	JoyToKey program	[32]							+		+		+	+						
S12	XBox Adaptive Controller (accessible game controller)	[30][33]							+		+		+	+						
S13	Head controlled mouse emulators	[34][35]									+	+	+	+						
S14	Tobii Eye Tracking System	[36]									+	+	+	+						
S15	Google Chrome apps and extensions	[37]									+	+	+	+						
S16	Expanded keyboards	[19][25]													+					
S17	Mini keyboards	[5][19]													+					
S18	Virtual keyboard	[32][26][36]														+	+			
S19	Morse code input	[38][39]															+			
S20	Speech recognition input	[40][41]															+			
S21	Abbreviation expansion (Macro)	[42]															+			
S22	Text help systems	[43]															+			
S23	Kinect-based framework	[20]																+		
S24	Neuroprostheses and Brain-Computer Interfaces (BCI)	[21]																+		
S25	EPOC+	[44]																+		
S26	Scanning documents into accessible computers	[5][22]																	+	
S27	Electronic reading	[5]																	+	
S28	Electronic references	[5]																	+	
S29	Virtual assistance	[23][24]																		+

Table 2. A framework based on identified Solutions addressing different challenges. The dark gray cell are those solutions which are used in the experiment - explained in the next section.

4. Experiment

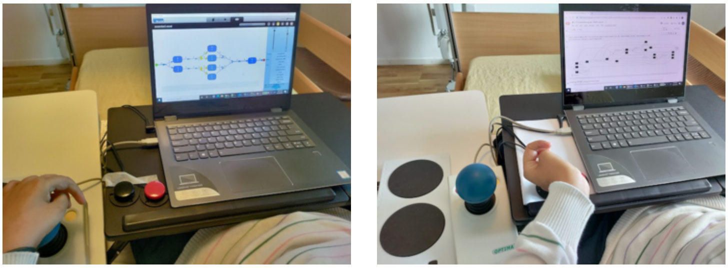
Here, results from the self-experimentation are presented in this way: 1) the conditions of the subject, 2) the process mining settings and content, 3) the results of the experiment. This can aid in helping motor-disabled students overcome barriers in GUI and code-based tools.

4.1. The subject's background

The first author is a 34-year-old master's student with cervical spinal cord injury who attended courses about process modeling, design, and mining with GUI and code-based tools. The main challenges can be summarized as i) the use of modifier keys (CH07) due to the inability to move fingers to press two or more keys simultaneously, ii) the proper use of the mouse click function (CH09) due to lack of strength to click the mouse button, iii) the accurate pointing of the mouse cursor (CH10) due to the inability of holding and moving the mouse, iv) the mouse hold function (CH11) due to inability to perform the drag and drop function which includes clicking, hold and move functions, v) the mouse scroll function (CH12) due to limited dexterity to use the 'Scroll' function, and vi) the completely immobile upper limb with speech control (CH15) due to limited physical mobility.

4.2. Assistive technologies setting

Three experiments were set up to demonstrate the applicability of our findings, called *EXP1*, *EXP2*, *EXP3*, from the described challenges by choosing appropriate solutions



(a) Using ProM with the help of ATs (b) Using PM4Py with the help of ATs

Figure 1. Experiment setups showing how process mining applications are used using selected Assistive Technologies (ATs).

based on their availability (see the dark gray cell in Table 2), which includes: S06 (Sticky keys), S08 (External Buttons), S10 (Joy Stick), S11 (JoyToKey program[5]), S12 (Xbox Adaptive Controller (accessible game controller)), S15 (Google Chrome apps and extensions), and S20 (Speech recognition input). Each of these three experiments includes sets of solutions, i.e., *EXP1* includes S06, S08, S10, S11, S12. *EXP2* includes S06, S20. *EXP3* includes S06, S10, S15.

4.3. Process mining settings

4.3.1. Process mining tools and experiment materials:

We used ProM [46] and PM4Py [47] in our experiments. ProM [46] is selected as it contains a plethora of plug-ins to support a wide range of process mining algorithms. Also, this requires a GUI for users to interact with it, but this makes it challenging for students with motor disabilities to operate. PM4Py [47] is selected as it is open-source, also supports a wide range of process mining algorithms, and represents tools that student needs to write code to use it. Thus, PM4Py can assess difficulties faced by information systems students with motor disabilities. We used real teaching materials from a university course to enable the design and execution of business process models in an agile manner [48]. Here, we have used the process mining lab as the base for this experience, where we applied different process mining algorithms from control-flow to resource perspective discovery, e.g., [49].

4.4. Experiment result

The setting enabled performing all tasks in both labs independently using solutions selected for *EXP1* and *EXP2*. However, ProM lab cannot be done using selected solutions for *EXP3*. The reason is that S15 only works for Google Chrome and Firefox, so the scroll bars and sliding bars were barriers to doing the lab in practice. The *EXP1* took 2 and 1 hour for ProM and PM4Py, respectively. The *EXP2* took 4.5 and 1.5 hours for ProM and PM4Py, respectively. The *EXP3* took 0.5 hours for PM4Py. Figure 1 shows the device setups for these experiments when the author used them for both ProM and PM4Py.

PM4Py was found easier to use than ProM due to the convenience of using Sticky keys (S06) and Google Chrome apps and extensions (S15) in Google Colab. Chrome's

[5] JoyToKey: https://joytokey.net/en/. Accessed: 2022-08-03

ability to use apps and extensions made the process smoother. In contrast, ProM was considered more difficult, and we analyzed the challenges faced in the experiments for each UI element. Table 3 shows these challenges related to each UI element. Among these elements, *drop-down lists*, *scroll bars*, and *sliders* were very challenging due to the need to scroll. The use of scrolling requires the user to i) click on the scroll point, ii) hold it, iii) move it, and iv) release it with the correct coordination. External buttons, configured with the JoyToKey program (S11) and XBox Adaptive Controller (S12), are necessary for performing these functions. Apart from the UI, the External Buttons (S08) were very useful for selecting different options in ProM. Joystick (S10) was satisfactory and saved time in ProM and PM4Py. Mouse-grid (S20) was inconsistent and sensitive to background noise, making it problematic. More details on the experiment are available on GitHub[6].

		Challenges					
		CH07	CH09	CH10	CH11	CH12	CH15
Elements in Rich User Interface	Text fields	+	+	+			+
	Search field	+	+	+			+
	Buttons		+	+			+
	Tool tips			+			
	Drop-down list		+	+	+	+	
	Scroll bars		+	+	+	+	
	Sliders		+	+	+	+	
	Drop-down button		+	+			+

Table 3. The challenges faced for each user interface element in ProM which could be addressed in *EXP1* and *EXP2*.

5. Conclusion

The study found that process mining in ProM is complex for motor-impaired students. Thus, the UI elements were decomposed to shed light on challenges. These findings can aid process mining vendors in creating a more inclusive UI for motor-impaired users. The results can be generalized to other software with a GUI, as the elements are not specific to process mining. However, there were several limitations that shall be mentioned here: 1) The experiment was performed by one person, limiting generalization; future evaluations may require different setups for varying levels of disability. 2) The experiment used ProM and PM4Py; future research will explore general applications, especially those accessible via browser UIs. 3) Only the solutions available through the game lab at SU were chosen. It will be interesting to evaluate the performance of more diverse settings with different solutions, including accessible hands-free inputs and other input methods discussed in [50]. The authors aim to extend this research to cover these limitations.

References

[1] Crow KL. Four types of disabilities: Their impact on online learning. TechTrends. 2008;52(1):51.
[2] Chris Ward. Motor Disabilities and What You Need for Accessibility [Internet]; 2019. [cited 2022 Aug 01]. Available from: https://www.telerik.com/blogs/motor-disabilities-and-what-you-need-for-accessibility.

[6] https://github.com/Shubhra-1/AT4PM

[3] Ayotte D, Vass J, Mitchell J, Treviranus J. Personalizing interfaces using an inclusive design approach. In: UAHCI. Design and Development Methods for Universal Access: 8th International Conference, UAHCI 2014, Held as Part of HCI International 2014, Heraklion, Crete, Greece, June 22-27, 2014, Proceedings, Part I 8. Springer; 2014. p. 191-202.
[4] Wilson L. Assistive Technology for the Disabled Computer User.; 1993.
[5] Burgstahler S. Working together: People with disabilities and computer technology. [University of Washington], DO-IT; 2002.
[6] Povlsen B. Physical rehabilitation with ergonomic intervention of currently working keyboard operators with nonspecific/type II work-related upper limb disorder: a prospective study. Archives of physical medicine and rehabilitation. 2012;93(1):78-81.
[7] Gower V, Andrich R, Guerreschi M, Occhionero F, Rossi A, Mingardi A, et al. The ICT Assistive Devices Register: an instrument to support appropriate provision of Assistive Technology. Assistive Technology from Adapted Equipment to Inclusive Environments: AAATE 2009. 2009;25:264.
[8] Ahmad FK. Use of assistive technology in inclusive education: making room for diverse learning needs. Transcience. 2015;6(2):62-77.
[9] Shih CH. Assisting people with multiple disabilities to improve computer typing efficiency through a mouse wheel and On-Screen Keyboard software. Research in developmental disabilities. 2014;35(9):2129-36.
[10] Koester HH, Lopresti E, Simpson RC. Toward automatic adjustment of keyboard settings for people with physical impairments. Disability and Rehabilitation: Assistive Technology. 2007;2(5):261-74.
[11] Brown C. Assistive technology computers and persons with disabilities. CACM. 1992;35(5):36-45.
[12] Eom GM, Kim KS, Kim CS, Lee J, Chung SC, Lee BS, et al. Gyro-mouse for the disabled:'click'and'Position'control of the mouse cursor. IJCAS. 2007;5(2):147-54.
[13] Gerdtman C, Lindén M. Six-button click interface for a disabled user by an adjustable multi-level sip-and-puff switch. In: Proceedings of SIGRAD 2010: Content aggregation and visualization; November 25–26; 2010; Västerås; Sweden. 052. Linköping University; 2010. p. 59-63.
[14] Shih CH, Shih CT. Assisting people with multiple disabilities improve their computer pointing efficiency with thumb poke through a standard trackball. Research in developmental disabilities. 2010;31(6):1615-22.
[15] Chen HC, Liu YP, Chen CL, Chen CY. Design and feasibility study of an integrated pointing device apparatus for individuals with spinal cord injury. Applied ergonomics. 2007;38(3):275-83.
[16] Wobbrock JO, Gajos KZ. Goal crossing with mice and trackballs for people with motor impairments: Performance, submovements, and design directions. TACCESS. 2008;1(1):1-37.
[17] Kim SP, Simeral JD, Hochberg LR, Donoghue JP, Friehs GM, Black MJ. Point-and-click cursor control with an intracortical neural interface system by humans with tetraplegia. IEEE TNSRE. 2011;19(2):193-203.
[18] Gupta T, Verma H, Verma G, Sahoo L. A portable & cost effective human computer interface device for disabled. In: CSNT 2015. IEEE; 2015. p. 1268-73.
[19] Chi CF, Pan JS, Liu TH, Jang Y. The development of a hierarchical coding scheme and database of job accommodation for disabled workers. IntJIndErgon. 2004;33(5):429-47.
[20] Chang R, Lau S, Sim K, Too M. Kinect-based framework for motor rehabilitation. In: ICORAS 2016. IEEE; 2016. p. 1-4.
[21] Ramos-Murguialday A, Schürholz M, Caggiano V, Wildgruber M, Caria A, Hammer EM, et al. Proprioceptive Feedback and Brain Computer Interface (BCI) Based Neuroprostheses. PLOS ONE. 2012 10;7(10):1-10. Available from: https://doi.org/10.1371/journal.pone.0047048.
[22] Fichten CS, Ferraro V, Asuncion JV, Chwojka C, Barile M, Nguyen MN, et al. Disabilities and e-learning problems and solutions: An exploratory study. Journal of Educational Technology & Society. 2009;12(4):241-56.
[23] Correia W, Macedo J, Penha M, Quintino J, Pellegrini F, Anjos M, et al. Virtual Assistants: An Accessibility Assessment in Virtual Assistants for People with Motor Disability on Mobile Devices. In: AHFE 2019 International Conference. Springer; 2019. p. 239-49.
[24] Siebra C, Correia W, Penha M, Macedo J, Quintino J, Anjos M, et al. Virtual assistants for mobile interaction: A review from the accessibility perspective. In: OzCHI'18; 2018. p. 568-71.
[25] Turpin G, Armstrong J, Frost P, Fine B, Ward C, Pinnington L. Evaluation of alternative computer input devices used by people with disabilities. Journal of medical engineering & technology. 2005;29(3):119-29.

[26] Nagendran GA, Singh H, Raj RJS, Muthukumaran N. Input Assistive Keyboards for People with Disabilities: A Survey. In: ICICV 2021. IEEE; 2021. p. 829-32.
[27] Hatakeyama T, Koizumi Y, Umeda Y, Uchio M, Kasuga M. USER FRIENDLY POINTING DEVICE FOR PEOPLE WITH SEVERE PHYSICAL DISABILITIES USING INFRARED LIGHT. KANSEI Engineering International. 2000;1(3):7-14.
[28] Anson D, Lawler G, Kissinger A, Timko M, Tuminski J, Drew B. Efficacy of three head-pointing devices for a mouse emulation task. Assistive Technology. 2002;14(2):140-50.
[29] Trewin S, Pain H. Keyboard and mouse errors due to motor disabilities. International Journal of Human-Computer Studies. 1999;50(2):109-44.
[30] Iacopetti F, Fanucci L, Roncella R, Giusti D, Scebba A. Game console controller interface for people with disability. In: CISIS 2008. IEEE; 2008. p. 757-62.
[31] Wobbrock JO, Myers BA, Aung HH, LoPresti EF. Text entry from power wheelchairs: EdgeWrite for joysticks and touchpads. In: ASSETS'03; 2003. p. 110-7.
[32] Pino A. Free assistive technology software for persons with motor disabilities. In: Open source technology: concepts, methodologies, tools, and applications. IGI Global; 2015. p. 462-505.
[33] Fanucci L, Iacopetti F, Roncella R. A console interface for game accessibility to people with motor impairments. In: IEEE ICCE-Berlin 2011. IEEE; 2011. p. 206-10.
[34] Pereira CAM, Neto RB, Reynaldo AC, de Miranda Luzo MC, Oliveira RP. Development and evaluation of a head-controlled human-computer interface with mouse-like functions for physically disabled users. Clinics. 2009;64(10):975-81.
[35] Dutt-Mazumder A, Huggins JE. Performance comparison of a non-invasive P300-based BCI mouse to a head-mouse for people with SCI. Brain-Computer Interfaces. 2020;7(1-2):1-10.
[36] Prabhu V, Prasad G. Designing a virtual keyboard with multi-modal access for people with disabilities. In: WICT 2011. IEEE; 2011. p. 1133-8.
[37] Botelho FH. Accessibility to digital technology: Virtual barriers, real opportunities. Assistive Technology. 2021;33(sup1):27-34.
[38] Yang CH, Chuang LY, Yang CH, Luo CH. Morse code application for wireless environmental control systems for severely disabled individuals. IEEE TNSRE. 2003;11(4):463-9.
[39] Yang CH. Adaptive Morse code communication system for severely disabled individuals. Medical Engineering & Physics. 2000;22(1):59-66.
[40] Haque T, Liang E, Gray J. The adjustable grid: A grid-based cursor control solution using speech recognition. In: Proceedings of the 51st ACM SE Conf; 2013. p. 1-6.
[41] Zhu S, Feng J, Sears A. Investigating grid-based navigation: The impact of physical disability. TACCESS. 2010;3(1):1-30.
[42] Cai S, Venugopalan S, Tomanek K, Narayanan A, Morris MR, Brenner M. Context-Aware Abbreviation Expansion for AAC Using Large Language Models. In: NAACL(to appear); 2022. .
[43] Barbetta PM, Spears-Bunton LA. Learning to write: Technology for students with disabilities in secondary inclusive classrooms. English Journal. 2007:86-93.
[44] Šumak B, Špindler M, Pušnik M. Design and development of contactless interaction with computers based on the Emotiv EPOC+ device. In: MIPRO 2017. IEEE; 2017. p. 576-81.
[45] Warland A, Paraskevopoulos I, Tsekleves E, Ryan J, Nowicky A, Griscti J, et al. The feasibility, acceptability and preliminary efficacy of a low-cost, virtual-reality based, upper-limb stroke rehabilitation device: a mixed methods study. Disability and rehabilitation. 2019;41(18):2119-34.
[46] Van Dongen BF, de Medeiros AKA, Verbeek H, Weijters A, van Der Aalst WM. The ProM framework: A new era in process mining tool support. In: ICATPN. Springer; 2005. p. 444-54.
[47] Berti A, Van Zelst SJ, van der Aalst W. Process mining for python (PM4Py): bridging the gap between process-and data science. arXiv preprint arXiv:190506169. 2019.
[48] Jalali A. Teaching Business Process Development Through Experience-Based Learning and Agile Principle. In: BIR Conference. Springer; 2018. p. 250-65.
[49] Jalali A. Reflections on the use of chord diagrams in social network visualization in process mining. In: RCIS Conference. IEEE; 2016. p. 1-6.
[50] Heilemann F, Zimmermann G, Münster P. Accessible Hands-Free Input Methods for VR Games. In: Computers Helping People with Special Needs: 18th International Conference, ICCHP-AAATE 2022, Lecco, Italy, July 11–15, 2022, Proceedings, Part I. Springer; 2022. p. 371-9.

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Accessibility of AR/VR/XR

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A Systematic Literature Review of Accessibility Evaluation Methods for Augmented Reality Applications

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Abstract. Augmented reality is increasingly becoming significant in people's everyday life in different sectors. Particularly to users with disabilities, augmented reality can be an instructional tool and assistive technology, making it worth a vital tool for users with disabilities. For such an important tool, it is essential to understand how these applications are evaluated in order to improve their throughput and extend their accessibility. In that regard, a systematic literature review for peer-reviewed articles published between 2012 and 2022 was conducted to discover which methods, metrics, and tools/techniques researchers use during the accessibility evaluation of augmented reality applications. The PRISMA methodology allowed us to identify, screen, and include 60 articles from three databases. The finding shows that most researchers use task scenarios as the method, qualitative feedback as the metric, and questionnaire as a tool to collect data for accessibility evaluation. The conclusion and future studies are also discussed.

Keywords. Accessibility, Augmented Reality, Evaluation Methods

1. Introduction

Augmented reality (AR) is increasingly becoming significant in people's everyday life in different sectors such as education, health, manufacturing, entertainment, and transportation [1]. Particularly to users with disabilities, AR can be an instructional tool [2] and assistive technology [3], making it an invaluable tool for them. Such a paramount technology must be accessible to everyone, including individuals with disabilities, so no one is left behind and everyone equally benefits from it. Besides, creating an accessible AR promotes social values and inclusion, widens the pool of users, and does the right thing.

Having such an essential tool that should be accessible to all people is alerting that there should be methodologies for evaluating and confirming its accessibility. Various studies developing individual accessible AR applications have employed various

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evaluation methods for confirming the accessibility of such AR products. It is crucial to inform various communities about the types of disability when using the AR device and at what stage of AR app development the evaluation methods were performed.

Other works have tried to inform readers of methods used to evaluate the usability of AR apps. Though usability is closer to accessibility, these works focused on the usability of AR applications by different groups of users [4]. A detailed report from existing literature on how people with disabilities evaluate AR applications is missing. Nevertheless, other studies conducted a systematic literature review (SLR) of AR applications for people with disabilities, for instance, work by [5]. However, neither of these works focuses on how users with disabilities conduct accessibility evaluation of AR applications. Therefore, this study wants to conduct an SLR of accessibility evaluation methods reported in the conference papers and journal articles in the period 2012 to 2022 by using the PRISMA methodology [6].

This study wants to answer the following research questions:

RQ1: What is the demography of users with disabilities evaluating AR applications designed for people with disabilities?

RQ2: Which methods are employed to conduct the accessibility evaluation of AR applications for people with disabilities?

RQ3: How are users with disabilities involved during the development process of evaluated AR applications for people with disabilities?

The remaining part will explain the methodology used in this study, followed by the result and discussion, which answers our research questions, and a conclusion.

2. Methodology

A systematic literature review (SLR) was conducted using the PRISMA approach to focus on evaluating the accessibility of AR applications. The PRISMA methodology consists of four phases: identification, screening, eligibility, and inclusion (Figure 1). Three databases were searched: IEEExplore, ACM Digital Library, and SCOPUS using a predefined search strategy during the identification phase. Journal articles and conference proceedings were included, and the search query applied to titles, abstracts, and metadata as follows: In the title (T), the search string was ("Augmented Reality" OR "Mixed Reality"). In the abstract (A), was ("Accessib*" OR "Disab*" OR "Impair*" OR "Special Need"), and in all metadata (M), was ("Evaluat*" OR "Validat*" OR "Verif*" OR "User Study"). The general search query was T AND A AND M. The asterisk symbol (*) was utilized to capture variations of words, and all searched databases supported its usage. The manual search was also performed to add 14 relevant articles not captured by the automated process. The database search concluded on 25.11.2022, resulting in 637 records. After removing duplicates, 530 unique records remained.

In the screening phase, publications were assessed based on predefined inclusion and exclusion criteria in Table 1. In total, 353 publications did not meet the criteria and were removed, making 177 articles eligible for full-text analysis.

The third phase, eligibility, involved reviewing the full-text articles based on the criteria presented in Table 1. Articles implementing AR solutions and describing accessibility evaluations performed by people with disabilities were included. For example, articles where administrators, such as occupational therapists, parents, or teachers, evaluated AR instead of users with impairments were excluded. By the end of this phase, 117 articles had been excluded, and 60 were eligible for inclusion in the final analysis of SLR. The selected articles were included in the SLR for the final review. The list of these articles is attached as Appendix I in this link [https://bit.ly/3Wa80jz].

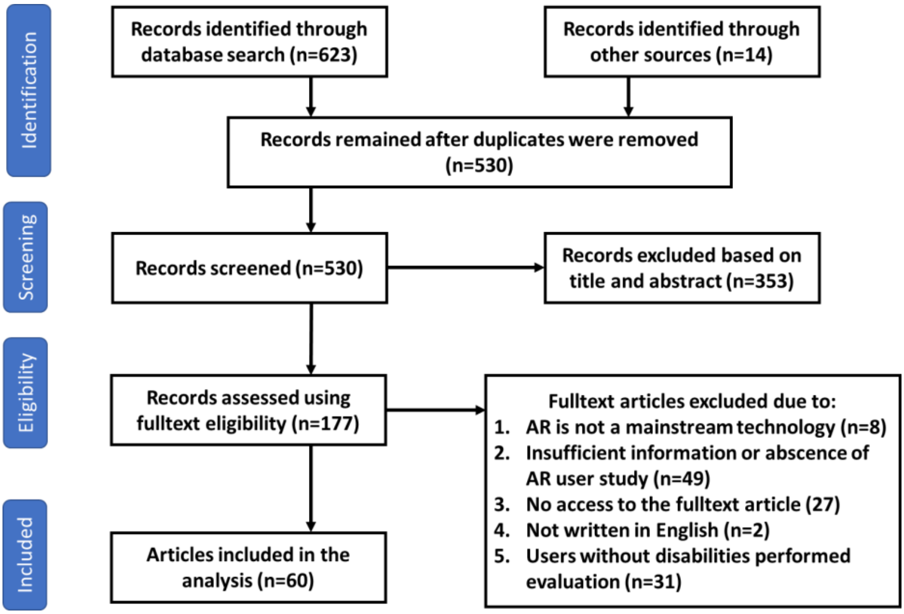

Figure 1. The PRISMA methodology phases during the systematic literature review

Table 1: Inclusion and Exclusion criteria

Inclusion Criteria	Exclusion Criteria
i. The article presents a solution using AR technology, i.e., AR is the mainstream technology.	i. Accessibility is mentioned in different contexts apart from disabilities, such as affordability, availability, or reachability. ii. The perspective of an AR solution is not related to people with disability.
ii. The solution is targeting people with disabilities	iii. No concrete AR solution is mentioned. iv. The solution mentions AR, but it is VR or interactive simulation.
iii. The solution has been evaluated for accessibility	v. The article is theoretically based, such as reviewing or surveying other articles.
iv. The availability of Fulltext	
v. The article is published in a peer-reviewed journal	vi. Insufficient information is provided about evaluation methodologies or AR solutions.
	vii. The article is not written in the English language.
	viii. The article is published before 2012.

3. Results and Discussion

The list consists of 60 articles with authors from 26 countries. The number of articles has steadily increased from one article per year in 2012 to 12 in 2022, showing that awareness of developing and evaluating AR solutions for people with disabilities is increasing.

In responding to RQ1, the survey encountered AR applications in five categories of disabilities: mobility impairments (MI), visual impairments (VI), hearing impairments (HI), spinal cord injury (SCI), and cognitive impairments (CI). As illustrated in Figure 2, many AR applications evaluated were CI (53%), followed by VI (28%). This distribution might be due to the vast CI category that constitutes many sub-categories compared to other categories of disabilities. This finding aligns with other surveyed articles, such as [5].

Further, the study found that most articles (61%) had less than 10 participants in their user studies (Figure 3). A similar finding was reported by [2] as one of the limitations in many AR studies for educational inclusions. Quintero J. et al. [2] argued that the cumbersome recruitment process is a primary reason for the smaller sample size in user studies. Moreover, it is hard to locate the subjects and challenging to acquire the necessary documents, such as consent and ethical clearance, for participation in the research process [2].

Though acquiring legal documents such as ethical approval from the competent body and participants' consent may complicate the recruitment process, it is a legal procedure to observe. The study found that 37% of studies (Figure 4) did not report whether they had ethical approval and participants' or their parent's consent. Figure 5 shows the percentages of studies with or without ethical approval for each disability category. The studies that involved participants with disabilities without having ethical clearance are unethical and do not abide by the Helsinki Declaration [7], which emphasizes informed consent, respect for individuals, and the welfare of research objects.

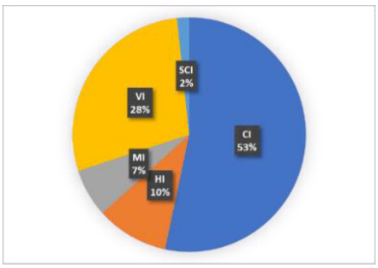

Figure 2: Categories of AR applications according to disabilities

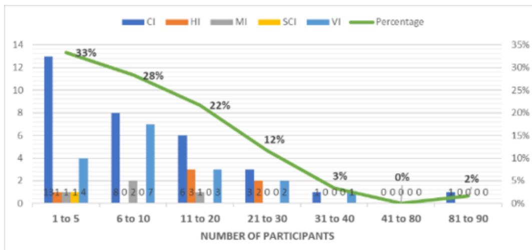

Figure 3: Number of participants in each study

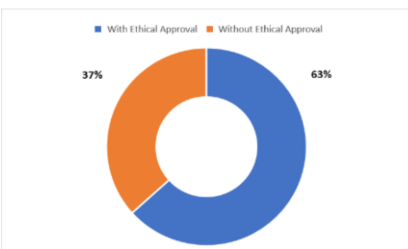

Figure 4: Ethical Approval in the Surveyed Articles

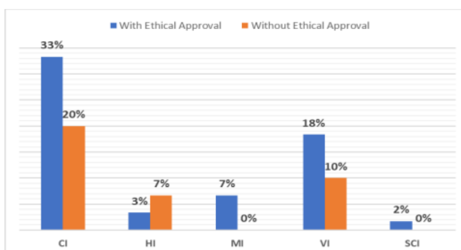

Figure 5: Ethical Approval per categories of disabilities

In responding to RQ2, this study discussed the methods, tools/techniques, and metrics used while evaluating the AR applications used by people with disabilities. As illustrated in Figure 6, researchers employed task execution (61%), experiment (18%), single subject design (SSD)(17%), heuristic evaluation (1%), and Quasi-experimental design (3%) to evaluate the accessibility of AR applications. These findings agree with other studies. For instance, in evaluating AR applications, [8] found that task execution was the most used method, and the heuristic was the least used method. [9] argued that the heuristic method is the least used due to the absence of accessibility guidelines and consolidated design in AR applications. Further, this study found that many studies use more than one method. This finding was also noted by [10]. For instance, in our study, 12 of 13 combined experimental methods with task execution, whereas one study combined quasi-experimental design with task execution. Studies that employed SSD or heuristic methods were not combined with other methods.

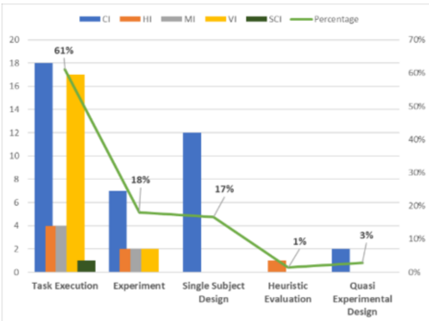

Figure 6: Accessibility Evaluation Methods

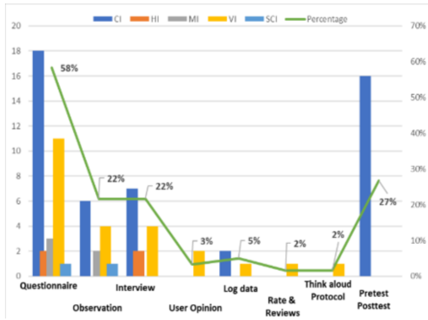

Figure 7: Tools/Techniques Used

Among the articles that employed the experimental method, 77% used traditional technology as a control against AR technology, while 13% used users without impairment as a control. When the methods used by researchers in the specific category of disabilities were compared (Figure 6), it was noted that all categories employed task execution, only CI articles employed SSD, and only HI articles employed Heuristic evaluation. SSD method was also proposed by [11] to evaluate AR articles in special education and counseling. Moreover, [12] argued that SSD is proper for a smaller sample size to establish evidence of invention application.

Unlike methods, data collection techniques determine how researchers conduct the data collection process. As shown in Figure 7, researchers employed eight different tools/techniques to collect data during accessibility evaluation. These are questionnaire (58%), observation (22%), interview (22%), user opinion (3%), log data (5%), user rating and reviews (2%), think-aloud protocol (2%), and pretest-posttest (27%). Moreover, the pretest-posttest technique was employed in CI only. This technique applies within the SSD method, which fits the CI category. In this method, pretest data collection is conducted during baseline, followed by the application of the AR system, and later the posttest is conducted to record the effect of the AR invention [12]. A similar finding was found by [13] for AR applications used for learning by children and adolescents with an autism spectrum disorder.

Furthermore, like the finding by [10], this study also found that multiple metrics are used to measure the success of accessibility evaluation. In our study, 10% of all research used three metrics: time on task, error on task, and task completion rate, whereas 32% used more than one metric (Figure 8). Moreover, da Silva et al. [14] proposed the usage of multiple metrics in order to reduce biases and minimize errors during the evaluation

The response to RQ3 discusses user involvement and the device used in the development process. The involvement of actual users is crucial for successfully developing accessible AR applications. Through this, researchers journey together and understand the user needs and how users interact with the AR system [15], particularly users with disabilities.

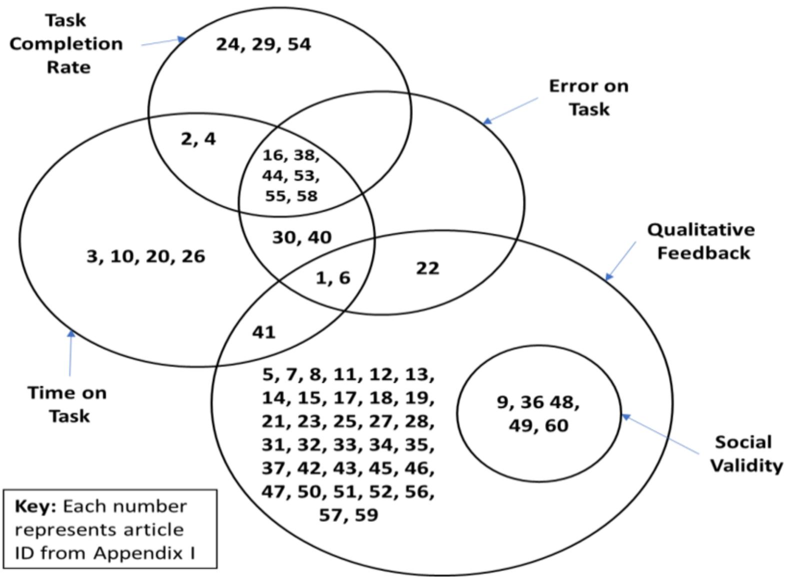

Figure 8: The Metrics used in different articles to measure various components during the evaluation

This study encountered five user-centered methodologies: participatory design, user-centered design, iterative design, prototyping, and universal design. In the proportion of articles that reported user involvement (Figure 9), participatory design (39%) was the most used, and universal design (4%) was the least. Unfortunately, many surveyed articles (57%) did not report how users were involved during AR application development evaluation. Although our study was about accessibility evaluation methods, it is vital to understand how users were involved during development for meaningful interpretation of evaluations.

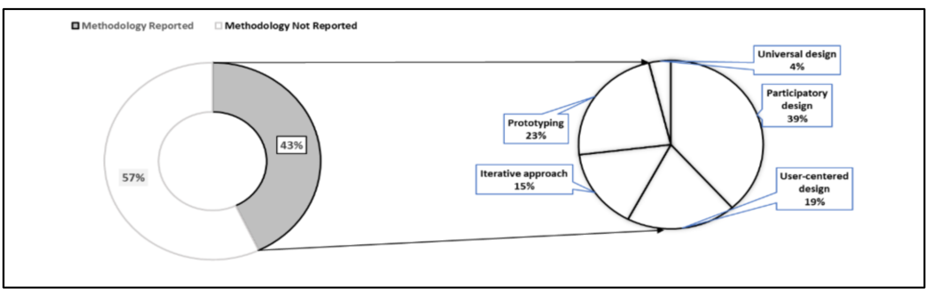

Figure 9. User Involvement Methodologies Reported

The device used for AR applications is significant for users with disabilities because the accessibility configuration differs for different device vendors. This work found that the devices (Figure 10) used are handheld (47%), head-mounted (31%), and other devices (22%). The handheld devices included smartphones and tablets from Android and iOS, while the head-mounted devices included Hololens, Oculus Rift, HTC Vive, RhinoX, AIRO headsets, and Google glasses. Moreover, the other devices group consisted of overhead projectors, Television, Xbox PlayStation, and computers. The distribution of how the devices were used per each category of disability is shown in Figure 10.

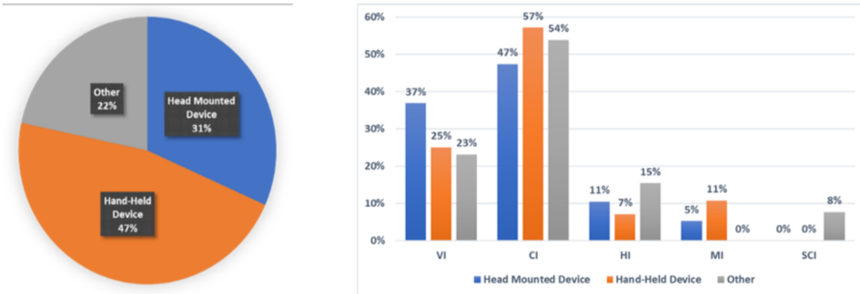

Figure 10: Device used during Accessibility Evaluation

4. Conclusion

Accessibility of AR applications is crucial for removing barriers for users with disabilities to benefit from immersive technologies. This paper reviewed the accessibility evaluation of AR applications for people with disabilities between 2012 to 2022. This review may help the AR communities, such as developers and evaluators, who want to improve the accessibility of AR applications in order to achieve social and digital inclusion. Developers should use a user-centered approach such that users with disabilities are included at the beginning of the process and in all stages of development. On the other hand, the evaluators and experts in HCI would use these results to understand which methods are currently used and which should be improved.

Several issues in the RQ1 need further research. First is the presence of a smaller sample size in many publications that evaluated AR applications for users with disabilities. The smaller sample size can affect the generalization of the research results and cause bias. We propose conducting more research to find the cause and solution. In addition, this study noted that SSD was suitable for a lower number of subjects in the CI group during evaluation. We propose that more research be conducted to determine whether this method applies to other groups of people with disabilities. In addition, we propose more research to discover other methods to solve the lower sample size problem.

In the RQ2, we describe the methods, techniques, and metrics used during the accessibility evaluation of AR solutions for people with disabilities. We noted the varieties of methods for different AR applications, which can confuse other researchers when choosing which method to employ for thorough research. We propose further research that will produce the guidelines or a framework to help decide which method to apply for a particular disability in given conditions, such as sample size, type of solution, interaction types, and other conditions.

In the RQ3, it was noted that many articles did not document users' involvement during software development. Documenting user involvement is critical, especially for users with disabilities, because their involvement improves the researcher's understanding of how they interact with AR applications [16]. Also, in this study, during the eligibility stage, some articles were ineligible because non-real users, e.g., blindfolded, were used to evaluate AR applications instead of users with vision impairment. Though there are circumstances like the users are children with mental disabilities hence the difficulty to involve them in testing. However, since the system is designed for users with a disability, it must be tested by actual users, not representatives.

Acknowledgments

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References

[1] Sharma A, Mehtab R, Mohan S, Mohd Shah MK. Augmented reality – an important aspect of Industry 4.0. Industrial Robot: the international journal of robotics research and application. 2021;49:428–441. doi: 10.1108/IR-09-2021-0204.
[2] Quintero J, Baldiris S, Rubira R, Cerón J, Velez G. Augmented reality in educational inclusion. A systematic review on the last decade. Frontiers in Psychology [Internet]. 2019;10. doi: 10.3389/fpsyg.2019.01835.
[3] Herskovitz J, Wu J, White S, Pavel A, Reyes G, Guo A, Bigham JP. Making Mobile Augmented Reality Applications Accessible. Proceedings of the 22nd International ACM SIGACCESS Conference on Computers and Accessibility. New York, NY, USA: Association for Computing Machinery; 2020.
[4] Lim KC, Selamat A, Alias RA, Krejcar O, Fujita H. Usability Measures in Mobile-Based Augmented Reality Learning Applications: A Systematic Review. Applied Sciences. 2019;9:2718. doi: 10.3390/app9132718.
[5] Žilak M, Car Ž, Čuljak I. A Systematic Literature Review of Handheld Augmented Reality Solutions for People with Disabilities. Sensors. 2022;22:7719. doi: 10.3390/s22207719.
[6] Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, Shamseer L, Tetzlaff JM, Akl EA, Brennan SE, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71. doi: 10.1136/bmj.n71. Cited: in: : PMID: 33782057.
[7] Association (WMA) WM. Declaration of Helsinki. Ethical Principles for Medical Research Involving Human Subjects. Jahrbuch für Wissenschaft und Ethik. 2009;14:233–238. doi: 10.1515/9783110208856.233.
[8] Cavalcanti VC, Santana MI de, Gama AEFD, Correia WFM. Usability Assessments for Augmented Reality Motor Rehabilitation Solutions: A Systematic Review. International Journal of Computer Games Technology. 2018;2018:e5387896. doi: 10.1155/2018/5387896.
[9] Dünser A, Billinghurst M. Evaluating Augmented Reality Systems. In: Furht B, editor. Handbook of Augmented Reality. New York, NY: Springer; 2011. p. 289–307. doi: 10.1007/978-1-4614-0064-6_13.
[10] da Silva MMO, Teixeira JMXN, Cavalcante PS, Teichrieb V. Perspectives on how to evaluate augmented reality technology tools for education: a systematic review. J Braz Comput Soc. 2019;25:3. doi: 10.1186/s13173-019-0084-8.
[11] Baragash RS, Al-Samarraie H, Alzahrani AI, Alfarraj O. Augmented reality in special education: a meta-analysis of single-subject design studies. European Journal of Special Needs Education. 2020;35:382–397. doi: 10.1080/08856257.2019.1703548.
[12] Alnahdi GH. Single-subject designs in special education: advantages and limitations. Journal of Research in Special Educational Needs. 2015;15:257–265. doi: 10.1111/1471-3802.12039.
[13] Khowaja K, Banire B, Al-Thani D, Sqalli MT, Aqle A, Shah A, Salim SS. Augmented Reality for Learning of Children and Adolescents With Autism Spectrum Disorder (ASD): A Systematic Review. IEEE Access. 2020;8:78779–78807. doi: 10.1109/ACCESS.2020.2986608.
[14] da Silva MMO, Roberto RA, Teichrieb V, Cavalcante PS. Towards the development of guidelines for educational evaluation of augmented reality tools. 2016 IEEE Virtual Reality Workshop on K-12 Embodied Learning through Virtual & Augmented Reality (KELVAR). 2016. p. 17–21.
[15] Mao J-Y, Vredenburg K, Smith PW, Carey T. The state of user-centered design practice. Commun ACM. 2005;48:105–109. doi: 10.1145/1047671.1047677.
[16] Ramos Aguiar LR, Álvarez Rodríguez FJ, Ponce Gallegos JC, Velázquez Amador CE. Elicitation of Requirements for Extended Reality Generation Considering Universal Design for Learning and User-Centered Design for People with Disabilities. In: Antona M, Stephanidis C, editors. Universal Access in Human-Computer Interaction User and Context Diversity. Cham: Springer International Publishing; 2022. p. 262–276.

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The Use of Extended Reality in Rehabilitation for Patients with Acquired Brain Injury: A Scoping Review

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Abstract. *Background*: Extended reality (XR) seems promising for rehabilitation for people with acquired brain injury in terms of reducing professional supervision, faster recovery, shorter hospital stays, and reduced expenses. Since there is no overview this scoping review describes how XR can be utilized in rehabilitation, particularly for people with acquired brain injury (ABI). *Methods*: The Arksey and O'Malley framework and PRISMA-ScR reporting guideline were followed. Studies between 2010 and May 2022 screened from healthcare as well as technical databases were imported in RAYYAN. Three researchers selected relevant articles in three rounds based on title, abstract and full text. *Results*: 75 articles were included in this scoping review. Most studies used VR as technology with therapy objectives in three main categories: cognitive, physical and diagnostic. The outcomes of the studies show potential and promising results of the use of XR, and enthusiasm with as well patients as professionals. A selection of four domains of the NASSS framework: condition, technology, value proposition and adopters were reported. Important lessons learned by the included studies are development of XR software, improvement of the hardware, improving feeling of safety and giving support to the patient, and support healthcare professionals for acceptance of XR. *Discussion*: the use of XR for people with ABI has potential and is promising but not common practice yet. Future research should focus on implementation factors with a diverse and inclusive patient group using service modelling.

Keywords. Extended reality, virtual reality, augmented reality, rehabilitation, acquired brain injury, service model, implementation, scoping review.

1. Introduction

Acquired brain injury (ABI) is any type of brain damage that occurs after birth and is one of the leading causes of long-term adult disability worldwide [1]. Depending on the severity of the brain damage and the symptoms of the disability, rehabilitation can be prescribed. For people with ABI requiring rehabilitation, extended reality[2] (XR) seems a promising intervention supporting the rehabilitation process and is expected to have a positive impact by providing patients with intensive therapy delivered with limited

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[2] Extended reality is an umbrella term used to describe technologies combining the physical and virtual world. Technologies associated with XR are Virtual Reality (VR) Augmented Reality (AR) and Mixed Reality (MR).

supervision, resulting in faster recovery times, shorter hospital stays, and reduced expense [2, 3, 4, 5]. The technological advancements of XR are progressing rapidly, but currently there is no overview on how XR can be utilized in rehabilitation for patients with ABI. Therefore, we conducted a scoping review with the main research question: 'What is known in the existing literature on using XR in rehabilitation for patients with acquired brain injury?', with the following sub-questions: 1) What are rehabilitation therapy objectives of the reported XR interventions? 2) What are outcomes of the reported XR interventions? 3) what factors should be considered when implementing XR? 4) What are lessons learned about using XR interventions in rehabilitation practice?

2. Methods

In our scoping review, the Arksey and O'Malley framework and PRISMA-ScR reporting guideline were followed [6, 7]. Three databases on healthcare were searched: PubMed, CINAHL, Cochrane reviews, Embase, and one technological database: IEEE Xplore. In line with the framework the initial search was checked by two information specialists. The following search string was used: *(Virtual Reality OR Augmented Reality OR Extended Reality OR Mixed Reality) AND (Brain diseases OR Brain injuries OR Stroke OR Cerebrovascular disorder OR Cerebrovascular accident OR CVA OR Acquired brain injury OR ABI) AND (Rehabilitation OR Stroke Rehabilitation OR Rehabilitation centers OR Physical education OR exercise OR Physical therapy modalities OR patient centered care OR aftercare OR training OR Clinical Practice)*.

Studies between 2010 and May 2022 found were imported in RAYYAN after removing duplicates [8]. The selection for relevant studies consisted of three selection rounds: 1. Title, 2. Abstract, and 3. Full text in which three researchers (LBS, RvdH, WK) participated as reviewer. Every round consisted of discussing a pre-selection until consensus was reached on exclusion criteria. Exclusion criteria were: 1. Not in English or Dutch, 2. Not for people with ABI, 3. No XR or no immersive VR, 4. No patient test involved/included, and 5. Other: limited to study protocol, no full text available and duplicate article. Subsequently, the studies were equally divided among the researchers. Finally, a data charting form was used to extract the relevant information from the included articles. Two researchers (LBS, WK) performed a content analysis focusing on answering the sub-questions. More specific, the NASSS framework is used in this analysis in answering sub-question 3. This technology implementation framework is for studying non-adoption and abandonment of technologies by individuals and the challenges to the scale-up, spread, and sustainability of such technologies in health and care organizations [9].

3. Results

In total, 75 articles were selected, with a Fleiss' Kappa score for interrater-reliability of: 0.74 for titles and 0.40 for abstracts [10]. Virtual reality (VR) was used in 70 articles, 5 articles described augmented reality (AR) and mixed reality (MR) was not found. The HTC Vive (n=21) was the most used VR head mounted display (HMD), and the AIRO II (n=2) the most used AR HMD. Target audience included stroke patients (n=63), traumatic brain injury (TBI) (n=7), and five studies included two or more conditions including patients suffering from multiple sclerosis, stroke and TBI. Studies were mostly conducted in a laboratory (n=31) and rehabilitation (n=28) setting, study designs varied from experimental and pretest-post-test-studies (n=22), RCTs (n=11), case studies (n=9), pilot studies (n=6), feasibility/acceptability studies (n=5), cross-sectional studies (n=2) and a qualitative study (n=1). In addition, different kinds of reviews were found systematic reviews (n=4), reviews (n=4), meta-analysis (n=2), and scoping reviews (n=2). Finally, 7 studies did not describe the study method.

3.1 Sub-question 1: Rehabilitation therapy objectives of reported XR interventions

The rehabilitation settings in the studies varied: hospital (n=18), rehabilitation clinic (n=24), home (n=5), combination of rehabilitation clinic and home (n=1), and unreported setting (n=27). Therapy objectives could be divided into three main categories: physical, cognitive and diagnostic:

- Physical (n=41): Aimed at improving movement and balance, such as reach and grasp functions, balance, walking speed, motor function, improving hand function, and reduce risk of falling. Focus could be on lower and upper extremities, the entire body, but also motor function in balance or gait. E.g., a VR environment in which the patient has to grasp virtual balls from a table and release the ball in a basket on another table [11];
- Cognitive (n=14): Targeted at neglect, education and training in memory, attention impairments, and task sequence. E.g., a supermarket in which the patient has to do grocery shopping with or without a shopping list [12];
- Diagnostic (n=13): Including assessment of motor skills, assessing extra personal/unilateral spatial neglect, detecting prospective memory problems, task requirements with eye tracking. E.g., a visual search task for patients with neglect in which the patient has to orally identify each flashing object [13].

The remaining studies included reviews (n=5) and experimental studies (n=2) reporting multiple categories.

3.2 Sub-question 2: Outcomes of reported XR interventions

A variety of research instruments were used in the included studies, gathering both qualitative and quantitative data. The research instruments used in multiple studies were: Fugl-Meyer Assessment of Upper Extremity (FMA-UE) (n=13), Simulator Sickness Questionnaire (SSQ) (n=8), System Usability Score (SUS) (n=7), Action Research Arm Test (ARAT) (n=7), and the Berg Balance Scale (BBS) (n=7).

Although limited evidence for the use of XR for patients with ABI is available [14, 15, 16, 17], most studies describe that XR has potential and is promising for this patient group [11, 18, 19, 20, 21, 22, 23, 24, 25, 26]. While there are no statistical differences to present based on the included studies, they do suggest an increase of therapy outcomes when using XR [13, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36]. The limited evidence available is based on small numbers of included patients and hence, limits generalizability of the findings [13, 37, 38, 39, 40].

From patients' perspective, XR improves patient experience, captures useful biofeedback, and is easy to use [41, 42]. Patients have an open attitude towards XR, are mostly enthusiastic and embrace XR to use it to their advantage, despite not being previously exposed to XR [4, 12, 42, 43, 44, 45]. Specifically virtual reality is perceived more as a game and less as a task and it is reported as fun and motivating rehabilitation to improve functioning in daily life [18, 31, 46, 47]. Cybersickness was assessed through questionnaires during the studies: six studies reported some mild symptoms of cybersickness [22, 24, 35, 36, 39, 42, 43].

From professionals' perspective, the game levels and diversity for training options in XR for rehabilitation are interesting to motivate patients [20, 31]. Furthermore, the possibility of monitoring the progress of patients is of added value for the therapy in terms of outcomes: professionals can create a tailored rehabilitation program for the patient [41].

3.3 Sub-question 3: factors to consider when implementing XR.

This section provides an overview of the factors that should be taken into account when implementing XR using the NASSS framework. The following domains were reported in the included articles: condition, technology, value proposition, and adopters, whereas the domains organization(s), wider system, and embedding and adaptation over time were not reported at all.

The condition domain is mostly described in patients' experience in general terms of among others; neglect, balance, upper extremity rehabilitation, paresis, but not to what extent these problems occur. Only three studies [21, 44, 48] explicitly focused on severely impaired patients, and one study [43] on mild impairments.

Domain technology describes the possibilities of the used technology in relation to the condition of the patient and technical issues of the software and hardware of the XR technology. Proper functioning technology is an absolute requirement to prevent frustration among patients and staff [47] and support implementation.

Value proposition includes the development of XR to contribute to quality of health care, improve patient recovery, minimal supervision, shortened rehabilitation stay, resulting in an increase of cost effective rehabilitation [41, 44]. The XR technology should be part of a therapy that is fun, portable, simple, acceptable, and useful [41, 47]. XR should not only be a promising tool to improve recovery [11, 25, 31, 32, 49], but also increase the effectiveness of home rehabilitation [24, 50]. Feasibility shows promising results [12, 51], whereas further research is needed to make the step from potential and promising to being effective in daily rehabilitation practice [14, 40, 52].

Finally, the adopters' domain, staff and patient were mentioned in many studies, whereas carer was mentioned in only one study [51]. For staff, it is interesting that XR facilitates monitoring the progress and enables more personalized treatment [51, 53], possibly at home [5, 29, 39, 50]. This implies an improvement of rehabilitation. However, the staff has to ensure the patients' safety [20, 54] and has to decide for which patient XR is beneficial. The patient attitude on the use of XR is mostly positive as described in the patient perspective earlier in this review. Some studies pay slightly more attention to the patient or the patient perspective: one recommends to explore how patients perceive XR when used in the clinical environment [46], another study describes making adjustments during the development to improve acceptability [26], and one study considers using another HMD to avoid dizziness while wearing it [55].

3.4 Sub-question 4: Lessons learned using XR interventions in rehabilitation

The lessons that were learned by the studies included in this review were inductively analyzed resulting in the following four topics: development of XR software, improvement of the hardware, feeling safe and give support to the patient, and support healthcare professionals for acceptance of XR. First, while XR-applications made significant progress, there is still a need for further development of the following components: challenging patient engagement [29, 56], introducing unexpected elements [57], and improvement of usability [55].

Second, improvement and development of hardware is necessary, for example: introducing haptic feedback [56], and adjusting the controller to make it accessible for individuals with impaired hand function [22, 48].

Third, feeling safe in rehabilitation is crucial for the patient and is the responsibility of the professional. Therefore, a careful introduction of XR is necessary, especially for patients with ABI [47, 50]. Professionals should tailor their support and determine the appropriate duration of the XR-application [20].

Finally, to foster the acceptance of XR among healthcare professionals, it is crucial to provide support in addressing factors such as lack of knowledge and resources [58].

4. Discussion

This scoping review created an overview of the existing knowledge base of use of XR for ABI-patients in rehabilitation. This review has several strengths, first two data analysts checked the search string, second the selection of the articles by three researchers with discussions until consensus was reached and third the data analysis by two researchers in the output table and the analysis with the NASSS framework of sub-question 3. Limitations of this review were no inclusion of grey literature and no update of our search since the databases were searched for in May 2022.

The included studies describe potential and promising results of the use of XR in rehabilitation for people with ABI. Most of the studies are experimental with the focus on VR, for people who had a stroke and need to practice the upper extremities. XR can be used for people with ABI, cybersickness seems to occur less frequently as long as the XR is introduced and the patient is guided by the professional. The developed XR technology focuses on the improvement of rehabilitation in terms of therapy outcome, fun, motivation, place and professionals independence and cost effectiveness.

This scoping review also revealed a contradiction: the use of XR in rehabilitation for ABI patients is described as potential and is promising, but is not yet deployed as conventional therapy in daily rehabilitation practice. The use of XR in this appears to be relatively new, since all included studies had an experimental character. However, applying the NASSS framework [9] to analyze the included studies, showed that both patients and professionals are included as stakeholders. Whereas carers, were (almost) not included while they have a vital role in the life of this patient group. These adopters are engaged in greater or less extent, but there is rarely any indication of the specific issues or severity of symptoms they experience. Possibly, this implies the included adopters were not representative for the target group.

Future research should include a more diverse and inclusive group during the development of XR in terms of severeness of the patients' impairments and perspective of patients, carers, and professionals. Furthermore, it is important to focus on the values of the patient, carer and professional involved in the implementation of technology to achieve the use of XR as common practice in rehabilitation care. There has not been explicit attention for these aspects in the included articles. Therefore, future research should focus on the use of XR in common practice by including the inclusive and diverse group of stakeholders exploring their norms and values for using this technology as conventional therapy. The exploration of these norms and values is complex and needs a specific approach. For example with the use of a service model that aligns the interests of different stakeholders for the implementation of technology in health care [59].

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References

[1] Collaborators GBDN. Global, regional, and national burden of neurological disorders, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016. Lancet Neurol. 2019;18(5):459-80.
[2] Laver KE, Lange B, George S, Deutsch JE, Saposnik G, Crotty M. Virtual reality for stroke rehabilitation. Cochrane Database Syst Rev. 2017;11(11):CD008349.
[3] Mekbib DB, Han J, Zhang L, Fang S, Jiang H, Zhu J, et al. Virtual reality therapy for upper limb rehabilitation in patients with stroke: a meta-analysis of randomized clinical trials. Brain Inj. 2020;34(4):456-65.
[4] John NW, Day TW, Pop SR, Chatterjee K, Cottrell K, Buchanan A, et al., editors. Virtual reality environment for the cognitive rehabilitation of stroke patients. 2019 11th International Conference on Virtual Worlds and Games for Serious Applications (VS-Games); 2019: IEEE.
[5] Pietrzak E, Pullman S, McGuire A. Using virtual reality and videogames for traumatic brain injury rehabilitation: a structured literature review. GAMES FOR HEALTH: Research, Development, and Clinical Applications. 2014;3(4):202-14.
[6] Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. Annals of internal medicine. 2018;169(7):467-73.
[7] Arksey H, O'Malley L. Scoping studies: towards a methodological framework. International Journal of Social Research Methodology. 2005;8(1):19-32.
[8] Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan—a web and mobile app for systematic reviews. Systematic Reviews. 2016;5(1):210.
[9] Greenhalgh T, Abimbola S. The NASSS Framework - A Synthesis of Multiple Theories of Technology Implementation. Studies in health technology and informatics. 2019;263:193-204.
[10] Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics. 1977;33(1):159-74.
[11] Mekbib DB, Debeli DK, Zhang L, Fang S, Shao Y, Yang W, et al. A novel fully immersive virtual reality environment for upper extremity rehabilitation in patients with stroke. Ann N Y Acad Sci. 2021;1493(1):75-89.
[12] Spreij LA, Visser-Meily JMA, Sibbel J, Gosselt IK, Nijboer TCW. Feasibility and user-experience of virtual reality in neuropsychological assessment following stroke. Neuropsychol Rehabil. 2022;32(4):499-519.
[13] Yasuda K, Muroi D, Hirano M, Saichi K, Iwata H. Differing effects of an immersive virtual reality programme on unilateral spatial neglect on activities of daily living. BMJ Case Rep. 2018;2018.
[14] [14] Aida J, Chau B, Dunn J. Immersive virtual reality in traumatic brain injury rehabilitation: a literature review. NeuroRehabilitation. 2018;42(4):441-8.
[15] Song Y-H, Lee H-M. Effect of immersive virtual reality-based bilateral arm training in patients with chronic stroke. Brain Sciences. 2021;11(8):1032.

[16] Tsatsis CG, Rice KE, Protopopova V, Ramos D, Jadav J, Coppola JF, et al., editors. Lateropulsion rehabilitation using virtual reality for stroke patients. 2017 IEEE Long Island Systems, Applications and Technology Conference (LISAT); 2017: IEEE.
[17] Zakharov AV, Bulanov VA, Khivintseva EV, Kolsanov AV, Bushkova YV, Ivanova GE. Stroke affected lower limbs rehabilitation combining virtual reality with tactile feedback. Frontiers in Robotics and AI. 2020;7:81.
[18] Gamito P, Oliveira J, Santos N, Pacheco J, Morais D, Saraiva T, et al. Virtual exercises to promote cognitive recovery in stroke patients: the comparison between head mounted displays versus screen exposure methods. International Journal on Disability and Human Development. 2014;13(3):337-42.
[19] Held JPO, Yu K, Pyles C, Veerbeek JM, Bork F, Heining SM, et al. Augmented Reality-Based Rehabilitation of Gait Impairments: Case Report. JMIR Mhealth Uhealth. 2020;8(5):e17804.
[20] Huang X, Naghdy F, Du H, Naghdy G, Murray G. Design of adaptive control and virtual reality-based fine hand motion rehabilitation system and its effects in subacute stroke patients. Computer Methods in Biomechanics and Biomedical Engineering: Imaging & Visualization. 2018;6(6):678-86.
[21] Jin M, Pei J, Bai Z, Zhang J, He T, Xu X, et al. Effects of virtual reality in improving upper extremity function after stroke: a systematic review and meta-analysis of randomized controlled trials. Clinical Rehabilitation. 2022:02692155211066534.
[22] Lee SH, Jung HY, Yun SJ, Oh BM, Seo HG. Upper Extremity Rehabilitation Using Fully Immersive Virtual Reality Games With a Head Mount Display: A Feasibility Study. PM R. 2020;12(3):257-62.
[23] Lubetzky AV, Kelly J, Wang Z, Gospodarek M, Fu G, Sutera J, et al. Contextual sensory integration training via head mounted display for individuals with vestibular disorders: a feasibility study. Disabil Rehabil Assist Technol. 2022;17(1):74-84.
[24] Marin-Pardo O, Laine CM, Rennie M, Ito KL, Finley J, Liew SL. A Virtual Reality Muscle-Computer Interface for Neurorehabilitation in Chronic Stroke: A Pilot Study. Sensors (Basel). 2020;20(13).
[25] Mekbib DB, Zhao Z, Wang J, Xu B, Zhang L, Cheng R, et al. Proactive Motor Functional Recovery Following Immersive Virtual Reality-Based Limb Mirroring Therapy in Patients with Subacute Stroke. Neurotherapeutics. 2020;17(4):1919-30.
[26] San Luis MAV, Atienza RO, San Luis AM, editors. Immersive virtual reality as a supplement in the rehabilitation program of post-stroke patients. 2016 10th International Conference on Next Generation Mobile Applications, Security and Technologies (NGMAST); 2016: IEEE.
[27] Connelly L, Jia Y, Toro ML, Stoykov ME, Kenyon RV, Kamper DG. A pneumatic glove and immersive virtual reality environment for hand rehabilitative training after stroke. IEEE Trans Neural Syst Rehabil Eng. 2010;18(5):551-9.
[28] Cortés-Pérez I, Nieto-Escamez FA, Obrero-Gaitán E. Immersive virtual reality in stroke patients as a new approach for reducing postural disabilities and falls risk: a case series. Brain sciences. 2020;10(5):296.
[29] Nagashima Y, Ito D, Ogura R, Tominaga T, Ono Y. Development of Virtual Reality-based Gait Training System Simulating Personal Home Environment. Annu Int Conf IEEE Eng Med Biol Soc. 2021;2021:5764-7.
[30] Palacios-Navarro G, Hogan N. Head-mounted display-based therapies for adults post-stroke: A systematic review and meta-analysis. Sensors. 2021;21(4):1111.
[31] Park W, Kim J, Kim M. Efficacy of virtual reality therapy in ideomotor apraxia rehabilitation: A case report. Medicine (Baltimore). 2021;100(28):e26657.
[32] Schiza E, Matsangidou M, Neokleous K, Pattichis CS. Virtual Reality Applications for Neurological Disease: A Review. Front Robot AI. 2019;6:100.
[33] Subramanian SK, Levin MF. Viewing medium affects arm motor performance in 3D virtual environments. J Neuroeng Rehabil. 2011;8:36.
[34] Tambone R, Giachero A, Calati M, Molo MT, Burin D, Pyasik M, et al. Using Body Ownership to Modulate the Motor System in Stroke Patients. Psychol Sci. 2021;32(5):655-67.
[35] Weber LM, Nilsen DM, Gillen G, Yoon J, Stein J. Immersive Virtual Reality Mirror Therapy for Upper Limb Recovery After Stroke: A Pilot Study. Am J Phys Med Rehabil. 2019;98(9):783-8.
[36] Winter C, Kern F, Gall D, Latoschik ME, Pauli P, Kathner I. Immersive virtual reality during gait rehabilitation increases walking speed and motivation: a usability evaluation with healthy participants and patients with multiple sclerosis and stroke. J Neuroeng Rehabil. 2021;18(1):68.
[37] Brassel S, Power E, Campbell A, Brunner M, Togher L. Recommendations for the Design and Implementation of Virtual Reality for Acquired Brain Injury Rehabilitation: Systematic Review. J Med Internet Res. 2021;23(7):e26344.
[38] Chen J, Xie Z, Or C. Effectiveness of immersive virtual reality-supported interventions for patients with disorders or impairments: a systematic review and meta-analysis. Health and Technology. 2021;11:811-33.

[39] Moraes TM, Zaninotto AL, Neville IS, Hayashi CY, Paiva WS. Immersive virtual reality in patients with moderate and severe traumatic brain injury: A feasibility study. Health and Technology. 2021;11(5):1035-44.
[40] Sabu R, Yasuda K, Kato R, Kawaguchi S, Iwata H, editors. Does visual search by neck motion improve hemispatial neglect?: an experimental study using an immersive virtual reality system. 2020 IEEE International Conference on Systems, Man, and Cybernetics (SMC); 2020: IEEE.
[41] Elor A, Kurniawan S, Teodorescu M, editors. Towards an immersive virtual reality game for smarter post-stroke rehabilitation. 2018 IEEE International Conference on Smart Computing (SMARTCOMP); 2018: IEEE.
[42] Knobel SEJ, Kaufmann BC, Gerber SM, Cazzoli D, Muri RM, Nyffeler T, et al. Immersive 3D Virtual Reality Cancellation Task for Visual Neglect Assessment: A Pilot Study. Front Hum Neurosci. 2020;14:180.
[43] Belger J, Krohn S, Finke C, Tromp J, Klotzsche F, Villringer A, et al., editors. Immersive Virtual Reality for the Assessment and Training of Spatial Memory: Feasibility in Individuals with Brain Injury. 2019 International Conference on Virtual Rehabilitation (ICVR); 2019: IEEE.
[44] Chatterjee K, Buchanan A, Cottrell K, Hughes S, Day TW, John NW. Immersive Virtual Reality for the Cognitive Rehabilitation of Stroke Survivors. IEEE Trans Neural Syst Rehabil Eng. 2022;30:719-28.
[45] Christou CG, Michael-Grigoriou D, Sokratous D, editors. Virtual buzzwire: Assessment of a prototype VR game for stroke rehabilitation. 2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR); 2018: IEEE.
[46] Gustavsson M, Kjork EK, Erhardsson M, Alt Murphy M. Virtual reality gaming in rehabilitation after stroke - user experiences and perceptions. Disabil Rehabil. 2022;44(22):6759-65.
[47] Moan ME, Vonstad EK, Su X, Vereijken B, Solbjor M, Skjaeret-Maroni N. Experiences of Stroke Survivors and Clinicians With a Fully Immersive Virtual Reality Treadmill Exergame for Stroke Rehabilitation: A Qualitative Pilot Study. Front Aging Neurosci. 2021;13:735251.
[48] Erhardsson M, Alt Murphy M, Sunnerhagen KS. Commercial head-mounted display virtual reality for upper extremity rehabilitation in chronic stroke: a single-case design study. J Neuroeng Rehabil. 2020;17(1):154.
[49] Park Y-H, Lee C-h, Lee B-H. Clinical usefulness of the virtual reality-based postural control training on the gait ability in patients with stroke. Journal of exercise rehabilitation. 2013;9(5):489.
[50] Funao H, Tsujikawa M, Momosaki R, Shimaoka M. Virtual reality applied to home-visit rehabilitation for hemiplegic shoulder pain in a stroke patient: a case report. J Rural Med. 2021;16(3):174-8.
[51] Thompson-Butel AG, Shiner CT, McGhee J, Bailey BJ, Bou-Haidar P, McCorriston M, et al. The role of personalized virtual reality in education for patients post stroke—a qualitative case series. Journal of Stroke and Cerebrovascular Diseases. 2019;28(2):450-7.
[52] Rohrbach N, Krewer C, Löhnert L, Thierfelder A, Randerath J, Jahn K, et al. Improvement of apraxia with Augmented Reality: influencing pantomime of tool use via holographic cues. Frontiers in Neurology. 2021:1491.
[53] Cidota MA, Bank PJ, Ouwehand P, Lukosch SG, editors. Assessing upper extremity motor dysfunction using an augmented reality game. 2017 IEEE International Symposium on Mixed and Augmented Reality (ISMAR); 2017: IEEE.
[54] Bryant L, Brunner M, Hemsley B. A review of virtual reality technologies in the field of communication disability: implications for practice and research. Disability and Rehabilitation: Assistive Technology. 2020;15(4):365-72.
[55] Plechata A, Nekovářová T, Fajnerová I. What is the future for immersive virtual reality in memory rehabilitation? A systematic review. NeuroRehabilitation. 2021;48(4):389-412.
[56] Bank PJ, Cidota MA, Ouwehand P, Lukosch SG. Patient-tailored augmented reality games for assessing upper extremity motor impairments in Parkinson's disease and stroke. Journal of medical systems. 2018;42:1-11.
[57] Banville F, Nolin P. Using virtual reality to assess prospective memory and executive functions after traumatic brain injury. Journal of CyberTherapy and Rehabilitation. 2012;5(1):45-55.
[58] Ogourtsova T, Archambault P, Lamontagne A, editors. Let's do groceries-a novel virtual assessment for post-stroke unilateral spatial neglect. 2017 International Conference on Virtual Rehabilitation (ICVR); 2017: IEEE.
[59] Broekhuis M, Weering MD-v, Schuit C, Schürz S, van Velsen L. Designing a stakeholder-inclusive service model for an eHealth service to support older adults in an active and social life. BMC Health Services Research. 2021;21(1):654.

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