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Open Access Compendium

Future Perspectives on Accessibility, AT and (e)Inclusion

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Aim and scope: To communicate and complete knowledge on ICT, AT and Accessibility for/with people with disabilities and older adults and connect research in these domains with the necessary practical background and user related aspects.

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Editorial

Welcome to the 3rd edition of our Open Access Compendium! After an intense co-operation with AAATE in 2022, we represent again ICCHP and "Future Perspectives on AT, Accessibility and (e)Inclusion", published on the occasion of ICCHP 2024 at Linz University, Linz, Austria.

After the Open Access Journal´s first two editions, the "Future Perspectives of AT, eAccessibility and eInclusion", ICCHP continues this publication covering a more practical view on AT, Accessibility, ICT with and for people with disabilities and older adults.

These last 2 years were subject to significant changes in ICT and all connected areas – AI and Large Language Models revolutionize education and term paper writing. E.g. Chat GPT writes Program Code – and Graphical AI – like e.g. Midjourney draws the pictures to it. Data Scientists already talk about "intelligence" and the threat of Super-Villain AIs manipulating political systems and elections.

AI also shows a merciless picture on how "society" or at least "the internet" sees and discusses "disability", "inclusion" and "Assistive Technology". In case you did not do so already, try it and ask e.g. Midjourney to draw a picture by just giving the terms Disability or Assistive Technology and see firsthand some main issues in the societal discourse that keeps us all from reaching our goals, accessibility and participation for "All". You will not see edge of tomorrow tech, nor laptops or tablets used by a person with a disability to take part in education or society – in most cases you see people in old, not fitting wheelchairs – and they are in most cases alone, standing in due distance from "where life is".

Asking ChatGPT to "Write 200 words in editorial style elaborating the potential of artificial intelligence, large language models and pervasive computing in making IT, internet and life more accessible to people with disabilities in the future also mentioning privacy and data security issues" delivers the following:

"Artificial intelligence (AI), large language models (LLMs), and pervasive computing hold tremendous promise in revolutionizing accessibility for individuals with disabilities. These technologies can transform how people interact with IT and the internet, fostering a more inclusive society.

AI, with its capacity to learn and adapt, can be integrated into assistive devices to enhance their functionality. For instance, voice recognition and natural language processing (NLP) can empower those with mobility impairments to control computers and smart home devices through voice commands. Similarly, computer vision can aid visually impaired individuals by describing their surroundings or reading text aloud.

LLMs like GPT-4 can significantly advance communication aids for individuals with speech or language disorders. By understanding context and generating human-like text, these models can assist in generating coherent, contextually appropriate responses, facilitating smoother communication for those who struggle with conventional methods.

Pervasive computing, embedding computing power in everyday objects, ensures constant support and accessibility. Smart environments can adapt to users' needs in real-time, offering tailored assistance and reducing barriers to accessing information and services.

However, these advancements also raise significant privacy and data security concerns. The reliance on vast amounts of personal data necessitates robust data protection frameworks to prevent misuse. Ensuring that AI systems are transparent, secure, and respect user privacy is crucial. As these technologies evolve, balancing innovation with ethical considerations will be vital to create a truly inclusive digital future."

So then – let's create, use and work together and make the best of this potential to foster and promote our mission in the right direction! We hope that this third edition of our Open Access Compendium delivers memories, knowledge and also new aspects to you – and to come back in 2026; again renewed, bigger and even more relevant and exciting.

Andrea Petz and Klaus Miesenberger, Editors

Contents

1. Inclusion4EU: Towards a Framework of Inclusive Software Design Processes and Practices

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Abstract

This research is based on a trans-European research project aimed at enhancing software design and engineering practices to promote inclusivity, involving stakeholders from academia, industry, and disability advocacy services. To explore the nature and meaning of inclusion, a number of different approaches to inclusion are outlined, including models of equitable design (Accessible Design, Inclusive Design, Universal Design, and Design for All), User Design processes (Co-Production, Co-Creation, User-Centred Design, Co-Design, and Participatory Design), and Software Engineering Methodologies (Linear, Spiral, and Agile). These three categories of models are combined to form a three-dimensional environment in which software development projects can be mapped into to assess their level of inclusion. Finally, some case studies are presented to illustrate this new 3-D space in action.

Introduction

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. As part of a new trans-European research project, Inclusion4EU, a group of European stakeholders from academia, industry and disability advocacy services are exploring ways to improve software design and engineering practices to encourage the development of software systems that are more accessible and inclusive. The key objectives in this process are:

- Through engagement with stakeholder groups, to develop a set of tangible outcomes (real world case studies and reports) on good and bad practices in software design and development;
- Via a survey of European institutions to understand the current practices, including best practices, challenges and future needs for teaching inclusive software design;
- Via a series of co-design sessions with participants from marginalized groups across Europe, to create a shared understanding around the needs, capabilities and preferences of older adults and people with disabilities for inclusive technology;
- 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;
- 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 1, with a focus on findings related to good design practices. In this abstract we provide a review of models of inclusive design, as well as processes of co-design that focuses on incorporating diverse users into the design process.

Equitable Design Models

There are a range of design models that consider the issue of inclusion, these include models such as Accessible Design, Inclusive Design, Universal Design, and Design for All. Although these terms are used interchangeably, they represent distinct philosophies of design, with different origins, and each is used more frequently in different disciplines. and they represent a successive widening of the target audiences. They are, however, all focused on design that includes the authentic consideration of people with a wide range of abilities.

Accessible Design

Accessible Design means designing a product or service that can be accessed by anyone, regardless of whether the individual has a disability or not (Armitage, 2016), and the simplest way to build in accessibility is from the beginning of the design process (Kalbag, 2017). There are a variety of potential accessibility issues that a user may have - visual issues, auditory issues, cognitive limitations, limited movement, speech disabilities, neurological limitations and temporary issues (Barrell, 2019). In the early days of the World Wide Web, Berners-Lee (1997) stated that "*it is critical that the Web be usable by anyone, regardless of individual capabilities and disabilities*". Web accessibility is concerned with ensuring that websites, tools and technologies are designed to be usable and accessible for all users, regardless of ability. The Web Accessibility Initiative (WAI) have developed a variety of guidelines to promote web accessibility that are based on four design principles (Brown and Hollier, 2015): *Perceivable*: e.g. provide text alternatives for non-text content, create content that can be presented in different ways; *Operable*: e.g., make all functionality available from a keyboard, help users navigate and find content; *Understandable*: e.g., make text readable and understandable, help users avoid and correct mistakes; and *Robust*: e.g., maximise compatibility with current and future user tools.

Inclusive Design

An inclusive design strategy requires understanding of diversity within the population and responding to the identified diversity with knowledgeable design decisions that addresses the needs of as wide a range of people as possible (Waller *et al*., 2015). It is very important that Inclusive design is incorporated into the overall design process from the initial concept stage, and all decisions throughout the development process should include the users' feedback (Waller *et al*., 2015). Recent international trends towards the integration of disabled people into the mainstream of society, has been reflected in the inclusive design process (Clarkson & Coleman, 2015). Whilst accessibility design is focused on users with disabilities, inclusive design has a much wider focus as it involves all aspects of diversity (Joyce, 2022). Narenthiran, *et al*. (2022) explored the use of mixed methods to understand how users adapted their personal workspaces during the COVID lockdown, to help develop more inclusive workspaces. To achieve this an exploration of the literature was undertaken, followed by a survey, circulated to students and staff at a large university in the UK, with the aim of understanding how people had adapted their home spaces during COVID lockdown and to explore what barriers they continue to face. The key conclusion of this research was that it is important to work with end users to understand their specific needs and identify creative and inclusive solutions.

Universal Design

The term "universal design" was created by American architect Ron Mace in the mid-1980s (Mace, 1985) to describe a new philosophy of design - "*the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design*" (Dolph, 2021; Story, *et al*., 1998). Watchorn, *et al*. (2021) developed a systematic review of current literature regarding applications of universal design to built environments. They used the person–environment–occupation (PEO) model as a theoretical framework for the review, which found 33 key peer-reviewed journal articles. Those articles are generally focused more on description, discussion, and commentary rather than empirical approaches; although, a combination of quantitative, qualitative, and mixed methods approaches is employed in many papers. They conclude that including a wider range of perspectives (occupations, social participation, multi-disciplinary and trans-disciplinary collaboration, and multicultural perspectives) in the ongoing discourse around UD would enable the concept to reach its full potential as a medium for social justice.

Design for All

"Design for All" is a similar notion to universal design, but its focus and origins are more closely related to the development of technologies that are usable by all (Burzagli, *et al.*, 2009), as opposed to the built environment. It is not intended to be a design approach to develop a single solution for everybody, but instead as a user-centred approach to providing products that can automatically address the possible range of needs, as such is it often characterized as a "Swiss army knife" approach to design (Nordby, 2004). Harper (2007) explored *Design for All* in the context of the World Wide Web, where he argued that it proposes that every web page should be designed so that as many people as possible can access it, regardless of any sensory or cognitive impairments. However, he observed that the concept means different things to different people, and this creates a barrier to full implementation of it. He notes that for some people it is a broad notion that impacts society at large, by making reference to socioeconomics, ethics, and issues of general discrimination, while others see it only as a technological issue and a problem to be solved.

Summary

In this research we consider each of these models as a progression in terms of the scope of the range of people for whom each considers within their design process, with Accessible Design representing the narrowest range of users, and Design for All representing the widest range of people and devices.

Table 1-1: Comparison of Models of Equitable Design

	Accessible Design	**Inclusive Design**	**Universal Design**	**Design for All**
Original Discipline:	Disability Studies (ref. Armitage, 2016)	Ergonomics (ref. Waller *et al.*, 2015).	Architecture (Ref. Mace, 1985)	Computer Science (ref. Burzagli, *et al.*, 2009)
Aimed at:	Specifically focused on people with disabilities.	Marginalised Groups (including age, size, and ability).	Marginalised Groups (including age, size, and ability).	Everyone, and a wide range of technologies as well.
Principles:	W3C/WAI Guidelines including WCAG and ARIA.	Inclusive Design Research Centre guidelines.	CAST Principles of Universal Design	All of the design principles from the other models.

User Design Processes

Software development processes that either include users as part of their development, or even consider users as part of the design process, are called "User Design Processes" (Norman, 1986). They typically involve gaining an understanding of the users and their needs by conducting user research which will lead to a series of goals, tasks, preferences, and pain points of the users. Following this a design process will occur, which may either directly involve users, or the outcomes of the previous stage. Next, a development process will occur, again either involving users or the user research, Finally, the system will be evaluated, typically with real users. Some examples are presented below.

Co-Production

Co-Production describes the development of public services and technologies where citizens are involved in the design process (Pestoff, *et al.*, 2013). In many cases it can involve citizens not only being consulted, but also being involved in the conception, design, steering, and ongoing management of public services (Bason, 2010). A typical definition of co-production is "*an asset-based approach to public services that enables people providing and people receiving services to share power and responsibility, and to work together in equal, reciprocal and caring relationships*" (CNW, 2023).

Co-Creation

Co-Creation refers to a joint design process that is similar to the Co-Production process outlined above, however instead of focusing on public services, it focuses on businesses and their interactions with customers. In a co-creation scenario, a business will take ideas and other input from their customers, to strengthen the relationship between them (Lopera-Molano and Lopera-Molano, 2020). The benefit of this approach is that it creates networks between not only the businesses and their customers; but others such as: suppliers, partners, and employees (Ramaswamy and Gouillart, 2010).

User-Centred Design

User-Centred Design (UCD) has its roots in the computer science domain, and it advocates the inclusion of user-centred considerations such as usability goals, user characteristics, and usage environment into the design process (Norman, 1986). It recommends including users in the design process when possible, but if not, allows for the use of alternative approaches such as *personas* (Gulliksen, *et al.*, 2003). Some common considerations in UCD developments include legibility, readability, understandability and accessibility (Suojanen, *et al.*, 2014).

Co-Design

Co-Design refers to design processes where designers incorporate input from non-designers (including customers, researchers, and other stakeholders) into their design. The nature of the collaboration will vary widely from project to project, and the designers and non-designers may not have an equal say in the design outcomes (Zamenopoulos and Alexiou, 2018).

Participatory Design

Participatory Design describes an approach where designers and non-designers (including customers, researchers, and other stakeholders) actively participate together in the design process (Ehn, 1992). It has its roots as a political movement in the 1970s to help form partnerships between labour unions and employers (Spinuzzi, 2005). There is a collection of methodologies that are associated with participatory design, which emphasizes not just consultation, but active, meaningful participation of the non-designers.

Summary

In this research we consider each of these models as a progression in terms of the degree to which users are involved in the development process, and the amount of control they have in the decision-making processes.

Table 1-2: Comparison of User Design Processes

	Co=Production	Co-Creation	User Centred Design	Co-Design	Participatory Design
Original Discipline	Political Science (ref. Pestoff, *et al.*, 2013).	Marketing (ref. Lopera-Molano, 2020).	Computer Science (ref. Norman, 1986)	Design Science (ref. Zamenopoulos and Alexiou, 2018).	Political Science (ref. Spinuzzi, 2005)
Participants	Designers are essential, but non-designers are often included also.	Designers are essential, but non-designers are often included also.	Designers are essential, but non-designers are often included also, or personas.	Designers and non-designers (including customers, researchers, and other stakeholders)	Designers and non-designers (including customers, researchers, and other stakeholders)
Locus of control	Public sector, typically, with the designers.	Private sector, typically, with the designers.	Typically, with non-designers, but not mandatory.	With the designers.	Shared between the designers and the non-designers.

Software Engineering Methodologies

Software Engineering Methodologies describe the project plans required to develop a software system, typically with timelines and tasks. Since the 1960s these approaches have been used particularly "*to develop large scale functional business systems*" (Elliott, 2004). These approaches have strong parallels with building architecture (Slayton, 2013), where in both cases the needs of the customer are identified, followed by a designing process, a development process, and a testing process. Below are three seminal methodology types, spanning the history of programming, to help explore the evolution of development approaches.

Linear Models

The earliest models of software development are described as "linear models", this means that the software project is divided into several stages, and each stage is undertaken sequentially. Crucially, in this type of model, the developers are not allowed to revisit a previous stage once it has been completed. Once of the oldest, and most seminal linear models is the "Waterfall Model", presented originally by Winston Royce in his 1970 paper "*Managing the Development of Large Software Systems*". It proposes a seven-stage linear model moving from "Systems Requirements", "Software Requirements", "Analysis", "Program Design", "Coding", Testing" and "Operations". Each stage ends with a "Validation and Verification" process where a check is done to ensure that the activity of the current stage matches the outcomes of the previous stage, and a second check to ensure that the activity of the current stage matches the overall goals of the process. It is important to note that Royce's paper specifically warns against this model being used literally, since the "Testing" stage begins so late in the process, and Royce feels that testing should start once the "Program Design" stage is done.

Iterative Models

A newer series of models for software development are referred to as "iterative models", which means, as before, the software project is divided into several stages, however, in this type of model, the developers are allowed to revisit previous stages as frequently as required. The most notable iterative model is the Spiral Model, as described by Barry Boehm, in his 1998 paper "A Spiral Model of Software Development and Enhancement". It presents a radically different approach to modelling the development process, whereby the final system is developed by producing a series of prototypes, and each prototype feeds into the next generation prototype in an iterative manner, until the final release is created. Within each prototype development there are four stages, outlined below:

1. **Determine Objectives**: This stage considers the aims of the current iteration, and details them as a series of requirements, and it also sets out an initial design for this stage.
2. **Identify and Resolve Risks**: This stage looks at the some of the risks that stem from the selected approach and identifies ways to mitigate or eliminate those risks.
3. **Develop and Test**: This stage is similar to the Waterfall Model or V-Model stages, where the systems is full designed, developed and tested.
4. **Plan the Next Iteration**: This stage looks at what has been developed, and looks at the overall goals of the project and how the next iteration will get us nearer to the overall goals.

Agile Models

The newest series of models for software development are referred to as "agile models", which means, as before, the software project is divided into several stages, however, in then further sub-divided into much smaller tasks that can be completed rapidly (Fowler and Highsmith, 2001). One of the most common agile models uses the analogy of the game of rugby to describe the software development process. The Scrum Framework divides the development process into 2-4 week intervals called "Sprints". The entire set of tasks to build the completed system are put in a list called the "Product Backlog", and the tasks to be done in the current sprint are put in the "Sprint Backlog". Within each Sprint the activities are broken down into 1-2 day tasks, and the team of developers typically have a daily meeting (called a "Daily Scrum") where each developer presents their progress for the day, and their planned tasks to the next 24 hours. When each Sprint is completed, there is a review process ("Sprint Retrospective") to reflect on what went well and what went badly in the completed Sprint. There is also another meeting at the end of each Sprint, called the "Sprint Review" where the progress of the team of developers is presented to all the key stakeholders.

Summary

In this research we consider each of these models as a progression in terms of the degree of autonomy that developers have in terms of the tasks they are doing, additionally each of these models sees a reduction in the granularity of stages in these models.

Table 1-3: Comparison of Models of Software Engineering Methodologies

	Linear Models	Iterative Models	Agile Models
Decade articulated:	1970s	1980s	2000s
Focused on:	Following a clearly articulated methodology.	Reducing potential risks that may occur in the development process.	Getting working software developed that matches the system specification.
Level of Documentation:	All stages and tasks are extensively documented.	All stages and tasks are extensively documented.	All stages and tasks are documented as needed.
Suitable for:	Large software projects with high staff turnover.	Medium software projects with high staff turnover.	Medium software projects with a core team of developers.

The 3-D ED/UC/ATE Design Space

This research proposes a new, three-dimensional design space that allows designers to represent different software development projects in this space to assess the degree to which the users and accessibility are considered as part of the design process, as well as other important inclusion considerations. The three main sections previously discussed are combined into a 3D space where each of the three sections serve as axes in this space. This space is called ED/UC/ATE, standing for: Equitable Design, User Centredness, Approach To Engineering),

This space can be used by software development organisations, either retrospectively, to reflect on the degree to which they have incorporated users and accessibility considerations into their previous projects, and if their trajectory is moving towards more inclusive practices or not. It can be also be used for a current project (or projects), with the recognition that software projects are dynamic by nature, and might move around the design space as the project progresses. In the following section some case studies will be mapped into this space to demonstrate the process.

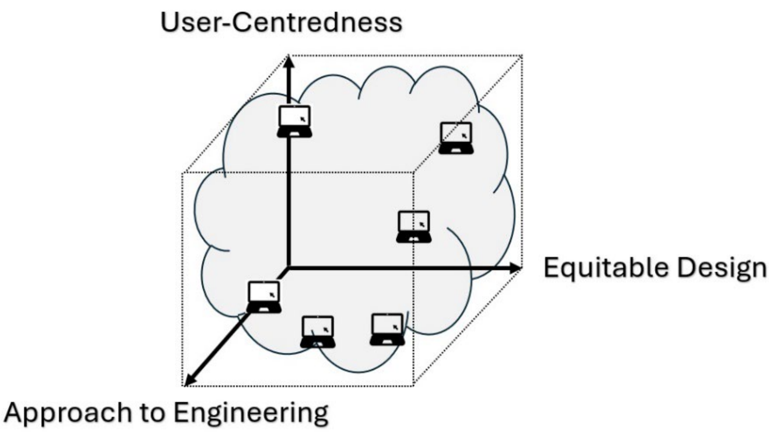

Figure 1-1: The ED/UC/ATE Design Space to model the Accessibility of a Software Design Project

Case Studies

Presented below are a number of accessibility case studies, where the case study is presented followed by a brief description of where this case fits in the 3D ED/UC/ATE space.

Case Study 1: The PLAY-IT Model

Developed by California State University, USA and Leeds Beckett University, UK, this case study focuses on a new approach to making User Experience Design research more inclusive by using an approach called the "Connectivity Model" to more easily include persons with autism in the participation process. User Experience (UX) Design is the process of designing a product or service so that a user has maximum satisfaction in using it, through user research, usability testing and iterative design. Using an inclusive design approach is an important step in achieving that goal, but the inclusion of persons with autism in participating group can sometimes be challenging, potentially due to their lack of sufficient cognitive ability or language skills to participate in the research process in meaningful ways. Further, lecturers and teachers may be reluctant to include such persons due to institutional regulations and ethical concerns. The "Connectivity Model" avoids the requirement for complex ethical clearance by facilitating observations via recorded videos. It analyses user behaviour looking at social, emotional, behavioural, physical and motivational needs, and considers constraints such as ability in the areas of physical, cognitive, and developmental areas.

On the ED/UC/ATE model, this case scores low on the ED scale, as it is focusing on a specific disability, high on the UC scale as the Connectivity Model can be used in many user design scenarios, and high on the ATE scale, because again the Connectivity Model can be used in many engineering methodologies.

Case Study 2: The Ryanair Website

Irish airline Ryanair has a stated aim to reach 225 million passengers by 2026, and a key part of achieving that goal is to improve their digital offerings. A key part of this process is the role of Ryanair Labs, the technology Hub of Ryanair. Ryanair was known in the past for its poor website. Colin O Brien head of QA at Ryanair Labs identified this as a key reason for growth not breaking through the 80m barriers and this lead to a major re-think about digital strategy. This has lead to renewed emphasis on redeveloping digital services. Lead by Ryanair labs user experience (Ux) is at the heart of this re-design. An extensive process of user feedback is built into development and deployment strategies. Activities include: User Testing, Empathy maps, Contextual Inquiries. Benchmarking, Surveys, and Shadowing. Development involved a 5-stage process Research, Design, Prototype, User Testing and Develop and launch. Users are heavily involved in the Research, testing and Deployment phases. Ryanair continues to grow its digital offering and has added services like a Day of Travel App and Digital Wallet. An important initiative in meeting its goals is its use of a customer panel. By driving a user lead policy Ryainar is on its way to achieving its 225 m passenger goals.

On the ED/UC/ATE model, this case scores high on the ED scale, as it is trying to capture as wide an audience as possible, high on the UC scale as they undertook many user design scenarios, and low on the ATE scale, as the methodology was relatively linear.

Conclusions and Possible Next Steps

This research presented a number of different approaches to inclusion including models of equitable design (Accessible Design, Inclusive Design, Universal Design, and Design for All), User Design processes (Co-Production, Co-Creation, User-Centred Design, Co-Design, and Participatory Design), and Software Engineering Methodologies (Linear, Spiral, and Agile). These three categories of models were combined to form a three-dimensional environment in which software development projects can be mapped into to assess their level of inclusion, this space is called ED/UC/ATE space. Finally some case studies were presented to illustrate this new 3-D space in action.

The next step in this project is to create software tools to allow software developers to model their projects in the ED/UC/ATE space in a dynamic manner. At the start of the project the developers (and others) will be asked a number of questions about the project to develop a baseline for the ED/UC/ATE model, and as the project progresses further questions will be asked to determine whether or not compromises are being made that will diminish the inclusiveness of the project, or on the contrary, if more users are being involved in the project than anticipated, or some other way is used to boost the inclusiveness of the project. It is anticipated that developers will also review existing completed projects to determine their level of inclusiveness, and to reflect upon activities in their organization that can lead to more inclusive software development.

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2. The Accessibility and Usability of Mobile Apps for Students' Mental Wellbeing in Higher Education

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Abstract

Students' mental wellbeing has increasingly become a challenge in higher education. Studies have highlighted the positive impact of mobile apps on enhancing the mental health. However, despite these benefits, issues related to accessibility and usability in mental health apps pose barriers for diverse students, limiting their ability to take full advantage of these apps. This study aims to identify digital barriers and provide recommendations for designing and developing mental health apps with a high level of accessibility and usability. To achieve this objective, we conducted both automated and heuristic evaluations in addition to user testing on five selected mental health apps. The results revealed that all the apps examined displayed accessibility and usability issues. To ensure that mental health apps achieve a high level of accessibility and usability, it is crucial for apps designers and developers to follow accessibility and usability principles and guidelines.

Introduction

The mental wellbeing of students poses an increasing challenge in higher education, as evidenced by national surveys indicating rising rates of anxiety and depression among university students over the past decade [1, 2]. The negative impact of COVID-19 on students' mental wellbeing in higher education has been highlighted by various studies [3, 4]. According to the World Health Organization [5], metal health is "a state of wellbeing in which an individual realizes his or her own abilities, can cope with the normal stress of life, can work productively and is able to make a contribution to his or her community". In the context of higher education, mental wellbeing of students has been identified as an key predicator of academic performance and retention [6]. Digital technologies have potential for enhancing students' mental wellbeing [7]. Research, such as [8], have shown the positive effects of mobile apps on improving students' mental wellbeing in higher education. Despite the documented benefits, accessibility and usability issues in mental health apps pose barriers for users, hindering their ability to take full advantage of these applications [9]. Challenges such as low contrast, inadequate navigation support, small text and icons, unclear error messages make it difficult for students to effectively utilize these apps to improve their mental wellbeing. However, there is a limited focus in literature on the usability and accessibility aspects of these mental health apps [4].

The aim of this study is to identify digital barriers present in mental health apps for students in higher education and provide recommendations for designing and developing mental health apps with a high level of accessibility and usability. To achieve this goal, we conducted both automated and heuristic evaluations, as well as user testing.

Related Work

Ensuring the accessibility of mental health apps involves securing that these apps do not pose barriers for students. They should comply with the principles of perceivability, operability, understandability and robustness outlined in the Web Content Accessibility Guidelines (WCAG) [10]. Previous studies, such as [11] focusing on the accessibility of mobile apps, have evaluated various applications to determine their compliance with accessibility guidelines. However, to the best of our knowledge, there is currently no literature specifically addressing the accessibility of mental health apps for students in higher education.

Studies such as [9] have emphasized the crucial role of usability in mental health apps for enhancing user engagement. In the context of mental health apps for students in higher education, previous research has conducted usability evaluation as part of the design and development process or along with assessing the acceptance and efficacy of app-based interventions [12]. Quantitative data on usability were collected using questionnaire based on metrics like the System Usability Scale (SUS)[13], Mobile Application Rating Scale (MARS) [14], and Nielsen's 10 heuristics [15]. Some studies, such as [16] collected qualitative data through semi-structured interviews. The literature has also explored the usability of mental health apps such as stress management apps [17] without specifically targeting university students.

Methods

In this study we employed an approach that combines automated and heuristic evaluations, in addition to user testing to identify accessibility and usability challenges in mental health apps for students in higher education. Five apps aimed enhancing mental wellbeing among university students were chosen for evaluation. The selection of these apps was primarily informed by a literature search, which identified apps that have demonstrated a positive impact on students' mental wellbeing. This search was supplemented by recommendations from health organizations, authorities, or student-related forums. In addition, factors such as the app's availability as a free download, total number of downloads, and rating received were also considered. The five apps subjected to our evaluations are Calm, Happify, Headspace, MyPossibleSelf and Smiling Mind. The apps were downloaded onto an Android 14 Samsung mobile phone. All the evaluations were conducted on this phone between February and April 2024.

For each app, we selected three key pages (home, explore and profile) for automated and heuristic evaluations. The selected pages underwent assessment using Google's Accessibility Scanner and Nielsen's 10 usability heuristics [15]. The user testing involved six university students (P1-P6) aged between 18 and 45. The participants are at the master's level, with subjects including computer science (P2, P3, P4, P5), design (P1), and economics (P6). All participants were first-time users of the apps. Only two participants (P2 and P4) had prior experience with similar apps, one with Motivation-Daily Quotes and the other with BetterHelp - Therapy.

Before conducting the user testing, two pilot tests were carried out with two university students to gather feedback on the procedure and data collection process. Based on this feedback, minor adjustments were made to the user testing plan. Upon signing the consent form, participants completed a pre-testing questionnaire to provide demographic information. Each participant was assigned three apps and a set of tasks to complete, ensuring that each apps were evaluated by at least three participants. Tasks were designed to cover the main functions of the app, such as watching a video, listening to a podcast, and checking profile. Participants were encouraged to explore the apps before carrying out the tasks. Throughout the user testing process, notes were taken to record the challenges encountered by the participants. After completing the tasks, participants filled out the SUS questionnaire [13]. A brief interview was then conducted with each participant to discuss their experiences, identify challenges, and explore potential areas for improvements. The interview was audio recorded and transcribed. All collected data were anonymized before analysis. This study received approval from the Norwegian Agency for Shared Services in Education and Research (Sikt) to ensure the ethical collection, storage, and processing of personal data.

The quantitative data including results from the automated accessibility evaluation, the pre-test questionnaire, and the SUS questionnaire, were summarized using descriptive statistics. The qualitative data including observation notes from the user testing and post-test interviews, were analyzed using a lightweight thematic analysis and categorized according to the four principles of WCAG and Nielsen's 10 usability heuristics.

Results

In this section we will present a detailed description of the challenges and issues identified, categorized based on the accessibility principles and usability heuristics. This will be followed by a summary of the findings and recommendations based on the results.

Accessibility

Results from the Accessibility Scanner

Table 1 presents the numbers of accessibility issues detected by the Accessibility Scanner. Calm has the highest number of accessibility issues, whereas Headspace has the lowest number. The most frequently occurring issue across all apps is small touch elements.

Table 2-1: Issues identified by the Accessibility Scanner.

Accessibility issues	Calm	Headspace	Happify	MyPossibleSelf	Smiling Mind	Total
Text contrast	21	3	55		7	86
Picture contrast	25	16	61	38	3	143
Text scaling	73	10	23			106
Touch element	57	27	20	24	43	171
Label element		2	1	48		51
Editable label element					6	6
Element description	13	4	1	7	11	36
Text not displayed	2	5	1		14	22
Total	191	67	162	117	84	621

Results from User Testing Categorized by Accessibility Principles

The *Perceivable* principle focuses on how information and interface components are presented to ensure users can perceive them effectively. All the evaluated apps exhibit some issues related to perceivability. For example, participants noted low contrast (ratio: 1.84:1, WCAG2.1 requires at least 4.5:1) on the Insights page in MyPossibleSelf. In Calm participants experienced difficulties in distinguishing videos from audios on the home page, while Headspace uses distinct icons for video, podcast, and music, facilitating easy recognition of different types of media. Furthermore, Headspace responds well to the dark mode setting of the phone, whereas Happify, MyPossibleSelf, and Smiling Mind provide display preferences (including dark mode) within their own settings. In Calm, users cannot set display preferences, and Calm does not respond to the dark mode setting of the phone. Although Smiling Mind does not properly respond to the dark mode setting of the phone, it works well with the app's dark mode setting (Fig. 1). Font sizes in the apps are generally deemed acceptable and adjust according to the phone's setting.

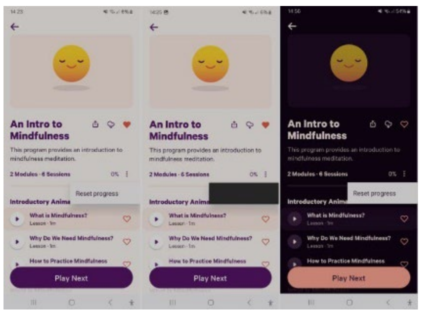

Figure 2-1: In Smiling Mind the text "Reset progress" is not visible when the phone is in dark mode, but it works properly when the dark mode is enabled in the app itself.

Calm, Happify and MyPossibleSelf were found to restrict their views to portrait mode, whereas Smiling Mind adjust its views according to the phone's orientation. Headspace has some videos in landscape despite the phone's portrait orientation. In addition, small buttons were found in Calm and Smiling Mind. However, it is worth noting that all apps can be zoomed in using the phone's accessibility feature.

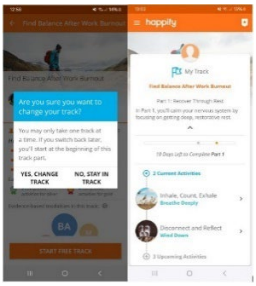

Figure 2-2: In Happify when changing track, the user is directed to the My Track page.

The *Operable* principle requires that users must be able operate and navigate interface components effectively. Calm, Happify, and MyPossibleSelf were found to have the most issues related to operability. For example, In Calm, when the user touches the screen while an audio is playing, it displays the screen saver without any warning. In Happify, if a user chooses to start a track from the explore page, the app directs them to the My track page where this is no information related to their previous action, causing users to feel lost (Fig. 2). In Headspace, due to non-conventional controls, the participants found it challenging to perform fast-forward or fast-backward actions, except for skipping forward or backward by 15 seconds (Fig. 3). They were not aware they could rotate the dial around the Play button. According to WCAG 2.1, the target size for pointer inputs should be at least 44 by 44 CSS pixels. Some buttons in MyPossibleSelf are found to be too small.

Figure 2-3: Audio controls in Headspace.

The *Understandable* principle requires that information and interface components must be comprehensible for users. All the apps were found to have issues with this principle. For example, Happify uses terms such as "track" and "upside", which were found difficult to understand. In MyPossibleSelf, on the Insights page, the mode circles (Fig. 4a) were displayed for different days, but participants found it unclear whether these circles were clickable. They were also unsure about the outcome of clicking these circles. Except for MyPossibleSelf, all the apps were found to contain an abundance information on at least one page, such as the home page or the explore page. This overload of information made it challenging for participants to quickly get an overview quickly or navigate to a specific item.

The *Robust* principle requires that the content should be interpretable by various user agents, including assistive technologies. Despite mobile operating systems such as iOS and Android providing accessibility API and guidelines for accessible app development, not all evaluated apps utilize these APIs or follow the guidelines. As a result, they either do not respond or only partially respond to the changes in accessibility settings in the phones' operating systems.

All the apps feature their own accessibility settings. Users have the option to select their preferred language in Calm, Happify and Headspace. In addition, Happify, MyPossibleSelf, and Smiling Mind allow users to choose display preferences, such as high contrast in Happify, dark mode in MyPossibleSelf, and dark, light mode or system default in Smiling Mind. Furthermore, Happify users can opt to be notified when an audio or video interaction is needed, and they can also turn off animations. Headspace provides users the possibility to toggle audio description on or off.

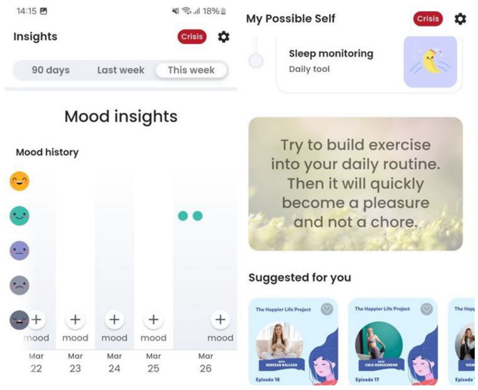

Figure 2-4: MyPossibleSelf (a, left) the two green dots are clickable. (b, right) the text box in the middle is clickable.

Usability

Results from the SUS questionnaire

Table 2 shows the average SUS scores and standard deviations for each of the five apps. Headspace achieved the highest score, while Happify obtained the lowest.

Table 2-2: Software Usability Scale (SUS) scores.

	Calm	Headspace	Happify	MyPossibleSelf	Smiling Mind
SUS score	80	77.5	40	61.67	63.75
SD	8.66	10.21	18.60	29.82	24.62

Results from Heuristic Evaluation and User Testing Categorized by Usability Heuristics

Heuristic 1: *Visibility of System Status*. Except for Calm and Smiling Mind, all other apps were found to comply with this heuristic. In Calm, clicking on an audio does not open a player page as expected. Instead, the app shows that the audio is playing in the bottom part of a page, which makes it difficult for the users to notice (Figure 5). Smiling Mind does not provide feedback when a user completes the mode assessment. In addition, when downloading a session, users are not informed about the purpose of the download or where the session is downloaded, whether to the phone or the cloud.

Heuristic 2: *Match between the System and the Real World*. Calm and Headspace were found to have some issues with this heuristic. In Calm, the mountain icon, intended for scene selection, was not understood by any of the participants. They struggled to associate the icon with its intended meaning. In addition, all participants who tested Calm attempted to click on the Profile icon, only to find it non-clickable, causing frustration. In MyPossibleSelf, some text boxes are clickable, but there is no visual distinction between clickable and non-clickable text (Fig. 4b). In Headspace, while playing podcasts, the control buttons do not resemble familiar real-world controls, as shown in Fig. 3.

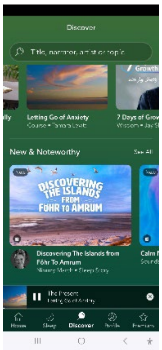

Figure 2-5: In Calm, it is challenging for users to notice that audio is playing at the bottom of the page.

Heuristic 3: *User Control and Freedom*. Headspace and Happify fail to satisfy this heuristic. The podcast controls in Headspace made it difficult for participants to fast forward or rewind to a specific time (Fig. 3). Happify directs users to a page where they are unable to return to their previous page, as shown in Fig. 2.

Heuristic 4: *Consistency and Standards*. Each of the apps exhibits some inconsistencies. For example, all the apps have the settings on different pages. Calm, Happify, and Headspace place Settings on the Profile page, MyPossibleSelf has the Settings icon in the top right corner on all pages, whereas Smiling Mind positions it in the More page. Furthermore, the icons for Settings vary across the apps. Only Headspace uses the same icon as the one for Settings in the phone. In addition, the video playing interfaces in Headspace and Smiling Mind lack consistency within the apps.

Heuristic 5: *Error Prevention*. All apps were found to have failed this heuristic. However, in Smiling Mind, when users try to reset their progress, the app provides a warning for the users to confirm. The main issues observed in the apps are with the icons, which are small or difficult to understand their meanings or determine if they are clickable. These issues can lead to errors when users interact with them.

Heuristic 6: *Recognition Rather than Recall*. Happify requires users to remember information from the previous screen (Fig. 2). In MyPossibleSelf, users can skip instructions when playing a relaxing video. However, once skipped, it is not possible to view the instructions again without exiting the video first. At this point, there is no indication of which video the user was watching.

Heuristic 7: *Flexibility and Efficiency of Use*. Except for Smiling Mind, all the other apps feature a Search function, facilitating easier navigation and access to specific information without having to browse through all pages or scroll up and down within a page. None of the apps allow users to define shortcuts.

Heuristic 8: *Aesthetic and Minimalist Design*. With the exception of MyPossibleSelf, participants commented that all other apps contain an excessive amount of information on one or more pages.

Heuristic 9: *Help Users Recognize, Diagnose, and Recover from Errors*. Except for MyPossibleSelf, which lacks the ability to easily watch the instructions once skipped, all the other apps have satisfied this heuristic. For example, In Smiling Mind, when users edit their profiles, the required field in the form is marked, and if this field is left empty, an error message is displayed underneath the field.

Heuristic 10: *Help and Documentation*. Happify and MyPossibleSelf include Frequently Asked Questions (FAQ) within the app, whereas Calm, Headspace and Smiling Mind direct users to the apps' websites for documentation. Participants expressed a preference for having FAQs available within the apps.

Summary and Recommendations

The evaluated apps were found to have various accessibility and usability issues, yet the results from the evaluations, particularly from the user testing, have been largely positive. All participants, despite being first-time users, were able to complete the tasks with only minor challenges. Overall, Headspace was deemed to have the highest level of accessibility and usability among the evaluated apps, although Calm received a slightly higher SUS score. Based on the evaluation results and feedback from participants, we have summarized the main findings and identified recommendations for improving the accessibility and usability of the apps.

One of the most frequently identified issues in almost all apps is the use of icons. Some icons appear as buttons but are not clickable, while others resemble conventional icons, but convey different meanings. In addition, the meanings of some special designed icons are difficult to understand, and many clickable icons are too small to press. These issues are related to both accessibility principles and usability heuristics. The use of conventional icons can help users easily recognize and understand the meaning of the icons, rendering the apps more predictable and preventing errors. For special designed icons unfamiliar to users, it is recommended to include text under the icons to facilitate understanding of their meanings. Ensuring that clickable icons are clearly distinguishable from non-clickable icons and increasing the size of clickable icons can help to eliminate many error-prone conditions.

Inconsistency emerges as another key challenge identified in this study. We have found different controls for videos and audios across the apps. Some apps fail to follow established conventions or use standard elements familiar to users from popular apps. These issues can negatively impact the understandability and predictability of the apps. Ensuring a consistent design within apps and following established standards and conventions can help reduce cognitive load and enable users to use the apps more efficiently.

Operating systems such as Android and iOS provide developer tools and accessibility APIs. However, in our evaluation, we have found that some apps do not adequately respond to the accessibility settings in the phone. Using developers' tools and APIs can ensure that the apps maintain internal consistency and align with the features in the operating systems.

Discussion

Automated tools such as Mobile Accessibility Testing (MATE) and Accessibility Scanner, as well as IBM Mobile Accessibility Checker (MAC), have been used to evaluate accessibility of mobile apps. Some studies have utilized heuristic evaluations based on WCAG [18], while others have conducted tests involving users with specific disabilities, such as blindness, visual impairment, or older users, to identify barriers the apps pose for these user groups [19]. In the study presented in this paper, we have combined automated evaluation, heuristic evaluation, and user testing to assess the accessibility and usability. By combining these methods, we were able to compare and validate findings from different methods and identify a wide range of accessibility and usability issues.

In the review of studies examining user perceptions of mental health apps, Chan and Honey [9] discovered that there is a lack of research reporting on user experience. Their paper highlights the importance of considering usability aspects of mental health apps and advocates for more comprehensive research evaluating the user experiences beyond merely assessing the impact on mental health outcome. Our study contributes to bridging this gap by focusing on the accessibility and usability of mental health apps.

Conclusions and Future Work

This paper presents a study evaluating the accessibility and usability of mobile apps for addressing students' mental health needs in higher education. The study employed a combination of automated evaluation, heuristic evaluation, and user testing to gain insights into the accessibility of usability of mental health apps. However, there are several limitations in this study, including the small number of participants and mental health apps evaluated, as well as the lack of information regarding the participants' mental health status and other potential impairments. Future research should recruit students facing mental health challenges and evaluate a broader range of mobile apps.

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3. 3D Model Distribution Service for Blind and Visually Impaired People

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Abstract

We are providing a 3D model distribution service for blind and visually impaired people. In this service, we print and send 3D models upon their requests, free of charge. 119 blind and visually impaired people and 16 supporters had submitted 313 requests for 3D models from November 2019 to the end of year 2023. We classified the 313 requests into the following categories: architecture, terrain, biology, map, vehicle, astronomy, coin, and others. Architectures occupy 51.4% of the total requests and rank on the top. The requests for architecture models were concentrated on world-famous architectures. Terrain models rank as second with 57 requests (18.2%). Reasons for requesting a terrain model are, on one hand, intellectual curiosity on their residential or visiting places and, on the other hand, practical uses such as educational materials and hazard maps. The places of the terrain models requested differed from client to client. We made and sent 237 models, which amounts to 75.7% of the total requests. As for other 76 requests, we recommended the client to purchase the model or declined because of the difficulty of modeling. By looking back on the 3D distribution service and analyzing the requests and responses, we discussed the way to continue this leading, unique service even after the end of the project.

Introduction

For blind and visually impaired people, three-dimensional (3D) objects lead them to much more accurate understanding of the shapes of objects than two-dimensional tactile graphics or explanation by words. However, in Japan there did not exist any 3D model supplying system in 2019 and even now. Currently, Braille libraries are distributed nationwide and supply to blind and visually impaired people Braille or audio books that are transcribed by, mostly, volunteer Braille or audio transcribers. Similar eco-systems are expected where 3D models of objects that blind and visually impaired people want to know the shape of are made by skilled volunteer 3D creators and supplied by "3D libraries". To construct such an ecosystem, the second author planned a research project and it started in November 2019 with the aid of public funding from Japan Science and Technology Agency (JST). At the same time, a 3D model provision service was launched using 3D printers as a pilot practice of this ecosystem.

State of the Art

The use of 3D printers as an access method to shape information by blind and visually impaired people has progressed over the past decade. Let us introduce some of the organizations and/or projects that are practically providing 3D models to the clients.

See3D is a non-profit U.S.-based organization that manages the printing and distribution of 3D printed models for people who are blind [1]. Blind or low vision individuals can place an order on the Web. Since 2017 the organization has distributed over 4,000 3D models to 50 states, 24 countries, and 82 organizations or schools (web site checked on April 3, 2024).

ANZAGG (The Australia and New Zealand Accessible Graphics Group) is a standing subcommittee of the Round Table on Information Access for People with Print Disabilities Inc. [2]. Its 3D printing working group have printed many 3D models, verified their usability scientifically [3], published guidelines for tactile users, and compiled a 3D database site useful for 3D printing.

An international project, tactiles 3D printing for VI, has been set up to supply 3D model database but also guidelines for designing and producing 3D models for visually impaired students [4]. Medien Augenbit [5] is another website which provide 3D printing and tactile graphics data for education of blind and visually impaired people. Btactile.com also collects 3D data as well as tactile graphics for blind and visually impaired people [6].

Although all of these services and databases are available from Japan, we have not heard the use of it by Japanese blind and visually impaired people and their supporters. The reasons for this may be that people are not aware of and/or feeling awkward in using these sites because of language barriers. For the prevalence of 3D models among blind and visually impaired people, it was necessary to launch a service in Japanese.

3D Model Distribution Service

In this service, we print and send 3D models to blind and visually impaired people upon their requests, free of charge (till the end of this project, March 2025). In general workflow of the service (Fig. 1), upon receiving a request, we search for 3D data available online that is permitted to 3D print and send to the third party, try printing and, if necessary, rectify them. 3D data downloaded from the database, especially for architectures, are printed as they are, without any modification for tactile exploration. It is crucial that the features of the models can be recognized by touch as well as that they fit in both hands for easy exploration. Taking these points into consideration, we print the model in the size of approximately 15 to 18 cm in their largest length [7]. If we cannot find the 3D data online and its modeling seems to be possible for us, we create the 3D data from scratch using 3D CAD software. The models printed are packaged and shipped to the client. To enhance model understanding, explanatory information should be added [8]. Thus, we write a brief description on the model and email this to the client.

3D scanning was used to make skeleton models and photogrammetry was used to model a big sculpture. Since these requests came from the project members, not from the general clients, they were excluded from the analysis below.

The first author and his assistant(s) have been mainly in charge of this service. From 2022, printing and sending jobs are partly shared by collaborators in the project group.

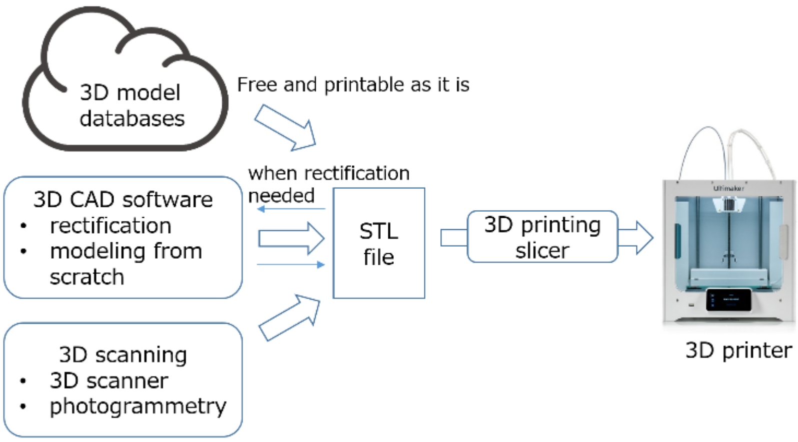

Figure 3-1: Flowchart of 3D data search, creation, and print.

Analysis of the Requests

119 blind and visually impaired people and 16 supporters had submitted 313 requests for 3D models from November 2019 to the end of year 2023. Here, we do not include nearly 400 models that we distributed to the participants of the five online tactile symposia we have held twice a year [9].

We classified the 313 requests into the following categories: architecture, terrain, biology, map, vehicle, astronomy, coin, and others. The numbers of each models produced are shown in Table 1.

Table 3-1: Classification of objects for which models were requested.

Object Type	Number of Requests (ratio)
Architecture	161 (51.4%)
Terrain	57 (18.2%)
Biology	40 (12.8%)
Map	16 (5.1%)
Vehicle	8 (2.6%)
Astronomy	7 (2.2%)
Coin	7 (2.2%)
Others	17 (5.4%)

Architectures occupy 51.4% of the total requests and rank on the top. Some clients wrote the reasons for requesting architectures: They visited the building for sightseeing, shopping, and so on, but could not understand the whole shape of it as no model was sold there. In addition to this, the reason we speculate is that several kinds of architectures are on our ever-printed model list. World-famous architectures that gathered many requests are Nortre-dame Abbey, Sagrada Familia, Acropolis, Athens, Taj Mahal, Angkor Wat, Sydney Opera House, and so on. As for Japan, popular architectures were Houses of Parliament, Atomic Bomb Dome and its original building (before the bombing), National Stadium, the venue of Olympic and Paralympic Games Tokyo 2020. The feature of the requests for architecture models is that multiple people, up to 13, requested for the same architecture. In fact, 14 architectures that more than four clients requested gathered 101 requests, which amounts to 62.7% of total 161 requests for architectures.

Terrain models rank as second with 57 requests (18.2%). Reasons for requesting a terrain model are, on one hand, intellectual curiosity on their residential or visiting places and, on the other hand, practical uses such as educational materials and hazard maps. The feature of the requests for terrain models is that the requested places differ from client to client, except for central Tokyo area and Mount Fuji.

Biology models rank as third with 40 requests (12.8%). One fourth of them were for new coronavirus, and another one fourth for DNA and neuron. These objects are popular even among the people who are not biology specialists. Because many blind people in Japan are traditionally working in massage, acupuncture, and moxibustion, where medical and biological knowledge are mandatory, various anatomical models were requested.

3D Data Availability, Modeling, and Printing

We made and sent 237 models (see Fig. 2 for examples), which amounts to 75.7% of the total requests. As for other 76 requests, we recommended the client to purchase the model, when they are available on the market at a reasonable price, or declined because of the difficulty of modeling or overload to respond to one client (ex. Total 47-prefecture models of Japan requires about a whole week to print, deburr, and check the joints).

3D data of most of world-famous architectures are available online (mostly from Thingiverse). In contrast, 3D data of some of Japanese architectures are hard to find. By far, we modelled from scratch eight buildings out of 24 kinds of architectures we sent. Two of them were too difficult for us that the modelling was outsourced to a specialized company.

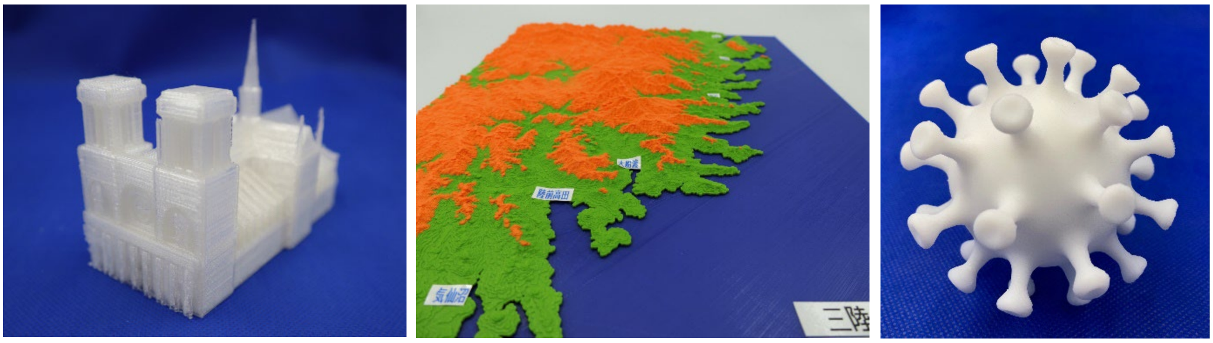

Figure 3-2: Examples of 3D models provided. (a, left) Notre-dame, (b, middle) Terrain, and (c, right) New Coronavirus.

3D data of terrain models are made at the website of Geographical Survey Institute, Japan [10] and are rectified for 3D printing with basic CAD software such as 3D Builder. The height of terrain models are usually multiplied by two to three times for easy understanding of altitude difference by touch when plains and low mountains are included.

Comments from the Clients

We have received some joyful feedback on receiving the models by email. However, we have not received any constructive feedback on how to improve the model for better understanding by touch.

Discussion

Up until now, the cost for modeling, printing, sending, and labor is covered by the public fund from JST. We need to discuss the way to continue this leading, unique service even after the project ends in March 2025.

Since 3D modeling requires specialized skill, pro bono work is essential in this process. To build a connection with the people who have 3D modeling skill and recruit them as volunteers, participation in exhibitions such as Makers' Day! is necessary.

3D data of World-famous architectures and educational materials that are useful worldwide are easily found online. Even though, it costs a good amount of money to print and send models. Although some of the clients wrote that they were willing to pay, the total cost for the filament, shipping, and the labor, which is rarely asked, will exceed the price the clients think reasonable (ex. 5000 Japanese yen, that is 31 Euro or 33 dollars at the exchange rate of April 3, 2024). Some other blind person(s) wrote that to know the shape it is enough to touch the model once, and he/she did not think they need to buy and keep it.

It is true that the total 135 requests with a few repeaters in four years are not a big number. In contrast, our online tactile symposia have gathered increasing number of participants with each session [9]. For the latest symposium held in February 2024, nearly 150 people including 100 who are blind and visually impaired had signed up. The feature of these symposia is that 3D models related to the topic of the lectures by the experts in one specific field such as gardens, castles, astrophysics, and astronomy are sent to the audience in advance, and they can listen to the lectures while touching the models. It is predicted that the participants of the symposia consider it reasonable to pay for the lectures and models. We hope that these symposia will work as a booster for recognizing the importance of 3D models for blind and visually impaired people.

By looking back on the 3D distribution service and analyzing the requests and responses, we examined the role of this service and devise a measure to continue it after the end of the project.

Acknowledgements

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4. Development and Assessment of Inclusive Tangible Shape Nets to Bridge Geometry Gaps for the Visually Impaired

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Abstract

Geometry plays a crucial role in fostering spatial understanding and problem-solving skills, essential for both academic excellence and real-world applications. However, students with visual impairments (VI) face challenges due to the limited availability of inclusive tools and resources for geometry. This results in a deficiency in effective learning and confidence. Due to the inherently visual nature of geometry, traditional teaching-learning methods (TLMs) need to be adapted to incorporate multi-sensory modifications for an inclusive learning environment. This paper presents an innovative solution- 'ShapeScape' kit to tackle these challenges. It features eleven shape cutouts/ 2D nets that can be folded and converted into corresponding 3D shapes. It has been specifically designed to augment the accessibility, usability, and overall efficacy of geometry education for this demographic. The kit's development underwent an iterative participatory design process, including rigorous testing through semi-structured interviews and usability assessments. The outcomes affirm the ShapeScape kit as a promising solution, serving to bridge the gap in personalised learning for VI students. This research contributes to the advancement of inclusive education practices, providing a tactile, low-cost, and effective solution to empower these learners in their journey towards proficiency in geometry.

Introduction

Visual impairment affects approximately 2.2 billion people worldwide, with India alone accounting for around 4.95 million blind individuals, including 0.24 million children [1]. Despite the widespread impact of this condition, very few VI students pursue higher education in STEM (Science, Technology, Engineering, and Mathematics) fields, particularly Mathematics [2]. This disparity is mainly due to the limited availability of resources and tailored TLMs [3], which hinder their understanding and observational perceptions of the world. Misconceptions about their skillset to comprehend visually-oriented concepts further exacerbate the issue. Many topics like Geometry aren't focused upon [4], affecting not only academic performance but also hampering their ability comprehend spatial relationships in everyday life [5]. This leads to a lack of confidence and prevents them from achieving the same level of excellence as their sighted counterparts. Thus, posing a less explored yet crucial question: 'How do individuals grasp these seemingly visually-oriented concepts without sight?'

Geometry plays a foundational role in various academic disciplines and real-world applications [5, 6], fostering engagement in spatial thinking and enhancing overall mathematical and cognitive development. Proficiency in such concepts enables individuals to comprehend fundamental ideas of shape formation, lines, angles, the number of sides, and how to build or arrange shapes within specific patterns [7].

Numerous studies recognise the need for engaging, game-based methods as they offer a superior approach compared to traditional methods [3, 5]. Van Hiele [8] emphasises that the initial stages of geometry involve playful activities such as mosaics, paper folding, drawing, and pattern blocks. The National Education Policy of India (NEP) 2020 also advocates for gamified education through toy-based activities like puzzles, blocks, and complex construction kits to enhance spatial reasoning, geometric understanding, and fine motor skills.

However, very few resources exist for VI students. While traditional methods like origami and shape nets have been employed to teach geometry to sighted students, these approaches are inaccessible to those without sight, particularly in developing countries like India. Despite the availability of online resources, they often lack tactile features crucial for effective learning experiences. Inclusive tools like GeoBoard or Cubeograph [9], while beneficial, are either costly or unavailable in India, exacerbating the accessibility challenge. Additionally, most teachers lack adequate training to effectively utilise these resources. The absence of accessible shape nets often results in the exclusion of VI students from classroom activities or necessitates adult assistance, leading to a loss of confidence among them.

Our interactions with special school administrators and teachers revealed that oftentimes, in India, the concepts of 3D shapes are removed from the curriculum, leaving VI students without a practical perception of these solids crucial in real-life scenarios. Additionally, they are encouraged to attempt algebraic questions over geometric ones during examinations. This is also affected by their lack of incidental learning [10] - an unplanned learning that contributes to 80% of learning in sighted students.

Recognising the gravity of this issue, previous research efforts have explored specialized tools and methodologies, such as tactile geometry books, pop-up mechanisms, and digital interface [11, 12]. These efforts prioritise accessibility, tactile engagement, cost-effectiveness, scalability, and ease of manufacturing [13, 14]. However, significant gaps persist in integrating VI individuals into higher education, hindering their academic and professional advancement.

Our Work

To address this gap, we propose the 'ShapeScape kit', a tactile learning tool accessible for both VI and sighted individuals. This kit comprises tactile cut-outs, or 3D shape nets, allowing users to fold paper into corresponding 3D shapes and unfold them in a fun and engaging manner. By representing the unfolded version of each shape, these nets illustrate all faces and their connections, promoting comprehensive spatial understanding. The design incorporates considerations like pre-creasing, elimination of adhesives, texture-based formation, and the use of tab and slots technique [15] for independent interlocking. Additionally, the design has been intentionally kept simple for easy replication by teachers and parents if needed.

Figure 4-1: 3D shape nets

The kit comprises eleven shapes, including three types of prisms (equilateral triangular, isosceles triangular, and hexagonal), rectangular prisms (cube and cuboid), pyramids (triangular, hexagonal, and square pyramids with equilateral triangles and isosceles triangles), cylinder, and cone. The packaging mirrors the shape nets, symbolizing the transition from 3D to 2D. Furthermore, an instructional manual, developed with inputs from special educators, features a digital version accessible via a QR code on the packaging.

This accessible and low-cost TLM follows the 'learning by doing' approach with minimum cognitive load. It empowers users to independently assemble 3D shapes, promoting a comprehensive understanding of geometric concepts, understanding of 3D objects in space, their formation, and 3D to 2D visualisation. This gamified approach not only employs interaction-based, multisensory engagement but also contributes to the development of spatial reasoning, problem-solving skills, and imagination. It serves in teaching:

i. **Concepts and Mathematical Language related to Geometry**: It enables the exploration of fundamental geometry concepts such as faces, edges, vertices, and parameters like perimeter, surface area, and volume. Through hands-on interaction with each shape, students develop a deep understanding of these concepts, surpassing what is achievable with traditional 3D models alone.

ii. **Classification:** Students learn to identify, compare, and analyze different shapes.

iii. **2D to 3D Visualisation:** Creating shapes from their nets illustrates the shift from 2D to 3D.

iv. **3D to 2D Visualisation:** Unfolding 3D shapes helps in understanding the conversion to 2D, crucial for interpreting tactile graphics, floor plans, and maps. This process also teaches students that the shape remains constant regardless of orientation

v. **Data Handling:** Students learn the number of 2D shapes needed for a 3D shape.

Methodology

The development process involved an iterative participatory design approach, such as empathising, understanding unmet needs, generating ideas and prototypes, and conducting user testing. This process unfolded across four phases, each culminating in user testing and feedback to inform the next steps.

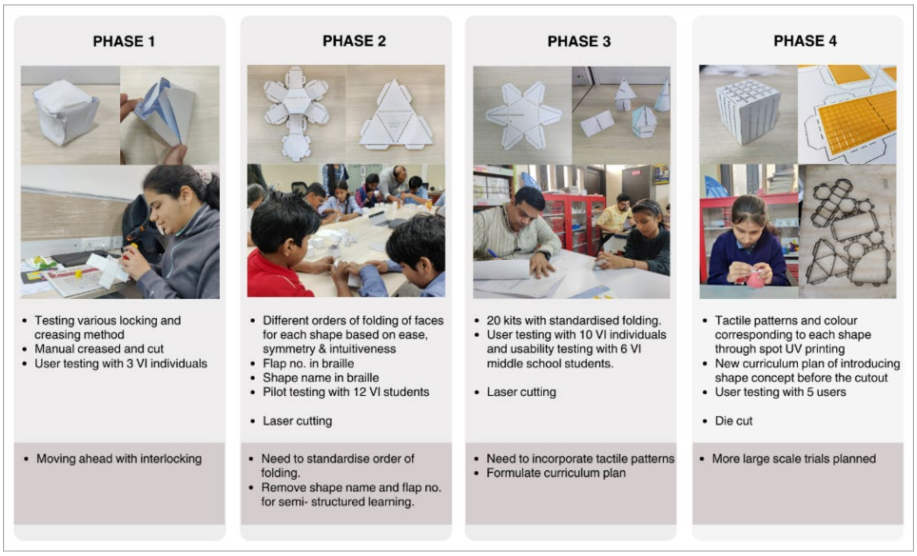

Figure 4-2: Phases of prototyping with user and user testing

Phase 1: Understanding the Preferences of VI Individuals

Process: Initially, we observed both sighted and non-sighted users creating 3D shapes from nets to identify the additional aids necessary for VI individuals. This helped assess their proficiency in paper manipulation, surface-based construction, and joining methods, as well as the effectiveness of this method in teaching 2D to 3D visualisation.

User Testing: Various pasting and creasing methods were explored, including the use of glue sticks and double tapes on different types of paper such as braille, pastel, and ivory sheets. However, testing with 3 VI individuals revealed that the tab and slots interlocking method was the most effective. In this method, the flaps of one face go into the slit of the other to lock the shape. This technique, similar to cake boxes is easily replicable and allows for multiple folding and unfolding cycles and was readily adopted by students even without prior exposure to crafts.

Phase 2: Finalisation of Product Use

Process: In this phase, pilot testing was conducted with a larger group of 12 VI students to assess the effectiveness of the 'tab and slots' technique and determine the target age group. Key design parameters included pre-cut tactile markings for folding, symmetry in the folding order for both left and right-handed users, and a low-cost, easily manufacturable, and replicable design. The order of flaps was refined through multiple iterations following the 'Simple to Complex' teaching maxim, prioritizing ease of assembly. Initially, prototypes were manually cut and creased, but we transitioned to laser-cut dashed lines to reduce labour and time. The shapes were labeled in Braille, alongside the order of flaps.

User Testing: Students quickly grasped the interlocking method and found the activity really fun. After this, the target age group was finalised as middle school students, considering the challenges younger students faced. However, shape labeling hindered independent thinking about their forms. Additionally, they tended to stick to previous folding methods rather than exploring alternatives. They frequently ignored Braille labels on flaps, preferring fewer instructions.

Phase 3: Evaluation of Product Usability

Process: The need for standardizing the folding method led to the final design: pick up the side walls first, followed by the front and back, akin to constructing a house. Users begin by orienting the cutout, identifying a circle on the bottom left of the horizontal line, before proceeding further with the folding process. These final designs, along with the inclusive packaging and instruction manual were then manufactured through laser cutting in sets of 20 for user testing.

Figure 4-3: Initial kit and its process of folding.

User Testing: These kits were tested 10 VI individuals who had completed their schooling. Surprisingly, all participants highlighted the kit's significance, as they themselves lacked exposure to such concepts due to lack of access during their education.

To further evaluate the product, a study was conducted to identify usability issues in assembling 3D shapes from nets, uncover common assembly errors and their causes, and assess whether the kit meets users' expectations. It employed a combination of qualitative methods, including semi-structured interviews and observations, along with quantitative usability testing. Six middle school students with total or partial vision loss participated in final usability testing, following a mix of convenience and snowball sampling methods. Typically, formative studies like this provide significant usability insights with 6-8 users, particularly when supplemented with follow-up questions [16].

Basic Orientation & Tasks: Participants underwent a 10–15 minutes orientation session to familiarise themselves with the kit's features and functionality. They were encouraged to explore independently and ask questions as needed. For the evaluation, the 11 shapes were categorized into 4 tasks, each representing a specific 3D shape category. Participants completed these tasks sequentially, starting with an equilateral triangular prism. They followed instructions to crease along dashed lines, distinguish the faces from the flaps, and then fold to gain a fundamental understanding of the shape.

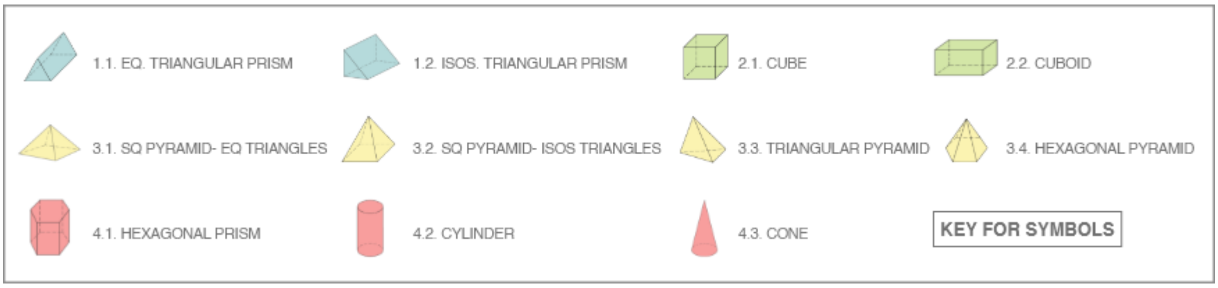

Figure 4-4: Key for symbols for each shape category.

Usability Metrics: Usability metrics included capturing users' feedback on the perceived effectiveness, efficiency, and satisfaction with the kit using issue-based and self-reported measures. Semi-structured interviews assessed the level of understanding before and after the activity. The methods used were Post task feedback (After Scenario Questionnaire [15], Expectation Measure [16], Time on task [17], and Severity Ratings [18]) and Post Session Feedback (System Usability Score [19]).

Results and Discussion: During the testing phase, it became evident that students lacked sufficient practical perception of 3D solids, with only a vague theoretical understanding of cubes, cuboids, cones, and cylinders. Their exposure and knowledge of other solids like triangular prisms and pyramids were limited, as the focus was primarily on 2D concepts. This further emphasised the immediate need to develop relevant TLMS as this required more attention than we originally anticipated.

Our intervention proved effective in conveying these concepts, as students immediately showed interest, eager to overcome perceived limitations. Even without prior exposure to arts and crafts, when provided with adequate resources and training, they found immense joy and satisfaction in learning new concepts and creating something on their own. Key findings from the usability studies are summarised below.

i. Post Task Feedback

a. After Scenario Questionnaire (ASQ) Results

The ASQ evaluates usability across effectiveness, efficiency, and satisfaction. Mean ratings for each task are shown in picture 5, with lower scores indicating higher satisfaction. Overall ASQ ratings for (1) Triangular prisms, (2) Rectangular prisms, (3) Pyramids, and (4) Complex solids were 1.72, 1.89, 1.55, and 2.56, respectively.

S.N	ASQ STATEMENTS (1-7) (1- STRONGLY AGREE; 7- STRONGLY DISAGREE)	1. TRIANGULAR PRISMS		2. RECTANGULAR PRISMS		3. PYRAMIDS		4. COMPLEX SOLIDS	
		Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
1	Overall, I am satisfied with the amount of time it took to complete the task.	1.83	1.17	1.83	0.75	1.83	0.41	3.00	2.65
2	Overall, I am satisfied with the support information when completing the task.	1.00	0.00	1.33	0.52	1.00	0.00	1.00	0.00
3	Overall, I am satisfied with the ease of completing the task.	2.33	0.82	2.50	1.38	1.83	0.41	3.67	2.08

Figure 4-5: Summary of ASQ responses.

ii. Expectation Measure Results

This evaluation method was utilised to gauge users' subjective reactions regarding their expectations for each task. It aided in prioritising tasks for improvement based on their quadrant placement. For 10 out of the 11 shapes provided, the mean expectation and experience ratings resided in the upper right corner (Do not touch it), indicating that participants perceived these tasks as easy both before and after task completion. However, a few users faced greater difficulty with the hexagonal prism, prompting the need for design improvements to enhance their overall experience (Picture 6).

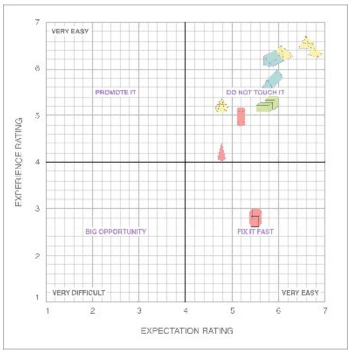

Figure 4-6: Expectation measure matrix

iii. Time on Task Results

Functioning as an efficiency metric for the system, the bar graph (Picture 7) illustrates the mean time taken by participants for each shape in seconds. The data indicates that participants completed pyramids more rapidly compared to complex solids. While the quicker completion of pyramids could be attributed to familiarity with the process, the prolonged time taken for complex solids suggests a higher level of difficulty. This observation aligns with the mean experience ratings for these solids as depicted in the experience measure matrix.

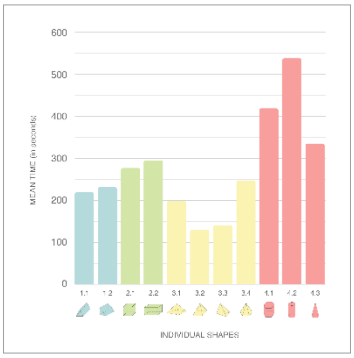

Figure 4-7: Time on Task.

iv. Severity Ratings for Identified Usability Issues

This process helped determine the severity of usability issues and aided in prioritising which issues needed to be addressed first during the refinement of the solution. At the end of each task, participants shared the usability issues they encountered, which were then categorised based on occurrence with a specific shape or multiple shapes (Picture 8). The right column indicates the design modifications that were implemented to address those issues. Subsequently, as part of phase 4, a new set of prototypes was created and tested with a few users.

NO.	SHAPE	NATURE OF PROBLEM/ USABILITY ISSUE	SEVERITY LEVEL	SHAPES or USERS NO. (for 1 shape)	DESIGN MODIFICATIONS IMPLEMENTED
U1		Certain shapes keep opening due to loose flaps within the slits, occasionally hindering users from completing the task.	4	3	Change in flap design to enhance the lock's tightness
U2		Users struggled to visualize and fold unfamiliar shapes, losing interest in them because of their lack of relatability.	4	5	New curriculum plan - introduction of detailed concept of shape and its real -life object before givng the net cutout.
U3		The two orientation parameters result in excessive instructions, leading users to forget orientation steps.	3	-	"Introduction of colors and tactile line patterns on one side of the paper for: 1. Clear identification of the main/outer side. 2. Improved distinction between faces and flaps/slits, aiding understanding of individual shapes within the net. 3. Reducing one parameter by identifying the circle on the top left of the blank side."
U4		If the net is initially flipped, users may forget to flip it, complicating the identification of the correct paper side.	3	-	
U5		Difficulty in distinguishing the circle, as it blends with the reference line.	2	-	
U6		The intermediate rectangular face (between longer sides) curves when its flap is inserted into the opposite slit.	2	1	Interchanged the posiiton of the flap and its corresponding slit.
U7		Challenging to insert the last face, as five flaps need simultaneous insertion into the slit.	4	4	Removal of flaps adjacent to the folded joinery, leaving only three flaps for insertion.
U8		Only those seeking a challenge attempted to fold these shapes, given their complexity of making.	1	2	Left as is to challenge students and enhance their proficiency with this method. Alternatively, tape can be used with assistance.

Figure 4-8: List of usability issues and severity ratings identifies during the task.

b. Post Session Feedback

i. System Usability Score (SUS) Results

At the conclusion of the session, participants completed the SUS questionnaire, where a higher final score indicates increased user satisfaction. This questionnaire was used to evaluate the overall perceived usability of the kit and capture information about Usefulness, Ease-of-Use, Ease of Learning, and Satisfaction. Standardised usability questionnaires (Picture 9) were utilised instead of self-defined questionnaires to ensure objectivity, replicability, reliability, validity, sensitivity, and scientific generalisation. With a score of 73.3, falling within the acceptable category of acceptability ranges and the good category of adjective ratings according to Bangor's assessment results [20], it is inferred that the kit is well-received. Notably, participants P4 and P5, despite being totally blind and lacking prior exposure to geometry and arts, expressed satisfaction, further supporting the inference that the kit is suitable for individuals with visual impairments.

S.N	SUS STATEMENTS	SCALE POSITION (1-5) (1- STRONGLY DISAGREE; 5- STRONGLY AGREE)					
		P1	P2	P3	P4	P5	P6
1	I think I would like to use this kit frequently.	4	4	5	5	4	3
2	I found the kit unnecessarily complex.	2	1	1	1	2	1
3	I thought the kit was easy to use.	4	5	5	4	2	2
4	I think I would need the support of another person to use all of the features of this kit.	1	1	5	4	5	1
5	I found the various features of the kit were well integrated.	5	5	5	5	3	3
6	I thought there was too much inconsistency with how the shapes were folded and interlocked.	2	2	1	1	2	2
7	I would imagine that most people would learn to use the concepts of this kit quickly.	3	5	5	5	5	3
8	I found the kit very cumbersome or awkward to use.	2	1	1	1	1	1
9	I felt very confident using the kit.	4	5	5	5	3	3
10	I needed to learn and familiarize myself with the method of folding and interlocking the shapes before I could get going with this kit.	4	4	5	5	4	4
	IND SCORES (For positive: (n-1) x 2.5; For negative: (5-n) x 2.5))	72.5	87.5	80	80	57.5	62.5
	FINAL SCORE	73.3					

Figure 4-9: SUS results

Phase 4: Revised Design and Curriculum Plan

A design decision was made to introduce tactile patterns on one side of the cutout, enhancing clarity in identifying the main side and facilitating easier orientation by streamlining one parameter. This also proved instrumental in distinguishing between faces and tabs, contributing to a better understanding of individual 2D shapes within the net. Initially, we experimented with tactile patterns using braille embossers, but encountered structural weaknesses. Consequently, we transitioned to the spot UV printing method, ensuring that each shape features a distinct pattern corresponding to its unique form. The different shape categories also have different colours so that it can be enjoyed by both non-sighted and sighted users (Picture 10).

Figure 4-10: Revised kit with spot UV printing

Another significant challenge arose as students, unfamiliar with most shapes, struggled to relate to what they had made, hindering the learning and visualisation process. To address this, we devised a new curriculum spanning three sessions, each designed to progressively build students' understanding of 3D shapes.

Following the principle of 'Real to Abstract,' it begins with an exploration of real-life examples of these shapes, leading to a conceptual discussion on their properties like faces, edges, and vertices. Students then engage in hands-on activities using shape nets provided in the kits to assemble these shapes. The first session covers prisms including triangular, cubes and cuboids. The 2nd session introduces pyramids like triangular, square and hexagonal pyramids. The final session delves into complex solids like the hexagonal prism, cone, and cylinder, employing similar folding techniques. This method proved more effective in teaching them the necessary concepts while making it an interactive, engaging session. Notably, the presence of one-on-one guidance significantly enhances the overall learning experience for these students.

Conclusions and Possible Next Steps

In conclusion, our holistic approach to addressing the fundamental challenges faced by VI students in understanding 3D geometry has not only yielded positive results but also paved the way for broader applications in educational methodologies. This interactive, user-centric design is not only affordable and scalable but also easy to manufacture, enabling the realisation of previously elusive geometric concepts. This holds significant implications for educators, as this game-based educational tool can be easily replicated by both teachers and parents, fostering an inclusive learning environment for VI students.

The interlocking technique used here proves to be an effective tool, eliminating prior doubts and offering a versatile solution. Its applicability extends beyond teaching 2D to 3D visualisation in geometry to potential incorporation in other domains like Google AIY kits. Thus, more continued efforts in bridging educational gaps can result in a more inclusive educational landscape where every learner, regardless of visual abilities, can explore, learn, and create with confidence and joy.

Moving forward, our next phase will involve manufacturing 100 kits for testing, with color adjustments for better accessibility and material exploration to prevent tearing. The user testing will be conducted in various states of India to accommodate diverse groups and gain a comprehensive understanding of the situation. Emphasis will be placed on assessing learning outcomes, including additional cognitive skills, cognitive load analysis, and geometric understanding compared to traditional wooden solids. Additionally, we are mapping the kit to the Expanded Core Curriculum (ECC) for wider integration into teaching practices.

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5. Evaluating Interactive Accessibility Personas on the BlindDate Website

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Abstract

This paper examines the evaluation of accessibility personas for students with disabilities in higher education. Personas are a design tool that can be used in the design and implementation of teaching and learning materials, and accessibility personas can therefore be useful in improving the accessibility of these resources. In this study we describe the evaluation of four accessibility personas that were developed for the BlindDate website, which aims to provide a virtual encounter with students with disabilities, describing the barriers they face and the strategies that can be used to increase access. For this to be useful to teaching staff, the personas themselves should be as authentic as possible of the experience of students with disabilities. The evaluation involved an online survey linked to the persona pages, with a combination of quantitative Likert items and qualitative open-ended responses. These items targeted aspects of how the persona was perceived, focusing on their perceived authenticity and representation of students with the specific disabilities. The paper describes the results from an initial 39 respondents who were themselves students with disabilities, or pedagogical experts specialising in particular disabilities. The evaluation was generally positive with most respondents finding that the personas were believable, or seemed similar to themselves or someone they knew.

Introduction

While there has been a significant increase in information and training in digital accessibility, this has tended to be very general and not necessarily highly contextualized. Sensitization efforts should also pay attention to the needs of different domains such as health or higher education, and how persons with disabilities (PwD) operate within these domains. One proposed solution to this issue is the *Hochschul Initiative Digitale Barrierefreiheit* (SHUFFLE) project [1] which includes several digital accessibility projects including one involving the development of BlindDate. This is a resource website aimed at improving the didactic and technical competences of teaching staff in higher education in Germany. Website users can have a virtual encounter with students with disabilities. This encounter takes the form of interaction with personas representing students with various access needs and demonstrating the challenges within their learning environment, and the strategies they use to overcome various barriers [2].

In this paper we examine the evaluation of our disability personas through two main questions: (i) How are the personas perceived overall? (ii) How well do the personas accurately represent students with disabilities?

Background

Personas are fictional profiles that are a frequently used design tool in digital product development [3, 4]. These personas, however, tend to be static, based on limited user data, and are not meant for use outside of the design team or organizational repositories. Interactive personas tend to include more experiential or participatory elements and can also be devised as a target product that direct users can interact with. These types of personas are in some ways closer in nature to the agents and avatars found in dialogue and game systems, and the interaction experience needs to be considered differently.

Most of the work on how best to evaluate personas has tended to focus on static personas used during the design process. The approach to evaluation within this traditional focus has been on qualitative feedback in the form of either informal or structured interviews, focus groups, or open-ended questions on surveys. Critics of this approach have suggested that a more rigorous approach should be applied to improve evaluation methodology and allow for replication, especially with the onset of quantitative persona creation methods [5]. Proposed solutions to this problem include the use of quantitative instruments such as the Persona Perception Scale (PPS) which was developed to evaluate how individuals perceive personas, since perceptions are strongly associated with the adoption of personas for design tasks. The unadapted PPS was validated for effectiveness using factor analysis studies [6, 7] with reliability scores for factors evluated using Cronbach's Alpha scores. The final survey includes 28 Likert items across six factors: Consistency, Completeness, Willingness to use, Credibility, Clarity, Similarity, Likability, and Empathy.

Interactive personas that have various elements that users can interface with, do not fit easily into now established evaluation formats for either static personas or the more embodied agents or virtual characters. The question of evaluation is further complicated when the personas are created to represent particular demographics rather than a generic user profile [8]. In these cases, the value of the persona relies on the validity of the representation of the experiences of the target group. In the case of accessibility personas for example, evaluation should focus on determining how well the persona represents the lived experiences shared by members of the disability group and their challenges and approaches in using the product of interest [9, 10]. In these cases, one aspect of their personal identity is extremely salient in their user experience, and any attempt at replicating this in personas has a greater requirement for authenticity than typically needed for generic personas.

Methodology

This paper examines the evaluation of three accessibility personas: Hannah, Gabriel and Maxi. They were developed using co-design methods [11] involving iterative qualitative feedback from PwD as well as pedagogical experts in Inclusive Education. Hannah is a 25-year-old Mathematics undergraduate student who uses a hearing aid and a cochlear implant. Gabriel is a 27-year-old student with a visual disability who studies in an undergraduate Social Work program, while Maxi is a 29-year-old Masters` student in Architecture who struggles with Depression and Anxiety. Following the development process, they have been implemented as interactive personas on the BlindDate website. On the site, users (teaching staff) can explore the stories of their learning experiences and strategies through text, audio, and video as well as through simulation games and other interactive activities.

With the implementation on the website, final design evaluations were used to assess the ability of the personas to accurately portray the disability groups that they represent. This took the form of online surveys linked to the individual persona pages, which respondents were encouraged to complete after reading and interacting with the persona on the website. Respondents were recruited at university disability awareness events and included 49 PwD and pedagogical experts who had not taken part in previous iterative feedback loops. The surveys included an item to identify as a member of the disability group or not, followed by selected items from the Persona Perception Scale (PPS), as well as a section for open-ended responses. There were 39 complete survey responses for analysis of the personas, though incomplete surveys with open-ended questions filled in were included in that analysis.

The PPS was adapted to reduce survey length, to focus on evaluating authenticity and representativeness, and because some items used sensory terms or referred to pictures, making the item immediately inaccessible to some respondents. The 8 selected PPS items included 1 question that targeted personas Completeness (contains all crucial information), 2 targeting Credibility (personas matching reality), 3 targeting Clarity (persona information clearly presented), and 2 evaluating Empathy (the respondent understands/shares the feelings of the personas). These items are scored using a 5-point Likert Scale from Strongly disagree to Strongly Agree.

Table 5-1: Selected items from the Persona Perception Scale (PPS)

Feature	Question
Completeness	The persona profile is not missing vital information
Credibility	The persona seems like a real person
Credibility	I have met people like this persona
Clarity	The information about the persona is well presented
Clarity	The text in the persona profile is clear enough to read
Clarity	The information in the persona profile is easy to understand
Empathy	I feel like I understand this persona
Empathy	I can imagine a day in the life of this persona

In addition to this, respondents were asked open-ended questions e.g. "*What is your impression of X and BlindDate? What positive and negative aspects do you notice?*"; "*Do you think that the X persona is realistic?*"; and "*Is the information provided by the persona complete from your point of view? Is anything missing?*". For respondents with disabilities similar to the given persona`s, "*Does X encounter similar barriers to you? Does X use similar strategies?*" These data were analyzed thematically with the feedback summarized for use by the development team.

Results

Quantitative Data

The results of the surveys for the three personas were combined to give an overall view of the personas and how they were perceived by the respondents (N=39). As seen in Fig. 1 the personas were positively assessed across all feature types. Combining the positive Agree and Strongly Agree responses, the results were the following: Q1: 78.5% did not think that there was any missing vital information; Q2: 79.7% thought that the persona seemed like a real person; Q3: 74.4% thought that they had met people like this persona; Q4: 79.7% thought that the information was well presented; Q5: 89.7% thought that the text was clear; Q6: 82% thought that the information was easy to understand; Q7: 79.4% felt that they understood the persona; and Q8: 64.1% thought that they could imagine a day in the life of the persona.

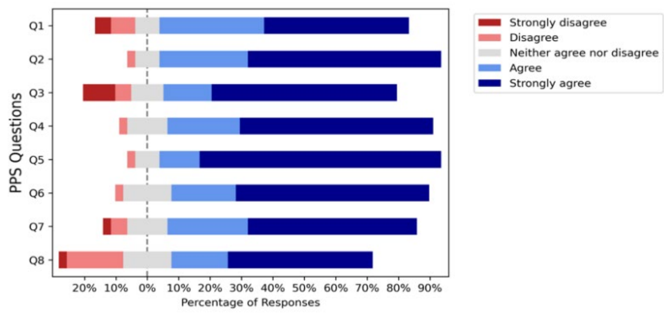

Figure 5-1: Perception of the here accessibility personas

These results were largely the same for the Hannah persona for which there were the most completed responses (N=23).The other personas at the time of this report, had too few responses to evaluate this way.

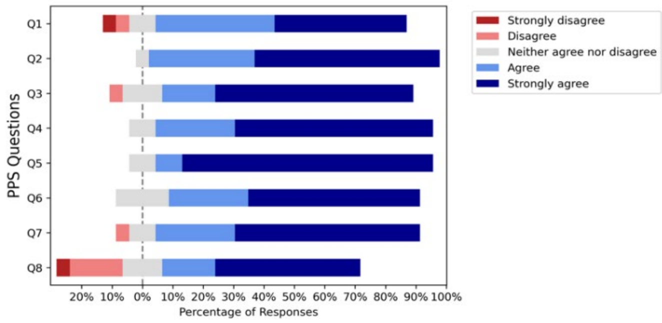

Figure 5-2: Perception of the Hannah persona

Q1: 82.6% did not think that there was any missing vital information; Q2: 95.7% thought that Hannah seemed like a real person; Q3: 83.6% thought that they had met people like Hannah; Q4: 91.3% thought that the information was well presented; Q5: 91.3% thought that the text was clear; Q6: 82.6% thought that that the information was easy to understand; Q7: 87% felt that they understood Hannah; and Q8: 65.2% thought that they could imagine a day in Hannah's life.

Qualitative Data

The open-ended questions were examined for direct feedback on the quality of the persona and the various interactive elements used to tell their stories. Responses appeared to be well thought out and insightful of the way in which the personas were viewed. Some responses about Hannah for example, included: "likeable"; "I think the reality is simulated well here"; "Hannah is very similar to me and other students with hearing impairments", as well as comments such as "Hannah is profoundly hard of hearing and therefore cannot represent all people with hearing impairments". Comments about Maxi included: "I like the profile" and that Maxi "uses similar strategies" to the respondent, while another felt the persona was "missing statements about the symptoms, the hurdles/challenges in studying, possible solutions, possibilities for support". Responses for Gabriel included: "The persona seems very human. The general information, memos and strategies all have positive aspects. You have the feeling that you can immerse yourself in Gabriel's everyday life.", "The persona is extremely successfully [made] and realistic".

These various responses not only touch on the appeal of the persona but also raises issues of what is considered completeness and representativeness. They also reflect of one of the main challenges of developing and using personas with disabilities: disability types often represent broad labels in which there can be a range of barrier types, strategies and access needs that cannot be encapsulated in a single persona.

Conclusions and Further Work

The quantitative and qualitative data provide interesting insights into how the personas are perceived. The approach to designing the personas was that it would be strategies-based with a focus on the agency and empowerment of the student with disabilities in collaboration with greater accessibility awareness and implementation from teaching staff. The adapted PPS items show a positive response to the persons in term of the completeness of information, apparent realness, and similarity to others with the same disability, with scores ranging from 64.1% to 89.7% for the combined personas and from 65.2% to 91.3% for Hannah. These results were corroborated by the content and types of responses in the open-ended section of the survey.

One area of weakness is in the Empathy features which scored the lowest for the three personas combined (Q7: 79.4% and Q8:64.1%) and for the Hannah persona (Q7: 87% and Q8:65.2%). While empathy is a notoriously difficult concept to evaluate, it is a central idea behind the use of the personas and the general approach to accessibility sensitization on the BlindDate website. The lowest scoring item was Q8: I can imagine a day in the life of this persona. While this was a relatively lower scoring item, it provides critical insight to the development team to reconsider how content or interactive elements may be adapted so that users of the website have an increased feeling that they can, even in a limited way, inhabit the daily lives of the personas and by extension the students with disabilities. Further work will focus on the continued evaluation of these three and other website personas as well as any changes to be made in evaluation methodology and persona content.

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6. Enhancing Inclusive Education through ICT – Lessons from three Case Studies Supporting Students with Different Challenges

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Abstract

This paper discusses the role of Information and Communication Technology (ICT) in fostering inclusive education within tertiary institutions. Recognizing the traditional academic setup's inadequacy to cater to a diverse student body, it argues for the necessity of integrating ICT solutions to address the varied needs of students, including those with disabilities, learning differences, and those facing cultural or linguistic barriers. Through the lens of three case studies, the paper vividly illustrates how ICT can be leveraged to create more accessible and personalized learning environments.

Introduction

The tertiary education sector has traditionally been designed to provide an excellent education for students with high performance and good cognitive skills. The traditional focus has been on building on the basic level achieved in the secondary school leaving examination, known as the Matura in Austria. Study programmes are based on an average level of education and do not take into account differences such as aptitude, prior knowledge, learning speed or learning style.

It was left to the students themselves to compensate for individual gaps in knowledge due to differing abilities, language barriers or personal challenges in terms of learning strategies, time management, mental strain and stress [1]. In this context, universities saw themselves as educational institutions for motivated young people who were ready to achieve cognitive excellence without much support.

The demand to achieve a higher level of academisation in Austria and to make tertiary education accessible to as many people as possible, but also the self-image that an inclusive view of humanity should not stop at the doors of the university, has been accompanied by a call for a more inclusive design of education. Now more than ever, universities are recognising their mission to contribute to the inclusion of students with special needs and are being asked to respond to the diversity of their students, not only addressing established issues such as accessibility, but also adapting their education to many different individual needs [2].

This also goes hand in hand with an intensive discussion about student-centredness and tailoring studies to individual needs, as is the case in many universities today. Curricula should no longer formulate standardised levels of study requirements, but should also address the individual challenges that arise in different life courses. So it is less about targeting students with particular challenges and more about recognising the individual educational needs of all people and taking these into account when designing educational programmes. This means that rather than finding special solutions for so-called marginalised groups, inclusion is being established as a general attitude in tertiary education.

As a result, the personal challenges faced by students can be complex [3]:

- A particular psychosocial burden that interferes with their own learning process
- Cognitive challenges in specific areas, such as dyscalculia or dyslexia
- Migration and the associated language barriers and cultural challenges

- Atypical life courses, reintegration into the labour and education market and studying at an older age.

Universities are called upon to take up these challenges and to provide an environment that promotes inclusive education, but also to take measures that actually support students in overcoming barriers in their day-to-day studies due to special needs.

This paper describes the opportunities and measures for inclusive education in the context of a degree programme and provides several practical examples that can serve as best practice for other universities.

State of the Art

Before illustrating and discussing examples of inclusion in practice through specific case studies, it is important to clarify the terminology and introduce the topic.

Inclusive Education

Inclusive education refers to an approach to education that aims to include all students, regardless of their abilities, disabilities or other factors that may differentiate them. The key principle of inclusive education is to create an environment where every learner feels welcome, valued and supported, and where different needs and learning styles are taken into account.

Key features of inclusive education include:

- Diversity: Inclusive education recognises and celebrates the diversity of students, including those with disabilities, different cultural backgrounds, learning styles, and abilities. [4]
- Equal opportunities: The aim is to provide all students with equal opportunities to participate in the same educational activities and settings. This often involves adapting teaching methods, materials, and classroom environments to meet the needs of diverse learners. [5]
- Participation: Inclusive education emphasises active participation and engagement of all students in learning experiences. It involves removing barriers to learning and ensuring that everyone can contribute to the best of their ability. [6]
- Support: Appropriate support services and resources are provided to meet the individual needs of students. This may include special educational services, assistive technology and additional classroom support. [7]
- Collaboration: Inclusive education promotes collaboration between educators, students, families and support professionals to create a supportive and inclusive learning environment. [8]

The aim is to move away from segregating students on the basis of difference and instead promote an education system that fosters a sense of belonging, mutual respect and understanding among all students. Inclusive education not only benefits students with disabilities, but also improves the overall educational experience for everyone involved.

The role of Information and Communication Technology (ICT)

Information and Communication Technology (ICT) can play a crucial role in supporting inclusive education, for example by providing tools and resources to meet diverse learning needs: [10]

- Accessibility Tools and Software:
  - Screen readers: These software programs convert digital text into synthesised speech and help students with visual impairments. Examples include JAWS and NVDA.

- Text-to-speech (TTS): TTS tools can read digital text aloud, helping students with reading difficulties or learning disabilities. Examples include NaturalReader and Kurzweil 3000.

- Adaptive Learning Platforms:
  Platforms that adapt content and learning activities based on individual progress and preferences can be beneficial for diverse learners. Examples include DreamBox, Smart Sparrow, and Knewton.
- Assistive Technologies:
  Speech-to-Text (STT): This technology converts spoken language into written text and can help students with writing difficulties. Examples include Dragon NaturallySpeaking and Google Speech-to-Text.
- Digital Educational Resources:
  E-books, online simulations and interactive educational content can cater to different learning styles and preferences. Platforms such as Khan Academy, Coursera and TED-Ed offer a wide range of educational resources.
- Collaboration tools:
  Online collaboration tools facilitate communication and teamwork between students. Google Workspace for Education and Microsoft Teams allow students to collaborate on projects and promote inclusivity.
- Personalized learning platforms:
  Adaptive learning systems, which tailor content and pace to individual needs, can benefit students with different learning abilities. DreamBox and Lexia Learning are examples of this.
- Communication Apps:
  Apps that support alternative communication methods, such as Augmentative and Alternative Communication (AAC) apps, can be valuable for students with speech or language impairments. Examples include Proloquo2Go and TouchChat.
- Virtual Reality (VR) and Augmented Reality (AR):
  Immersive technologies can create engaging and interactive learning experiences. For example, VR applications can simulate historical events, providing a more inclusive and accessible learning environment.

The use of ICT in education requires careful planning and consideration of the individual needs of students. By using these technologies, educators can create more inclusive and accessible learning environments for all students.

Methodology

This paper aims to explore different ways in which ICT can support inclusive education practices in the context of three specific study programmes. The methodology used is case study research, and in the following different use cases of applied ICT integration to support inclusive education are discussed. All examples come from a specific department at a University of Applied Sciences in Austria, which is responsible for three study programmes, one bachelor and two master programmes. Based on different challenges in everyday study life, the tailor-made solutions for each situation are described. In this way, an understanding of how to integrate ICT tools to create an inclusive learning environment that meets the diverse needs of students can be built.

- Objectives of study:
- To assess different use cases of the application of ICT in supporting diverse learning needs within the framework of inclusive education.
- To identify the challenges and opportunities associated with the use of ICT in promoting inclusivity.

- Data Collection: Conduct interviews with lecturers of the department to gather qualitative data on their experiences with ICT in inclusive education.
- Data Analysis: Qualitative analysis for themes emerging from interviews.

Description of Relevant Case Studies

The following overview shows the three case studies that were examined in the course of the case study analysis. The first case deals with the challenge of heterogeneity of prior knowledge and describes a case of asynchronous learning, the second case deals with language barriers and describes how international students can be prepared to enter the Austrian labour market and the third case shows the challenges of mentally impaired students and how they could be supported to continue their course of studies.

Providing Digital Educational Resources for a Self-directed Learning Process in a Management Accounting Course

This case study shows how students with heterogeneous prior knowledge can be given an individual learning process. By providing learning videos and enabling a personalised, asynchronous learning process, students can adapt their learning process to their individual abilities and prior knowledge.[11]

The introductory phase in particular is a challenge for both students and teachers. Varying levels of prior knowledge make it difficult to establish a uniform basis for advanced courses. In addition, experience shows that students learn at different paces in analytical subjects and that the amount of practice required varies from person to person. To meet these challenges, the format of the Management Accounting Bridge Course at the beginning of the Master in Supply Chain Management was changed to a fully online course. The aim was to give students the opportunity to learn the basics of management accounting at their own pace. The learning process was accompanied by tutorials with the lecturer, where open questions could be clarified. By providing all materials on MS Teams as a learning platform and YouTube as a medium for providing learning videos, the students were able to organise and control their learning process asynchronously. Although creating the learning materials and setting up the platform took a lot of effort in the first step, individual learning processes can be designed efficiently in subsequent courses.

- Implementation period: since September 2019
- Students involved: 120
- Main goal: Offer asynchronous and self-directed learning processes, depending on prior knowledge
- Feedback of students: Student feedback on the new course format was consistently positive. Students with no prior knowledge particularly appreciate the opportunity to watch videos more often and thus incorporate repetition. Students with previous knowledge appreciated being able to increase the pace of learning independently and only having to delve into areas where they still had gaps in their knowledge.
- Feedback of lecturers and study administrators: The lecturers' experience showed that the students were able to learn on their own using the digital learning materials. The limited tutorials that were offered were more efficient due to the students' individual preparation and discussions were more intensive and based on specific questions. From the lecturers' point of view, the level did not suffer, and satisfaction with the course increased due to the personalised learning processes.

Offer Online Language Training (Already in the Pre-study Phase and Beyond) to Promote Individual Language Skills and to Enable Students to Study in German

In order to enable foreign students without any knowledge of German to study in German and thus also to find a job in Austria later on, language skills are trained individually using online tools before the start of studies and during the first year of study.

Foreign language students have special needs during their studies. They need to gain confidence in the new language, they need the support of their fellow students and they need to find their way not only in a new language but also in a new cultural context. The better they are able to communicate with their fellow students at the beginning of their studies, the more confident they will be when they start. For this reason, it is important to consider the study environment and how the study experience can be best supported. By starting to fill language gaps before the start of their studies, students not only fill important language gaps, but also get to know the institution and the study environment by getting in touch with contact persons in advance. Online consultations, online language modules and the identification of special needs are all designed to meet the needs of foreign language students. Individual language training takes place in the pre-study phase and during the first year of studies.

- Implementation period: since September 2020
- Students involved: 50 each year
- Main goal: Intensive language training for better integration of foreign-language students before starting the semester, providing support in order to advance the entry into the first semester of study and to facilitate an integration into the Austrian labor market.
- Feedback of students: International students appreciate each opportunity to prepare themselves for their studies in Austria. They participate in the language trainings, are grateful for every support during the application process and value the online-opportunities given. Besides using the online-tools provided they state that every direct contact with study administrators or study fellows is helpful to manage the integration into the new and foreign context.
- Feedback of lecturers and study administrators: Lecturers have positive experiences of focusing on individual language training. Dropout rates are lower and the integration into the student cohort seems to be easier. Overall student satisfaction with foreign-language studies could be increased.

Offering Hybrid Teaching and Online Collaboration Using MS Teams to Integrate Students with Long-term Covid or Mental Illnesses

This case study describes how the University of Applied Sciences Upper Austria is using online tools to enable students who are unable to attend classes in person to continue their studies.

Particularly during the coronavirus crisis, but even before that, universities were confronted with the incidence of mental illness and the associated inability to attend. Long periods of depression or anxiety often make it impossible for students to continue their studies in the usual way. On the other hand, there is a strong desire to be able to continue with some degree of daily life in this difficult situation and not have to give up the degree they are aiming for.

There has always been a willingness in the programme to cater for these special needs, but the options have been limited and, in addition to repeating a year of study, compensation work has usually been the method of choice. With the increasing establishment of online learning tools at the university, the options have improved considerably and students can now participate in hybrid learning (the equipment for this was retrofitted in all lecture halls during the Corona crisis) or also work with their fellow students in group work from home via MS Teams. Students are now accustomed to this type of collaboration and it is usually straightforward in terms of group dynamics to integrate external participants. Awareness of mental illness and Long Covid has increased and the inhibition threshold of those affected to openly discuss and find solutions has definitely decreased.

- Implementation period: since September 2020
- Students involved: 9
- Main goal: Enable students who are unable to continue their studies on site for health reasons to continue on site for health reasons to continue their studies
- Feedback of students: Students value the opportunity to continue their studies and are grateful for online-participation modes. They argue that continuing their studies also supports the recovery.
- Feedback of lecturers and study administrators: The experience of study administrators shows, that continuing their studies in an online mode increases the probability that affected students are able to complete their studies.

Discussion of Case-Studies and Conclusions Derived from Theory and Case-Study Analysis

In the following, the results of the case studies are discussed and conclusions drawn from theory and empirical research. First, the application of the key features of inclusive education is discussed; second, the application of ICT tools is described; and third, the overall conclusions of this paper are drawn.

Application of Key Features of Inclusive Education

Following the key principles of inclusive education, these case studies show the application of different factors. In each case, diversity plays a key role. In the first case, different prior knowledge, in the second, language barriers and in the third, health issues are the key challenges. Equal opportunities are given to the students by considering their special needs in each of the case studies. In particular, students in cases two and three are given the opportunity to participate in the course. Language barriers as well as health issues may pose individual challenges to participation. Students in case two are supported with special language services for foreign language students. Cooperation is particularly important in case three, where students with mental health problems need special conditions in terms of their learning environment and intensity of study.

Application of ICT Tools

ICT was used in these examples to enable students with different barriers to study as normally as possible. The technologies, concepts and tools used are not specialised tools, but elements that are also used in various places in normal everyday study life. Essentially, these are tools that were introduced at the university for didactic or study organisation reasons, such as tools for creating and reproducing materials in different formats (e.g. videos, audios), tools for overcoming spatial distances (video conferences), software to support communication with students, learning platforms to support students at different speeds. Different combinations of these tools have proven useful in supporting students with special needs.

Conclusion

Identification of Successful ICT Tools and Strategies on the Satisfaction of the Students

The implementation of the Management Accounting course was evaluated over several years in terms of workload distribution and student satisfaction. The former was determined by analysing the students' access to the learning platform and evaluated in terms of its distribution during the semester.

Satisfaction was measured and analysed using semi-structured questionnaires. The results showed that the ICT tools used and the didactic set-up had an impact on the distribution of the students' workload. This is also linked to student satisfaction, which decreases significantly when the workload is unevenly distributed, even if this shift is due to student procrastination.

Information Technology Support for Students Depending on their Linguistic and Cultural Background

In order to support the integration of students with foreign language and cultural backgrounds, all courses in the first two semesters of the Bachelor's programme are offered in both English and German. The heterogeneity of the students is supported in particular by an individualised learning environment in parallel to the classroom teaching. Individual needs are also supported by different technical options, for example by allowing students to adapt the media used and the pace of learning to their own needs.

Combination of Different IT Tools for Customized Support

For example, due to reduced performance as a result of long-term covid or mental dysfunction, students require different speeds, different time windows or different spatial conditions. The Teaching Resource Platform has been and continues to be used as an information technology tool to provide support in these situations. The provision of teaching/learning materials in various forms is well received by the students, as is the possibility of attending the course at a later date if they are unable to attend in person or at a distance. This requires the use of different tools such as content in different formats, recording of courses, the possibility of online participation and self-testing to monitor learning progress. The situational use of IT supports student learning in a variety of ways.

The results of all three case studies show the possibility, but also the necessity, of an adaptive use of different tools and scenarios to support the success of students with special needs. The increasing heterogeneity of students over the last years can be partially addressed by the specific use of a wide range of IT tools.

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7. A Pedagogical Model for In-Situ Training Interventions: Creating Inclusive Educational Pathways with Assistive Technologies through the Support of GLIC Assistance Centers for the Ministerial "Sussidi" Grant.

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Abstract

This study examines a pedagogical model devised by a Center associate to the Italian AT Network GLIC, designed to enhance inclusive education through the deployment of Assistive Technologies (AT). Centered around an innovative support framework for teachers, this model operates as an in-situ in-formational and training desk in the Campania region, aiming to foster inclusive educational environments. By integrating technological aids and didactic sup-ports tailored for students with disabilities and special educational needs, the initiative seeks to address the accessibility challenges within the traditional educational landscape.

Anchored by the national "Sussidi" Grant since the 2017-18, this initiative has facilitated the provision of assistive technologies, aids, and teaching supports to state public schools. The research underscores a preliminary evaluation of the service's outcomes by analyzing aid requests from teachers of Salerno province who have applied for the grant.

The interdisciplinary team center’s efforts have contributed to promoting inclusive and accessible educational content. Empirical evidence from the last three grant cycles illustrates the positive impact of these educational interventions, substantiating the crucial role of AT in fostering an inclusive learning environment. This study highlights the increased specialization in requested assistive technologies, underscoring the evolving needs within inclusive education frameworks.

Keywords: Teaching aids, assistive technology, training, education, enabling environments.

Introduction

This article presents a pedagogical support model designed for educators, implement-ed as an on-site informational and training support desk provided by Manè Social Enterprise, an Assistive Technology (AT) Center located in the Campania region and affiliated with GLIC, the Italian Network of Consultancy Centers on Assistive Technology. GLIC, established as an interregional group in 1996, comprises more than twenty Italian centers that serve as reference points in the domain of computer and electronic aids for individuals with disabilities. These centers are stable, non-commercial entities, either public or private, that do not engage in the sale of technology but have instead initiated ongoing technical and scientific discourse and collaboration.

The centers within the GLIC network share commonalities in providing a range of services at various levels, including information, counseling, support, training, and research. Each center is staffed with a team and equipped with a range of aids and proposed solutions to address various challenges of independence in daily living contexts.

The initiative aims to foster the creation of inclusive educational environments through the integration of technological aids and educational supports tailored to students with disabilities and special educational needs. The research focuses on a pre-liminary evaluation of the outcomes of this service by analyzing the requests for aids submitted by teachers who participated in the "Sussidi" - Teaching Aids & Assistive Technology - grant in the province of Salerno.

State of the Art

The Ministry of Education "Bando Sussidi" Aids Grant

Since the 2017-2018 school year, the Italian Ministry of Education has launched an experimental program providing assistive technologies, aids, and educational supports to state public schools upon request. This initiative, known as the "Sussidi Grant," was established under Legislative Decree 63 of 2017 to promote specific actions aimed at achieving school inclusion goals.

Under the "Sussidi Grant," school institutions and their educators may apply for subsidies and supplementary systems for teaching, thereby facilitating accessible learning for students with disabilities. This initiative calls for the design and execution of projects tailored to the individual needs of students certified under Law 104/92. Leveraging its experience supporting schools since 2007 in Campania, the Manè team has developed a range of initiatives to enhance educators' access to supportive tools through on-the-job training. The interdisciplinary team at the Manè Center, comprising experts in assistive technology (AT), bioengineering, psychology, computer science, and social innovation, offers guidance and support to educators in selecting appropriate educational and assistive technologies based on the specific needs of students. The primary objective is to equip educators with the knowledge and skills necessary to create tailored applications for technological aids.

Active since 2020 in the province of Salerno, the help desk serves both curricular and support teachers across all educational levels and disciplines. Drawing on Italian research into pedagogy and assistive technologies, the discourse on technological inclusion in education is enriched with directly applicable perspectives and practices. The implementation of assistive technologies through the "Sussidi" grant provides critical support to educators and students with disabilities, enabling inclusion, access to educational content, and active participation in school activities. In recent years, the Manè Center has initiated various training and refresher initiatives targeting curricular and support teachers, with a focus on inclusion, accessibility, and the integration of educational and assistive technologies. These efforts are bolstered by multiple consulting and evaluation help desks, which determine the most suitable technologies for each student's needs.

The role of CTS - School Support Center - in Creating Inclusive Educational Pathways with Assistive Technologies through.

The role of CTS schools is crucial as they represent a public territorial network of Centers for Aids throughout the country. These centers are tasked with initiating training programs for both general and specialized teachers, disseminating knowledge, sharing good practices, and providing resources (both hardware and software) to enhance school inclusion for pupils with disabilities using New Technologies.

CTSs facilitate the procurement and efficient employment of new technologies for school accessibility. Established under the New Technology and Disability (NTD) project and distributed evenly across the country, the Network of CTSs provides ad-vice and training to teachers, parents, and pupils concerning technologies applied to students with disabilities. There are currently 100 Territorial Support Centers opera-tional throughout Italy, around one per province and three in the metropolitan bigger areas such as Rome, Milan and Naples.

The Training Proposal of the AT Center "Manè Social Enterprise"

Specifically designed to bolster the CTS school, the School Support Center, and the schools within the province of Salerno, the training initiatives aim to enable educators to discern and integrate the most appropriate educational aids and technologies within their pedagogical frameworks. Empirical evidence gathered from field observations and data analysis for the last three iterations of the "Sussidi" Grant (2021/22, 2022/23, 2023/24) offers a robust foundation for appraising the positive impact of these educational interventions. This data underscores the effectiveness of the undertaken actions and accentuates the pivotal role of the Assistive Technology (AT) Center in assuring the seamless integration of AT in educational environments. The tangible influence observed in educational dynamics and student advancement underscores the substantial benefits of the training support provided by the Manè AT Center, both in enhancing the inclusive education process and in fostering progressively inclusive educational settings. Following the identification of suitable AT, the team proceeded to support teachers in optimally utilizing the aids allocated under the "Sussidi" Grant, through targeted training interventions tailored to the specific aids and technologies provided.

Methodology

The team collaborated synergistically with the existing materials and human resources in the field, endeavoring to establish mechanisms of change pertinent to the educational contexts under reference. Consequently, this article presents a comprehensive overview of the seminal interventions implemented by the Manè Center with-in educational settings, alongside the favorable outcomes these have engendered in promoting inclusive instruction, sensitive to the distinct attributes of students. The Manè Center's suite of training programs, supportive frameworks, and specialized consultancy services engaged educators and students ranging from primary to secondary levels within the province of Salerno. The student cohort exhibited a diverse range of disabilities, including instances of concomitant impairments. The primary aim of these interventions was to tailor the selection of strategies and tools - including aids, technologies, and AT - to the pedagogical needs of individual students.

To identify instructional strategies and assistive technologies best suited to the specific needs of students, the Manè Center established counseling and assessment desks for teachers in the province of Salerno who requested them. The counseling sessions were attended not only by teachers, as appropriate, but also by the student's curricular teachers, the student's parents, and the student themselves. The counseling and evaluation intervention included interviewing the student's teachers for data collection, taking charge of the request and analyzing the demand made by the school; observing the student in the practice of daily school life to detect specific needs and residual abilities; and conducting tests of the use of aids and AT provided by the CTS, in relation to the student's disability and educational need. As a result of the counseling desk conducted, the Center prepared a technical report, reporting the assessment and indication of the strategies and aids deemed most appropriate for the student to ensure his or her access to education and school inclusion.

Subsequently, the technologies pinpointed during this process became central to the applications submitted by educators and institutions in conjunction with their participation in the annual "Sussidi" Grant.

In addition to the training counters, which were activated at the request of teachers and schools to meet the educational needs of specific students, the methodological approach adopted also entailed conducting face-to-face training sessions at the CTS headquarters, where educators were equipped with essential knowledge to discern the needs of students and to articulate more tailored requests for assistive technologies. During the training, teachers were introduced to the operating characteristics of the main assistive technologies for teaching and beyond. The trained teachers learned the importance of creating an educational model capable of implementing an inclusive and accessible educational process, including through the correct and appropriate use of assistive technologies, to enable students to overcome the limitations imposed by their disability status and access educational content and school life inclusively.

Each academic year, an allocation of approximately 12 hours of direct training ensured thorough preparatory grounding. Post-training, educators received dedicated support in developing personalized educational projects for their students; to facilitate nuanced and efficacious assistance in this domain, around 30 hours of support per academic year were provisioned.

The training provided, through the individual counters and group training sessions, has reached, in the three-year period 2021/22 - 2022/23 - 2023/24, about 300 teachers. Given that each teacher follows at least one student, it can be asserted that the training has indirectly reached at least 300 students, and it can be assumed that this number grows where trained teachers follow two or more students.

Results

The data analysis conducted revealed a discernible decrease in the number of requests for generalist computing devices, including computers and tablets, reducing from 92 during the 2021-2022 academic year to 70 in the 2023-2024 period. The following Figure 1 provides a graphical representation of this trend.

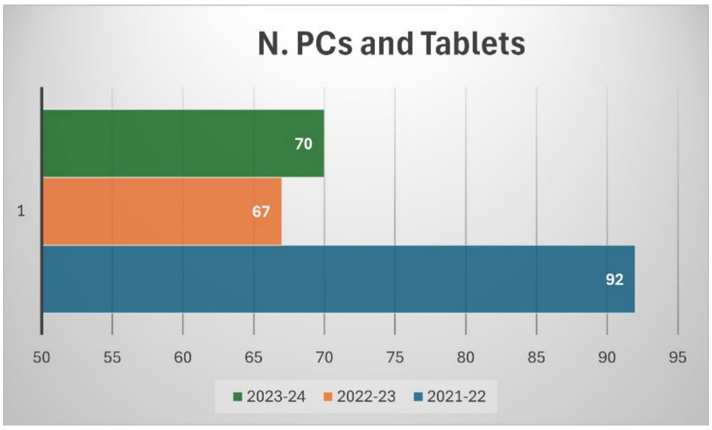

Figure 7-1 Trends in requests for generalist computing devices

In parallel, there was a notable increment in the requests for specialized assistive technologies, escalating from 70 to 88 within the same timeframe. The following Figure 2 gives a description of this trend.

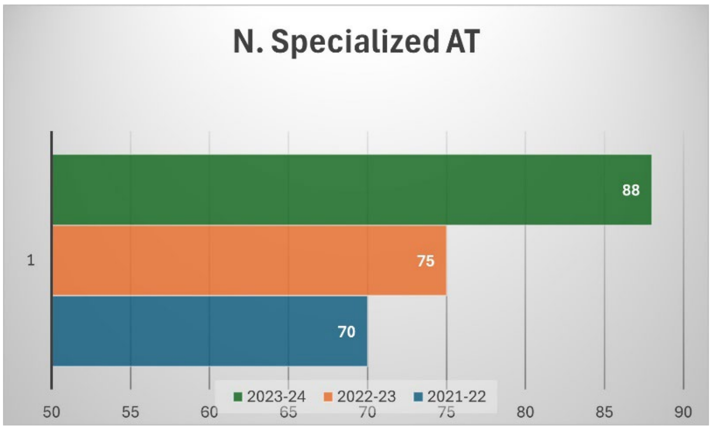

Figure 7-2: Trends in requests for specialized assistive technologies

This shift significantly influenced the average cost associated with each request, which saw an increase from 694.00 euros to 1054.00 euros per individual project.

These observed trends emerged from a comprehensive analysis of the funding data pertinent to the grant, spanning across the aforementioned three-year period.

The data analyzed were provided by the CTS Institute of Salerno province, which, as the reference school, has all the data on the projects submitted, with the measure “Sussidi” Grant, by schools in the area, within the three-year period examined in this study. The data tell what impact the support desks and training activities provided by the Manè Center had on the demands expressed in the projects by teachers, in terms of aids and teaching strategies.

The quantitative analysis of data pertaining to the recent cycles of the "Sussidi" Grant post interventions and submissions by educators that were subsequently ratified by the commission of the Regional School Office of Campania illuminates the critical role of the Assistance Center. This significance is observed not merely in facilitating the introduction of assistive technologies into educational frameworks and in generating conducive environments for the application of inclusive pedagogical approaches but also in guiding the selection towards aids that have, over time, demonstrated a trend towards increased specialization and suitability.

In conclusion, this research not only delineates an integrative pedagogical model for training interventions with a focus on Assistive Technologies but also implicitly aligns with the principles of Universal Design for Learning (UDL). By advocating for the strategic selection of technological aids, this study underscores the necessity of providing multiple means of engagement, representation, and action & expression - core tenets of UDL. The initiative outlined by the Manè Assistance Center, in concert with the Italian National GLIC Network and in response to the ministerial "Sussidi" Grant, exemplifies transformative practices that transcend traditional educational paradigms by fostering inclusivity and accessibility.

From the analysis of the results, the need emerges to delve into several significant inquiries for the future of inclusive pedagogy and the use of Assistive Technologies in the educational domain:

1. Personalization of Learning: How can the integration of assistive technologies into educational plans be optimized to support the individual specificities of students, in addition to effectively meeting their special educational needs?
2. Continuous Training and Updating of Educators: What training strategies and continuous updating modalities can ensure educators maintain current and compre-hensive competence on the evolution of Assistive Technologies and their didactic application?
3. Impact and Outcome Measurement: What methods and tools can be developed and implemented to more precisely and quantitatively assess the effect of Assistive Technologies integration on student performance and inclusion in education?
4. Overcoming Barriers to Adopting Assistive Technologies: What are the main challenges and resistances to the adoption of assistive technologies in daily teaching practice, and how can they be addressed and overcome to ensure broad inclusion?
5. Stakeholder Collaboration: How can collaboration among the various profes-sional figures (educators, technologists, psychologists, and other experts) involved in creating inclusive educational interventions that utilize Assistive Technologies be promoted and made more effective?

The exploration of these questions may further enrich the understanding and effec-tiveness of inclusive pedagogical interventions, contributing to the continuous im-provement of educational processes and the enhanced recognition of the individual potentials of each student.

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8. Accessible by Design? Exploring How Barriers Faced by Disabled Students are Resolved in Online and Distance Learning

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Abstract

Common policies and models for enhancing the inclusion of disabled students promote a trajectory of moving from adjustments and provision in response to individual requests and assessment of needs, towards an inclusive educational experience that is accessible by design. It is possible to see partial successes in this regard, particularly in the space of online and distance learning (ODL) However there remain prominent conceptual and practical challenges and a lack of clear data on what is working. This paper reports research conducted with students via a survey (n=50) and interviews (n=4) at an ODL higher education institution: The Open University UK. These aimed to better understand the extent to which study was experienced as accessible by design, where and how adjustments were effective, where further efforts should be focused to enhance provision. Students report barriers across types of materials, activities and assessments, however they were often able to resolve barriers related to study materials independently, and most of those related to assessments were resolved with support. Barriers in communicative activities such as tutorials and online forums were more often reported as unresolved. A range of features that represent an accessible by design approach were reported as useful, and students used various sources to gain guidance around accessibility. We discuss how the findings and further data collection processes could enable accessibility by design to be enhanced.

Introduction

Across the education sector and beyond, policies, models and strategies around disability argue for accessibility to be achieved by design to reduce reliance on complex processes of adjustment and support. Terms like inclusive design and universal design essentially focus on supporting the widest group of people to make use of something without barriers [1] but there is limited data on the extent to which this is currently achieved or how it can be further enabled.

A common lens through which to view accessibility in education is the need to avoid discrimination and support inclusion in mainstream contexts. In practice, this is achieved through several avenues. Firstly, efforts to design systems, curricula, environments, and processes to effectively serve the widest range of students from the outset. Secondly, anticipating barriers that would be faced by individuals in standard designs and being proactive in devising solutions in advance. Finally, responding when barriers are recognised to devise and put in place solutions in an ad hoc manner.

If much of what causes inequity for disabled students is predictable and avoidable through better design of teaching, activities, materials and systems, then it should be feasible to create mainstream provision of learning without barriers and reduce the need for responsive adjustments which can require substantial time and effort by students and staff and may not constitute ideal solutions.

This notion has a particular relevance and potential in online and distanced learning (ODL) where:

- Web-based systems and content are central and accessibility by design for these is relatively well defined through Web Content Accessibility Guidelines (WCAG).
- A larger proportion of ODL materials and activities are designed upfront prior to delivery when compared to in person teaching.

- Assistive technologies can be directly connected with digital platforms and content.
- For many disabled people ODL is the preferred or only suitable mode of study because of challenges around mobility, and greater flexibility in timing, formats, and communication.

Although WCAG is clearly important to making online teaching and learning accessible by design, research highlights that many barriers experienced by disabled students both in ODL and in broader tertiary education sit outside of the scope of this, relating to areas such as pedagogy, assessments, communications, and administrative processes [2].

There is a substantial literature around concepts of inclusive education and universal design for learning, but gaps remain in our understanding of the nature and prevalence of barriers students face, or how these barriers are resolved. In response, we developed a new survey method for students to report these and report here the results of a pilot of this. These findings help us understand what it can mean for study to be more accessible by design, and where we need to focus attention to enhance this.

State of the Art

While greater accessibility by design would be positive, we do not fully understand how to proceed or the value of existing efforts. Reviewing the evidence base, the key actions known to reduce gaps in success for disabled students are employing anticipatory approaches to adjustments, ensuring the provision of assistive technologies, and developing student's self-advocacy and self-regulation skills [3]. While training and inclusive learning strategies could be impactful our understanding of the efficacy and best approach for these is limited.

Much has been written about universal or inclusive design in education, particularly Universal Design for Learning (UDL) [4], which focuses on accommodating diversity through embedding choice and flexibility from the outset. Meta reviews of research suggest training in UDL can have a positive impact on teaching practices, enhance choice for students, and reduce the need for interventions by disability services. However, there is limited evidence of implementations enhancing outcomes in higher education, or how best to implement these approaches to maximise benefit to students [5,6]. Research often focuses on training staff and evaluating the impact of this, rather than the extent to which specific barriers have been removed for learners [7]. Here we respond to a need for more usable data on the barriers students are facing and whether and how these are being removed across features of study.

Research with disabled students gives different perspectives on what needs to change. For example, a survey of over 300 students by Disabled Students UK concludes that the lack of resourcing for staff to focus time on accessibility, and the administrative burden placed on students to get support in place, are key causes of barriers, and that changes to culture and leadership are needed [8]. An inquiry including many disabled student voices found that students face barriers not only due to inaccessible learning materials but also from staff not fulfilling agreed adjustments, lack of information sharing, and bureaucratic and financial burdens [2].

Many stakeholders make decisions that impact on the accessibility of higher education for students [9]. Furthermore, what we mean by an inclusive process of design is complex and underdetermined, reaching into questions of who's perspectives are privileged, and how diverse audiences are involved in decisions [10]. While guidelines can enhance accessibility by design by drawing on understanding of common barriers, accessibility exists in relation to individuals and the activities they aim to complete. Because of the complexity of this in education, it is argued that accessibility needs to be viewed as an ongoing process of improvement [11,12], and to do more by design, we need data to act on.

Methodology

To better understand what accessibility by design could entail and how current provision can be enhanced we conducted research with students and staff. Here we focus on data from a survey with students, containing quantitative and qualitative questions in the following sections:

'Disabilities and Your Study' asked students to describe their disabilities in open text and according to the categories used in university declaration and reporting. It then asks about their study environment and their usage of information and guidance sources about disability and accessibility.

'Your Experience of the Module' asks the student to identify if they faced barriers in relation to elements of studying a specific module (see figure 1 for the elements included), and whether these were resolved independently, with support from others, or if the barriers were not resolved.

'Accessibility Features and Module Design': asks students about their experience of using features of their module that represent an accessible by design approach, such as flexible study, tutorial recordings, alternative text or figure descriptions and others.

'Adjustments' checks whether students requested or received individual adjustments, what this was for and their experiences around this.

'Other Comments' is an opportunity to share further thoughts and ideas for improvements.

The survey was advertised to a total of 4,688 students who had disclosed disabilities and had previously studied one of a representative set of modules selected, including modules from each faculty and all levels of undergraduate study. The research was reviewed and given a favourable opinion by the Human Research Ethics Committee of The Open University (HREC/4725/Coughlan).

Results

50 responses to the survey were received and four participants also took part in follow up interviews, providing richer information based on the issues they raised in their survey responses. Table 1 shows the disability categories that participants declared in the survey.

Table 8-1: Disability categories declared by participants. Each participant identifies all relevant categories.

Disability Category	Total
Mental health issue (depression, anxiety, bipolar, PTSD)	21
Fatigue	15
Unseen disability (diabetes, epilepsy, asthma)	15
Mobility restriction	13
Specific learning difficulty (dyslexia, dyspraxia, ADHD)	12
Blind or partially sighted	5
Autism	4
Unsure/undiagnosed	4
Manual skills difficulty	4
Deaf or hard of hearing	3
Other disability	3

The open comment descriptions of disabilities provided by participants contain much more depth about individual circumstances. These highlight the limitations of these categories as the people declaring them can face different barriers, as well as having disabilities across multiple categories.

Survey results show how participants experienced barriers and resolution of these across elements of the study experience. Figure 1 shows the most common area where barriers were not resolved as online tutorials, with issues including audio quality and pedagogy. Forum activities raised barriers through distressing conversations and difficulty with instructions. Unresolved barriers were also reported with rich media including in captions. Barriers were relatively more likely in other forms of materials and tools, but were usually resolved independently or through adjustments.

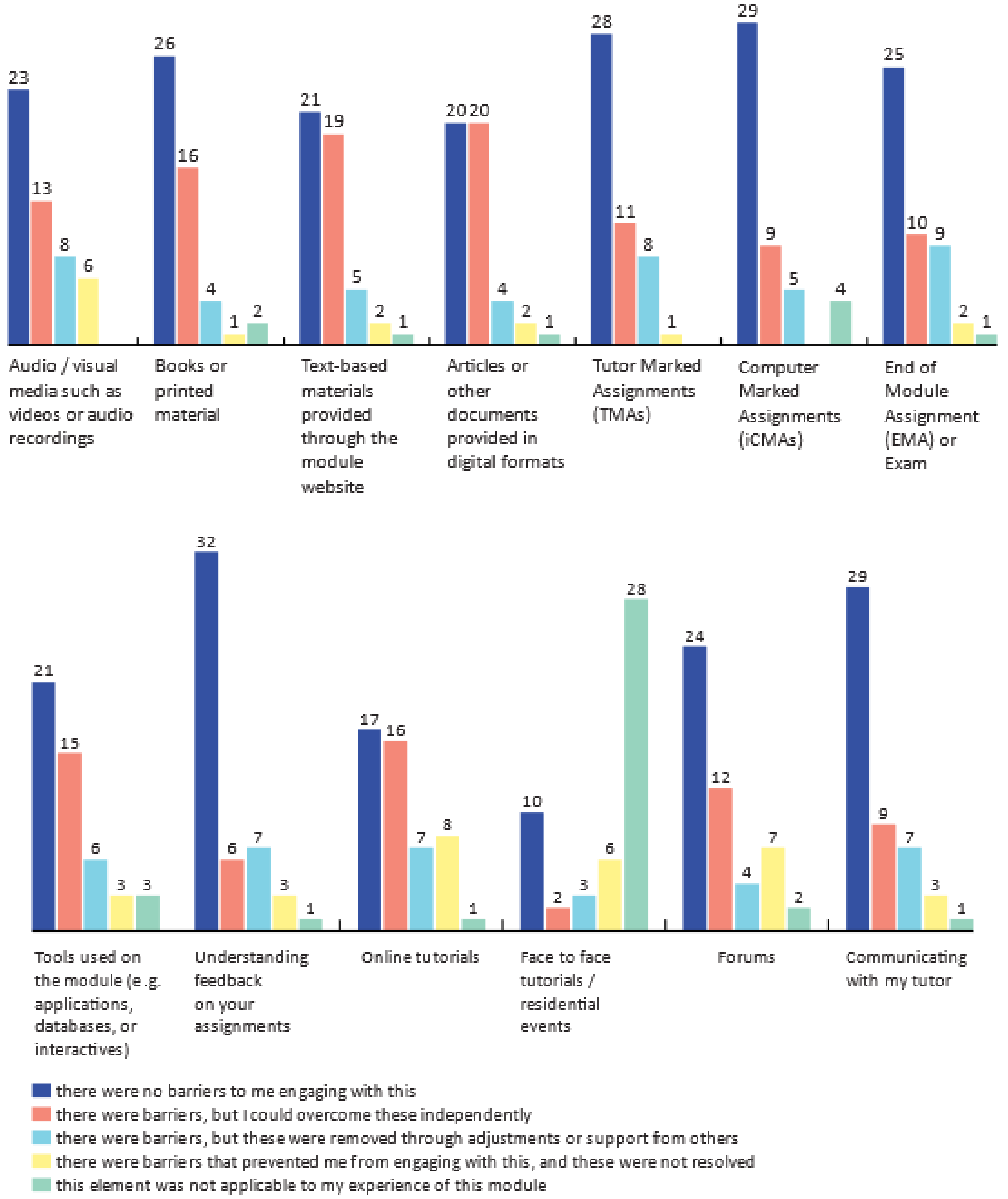

Figure 8-1: Responses to "For each of the following elements of your Module, we would like to know whether you experienced any barriers that impacted on your study. In each case, please select the one statement that best reflects your experience."

We also evaluated elements of study that represent an accessible by design approach. The elements most often used and found helpful were flexibility to study at any time (42 agreed), recordings of tutorials (33), and the availability of extensions to assignment deadlines (28). While 24 participants found downloadable versions of web-based materials helpful, a further 11 found these less helpful than they could be, pointing to potential to improve.

We asked where students got guidance around accessibility and most common was contact with their Tutor, reading the Accessibility Guides for information about the features of their module, or contact Disability and Student Support Advisors. Further sources used included the Library, university webpages, and peer support groups.

17 of 50 participants reported that they had individual adjustments made for them, so these were only requested by a minority (though a substantial one). 14 of these participants agreed that the adjustments made for them overcame the barriers they faced, and 13 agreed that the adjustments had been made in a timely manner. Table 2 indicates where these individual adjustments were made across the elements of study. This shows that such adjustments were common across both in-course and end of course assessments (most commonly allowing additional time), module materials (providing bespoke alternative printed or digital versions of materials), and for engagement with tutors (additional assistance or flexibility in how and when communication happened).

Table 8-2: Frequency of individual adjustments made according to which element of the module was adjusted. Participants were asked to select all categories that were relevant to the adjustments made for them

Element of study	Total
Module materials	8
Tutor marked assignments (assessments completed during the course of a module)	8
Support and communication from your tutor	8
End of module assessments / exams	6
Tutorials	4
Third-party resources, articles or books	2
Tools used in module activities	1
Forums	1

Discussion points

While this data is not necessarily generalisable to other institutions or teaching models, this work shows the potential to gather data systematically around accessibility barriers and solutions, the extent to which features intended to promote accessibility by design are used and effective, and how adjustments are currently being delivered.

In this initial study with a relatively small data set, we have not analysed the data according to the specific module studied. But with more data such analyses could lead to a process to identify with higher accuracy where barriers exist in the curriculum. Similarly, there is scope to analyse this form of data on barriers according to categories of disability, however there are challenges as categories can encompass a wide range of needs, and students can describe their disabilities in diverse ways [13].

A further approach with potential value would be to analyse changes over time, for example to see if there was a reduction in individual adjustments and increases in students either not facing barriers or able to overcome these independently. These could constitute valuable measures of success for initiatives to enable greater accessibility by design.

Staff may not predict every barrier that may be faced but we can do more to collect and learn from data and incorporate this into standard teaching designs as an ongoing process of information sharing and improvement. We also found that students appreciated the elements that represented an accessible by design approach, such as making study times flexible, and recording tutorials. Many students clearly value the ability to download study materials in multiple formats without having to request these, even if there was room for improvement in the delivery of this.

Reflecting on the data analysis reported here, barriers to accessing study materials and tools for online learning were more common but more often resolved independently. Rich media presented more requirements for support and more unresolved barriers than text-based sources, suggesting further work is needed to ensure consistent accessibility in these.

Barriers in tutorial and forum activities were less often resolved. There is less work ‘by design’ in these spaces. Tuition entails many individual staff devising and running a wide variety of activities, often improvised and with complex communications across multiple channels. Peer learning can also create barriers if students do not consider accessibility in interactions with each other. Further training in inclusive or universal design approaches could be impactful here, but there may also be a role for specific or adapted frameworks that are better suited to guiding staff towards creating inclusive online tuition [14].

Accessibility of assessment is of paramount importance to equity since it is directly linked to the outcomes achieved. There were a relatively large number of adjustments made to overcome barriers in assessment, indicating opportunities to do more in assessment design, enhancing flexibility and consideration of disabled students and the barriers they would face.

Further research conducted for this project looked to understand staff perspectives on the processes for individual responsive adjustments and accessibility by design. Combined with the data reported here, these lead to further recommendations such as:

- More systematic recording, sharing and reflection on the responsive adjustments made so that there can be an active process of exploring how these could be achieved by design in the future.
- Further collaboration to clarify responsibilities, ways of working, and achieving consistency across the multiple staff roles involved in making adjustments, including student support advisors, faculty, tutors, media specialists and library staff.
- Continual awareness building and piloting of technological innovations as these could both empower students to overcome barriers independently and reduce the ad hoc and time pressured work involved in making responsive adjustments.

Conclusions and Possible Next Steps

The research reported here contributes to understanding of how online and distance learning can become more accessible by design. Systematic approaches for students to report and provide feedback, such as the method piloted here, can play a valuable role alongside enhancing staff understanding of how teaching and learning can be designed to be accessible and inclusive. We will likely always need responsive adjustments in certain situations, and feedback can enhance processes for devising and putting these in place too. However, better evidence of where the barriers currently arise and the challenges these create should underpin strategies and encourage upfront investment in accessibility.

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9. User-friendly Serious Game Design for Diabetic Preschool Children

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Abstract

The "DIAB SMART" is a novel "serious game" designed for preschool chil-dren recently diagnosed with type 1 diabetes, a condition whose prevalence in childhood has tripled in the past 30 years. Aimed at addressing the in-creased need for knowledge during diagnosis and ongoing treatment, our primary motivation was to assist children with type 1 diabetes in learning crucial information. [1-2] We designed software that comprises two main components: the "DIAB SMART" game for children and an editor for par-ents. The game features three mini-games: "True-False," "Which," and "Plate," while parents and dietitians can modify the game database by up-loading meal/food data and images, as well as introducing new questions. The software underwent testing and evaluation by both adults and young children, utilizing modified System Usability Scale questionnaires. Results indicate high satisfaction levels among both parents and children. Notably, the versatility of "DIAB SMART" extends its utility to children with other conditions such as gluten or lactose sensitivity, and its user-friendly design makes it accessible for children with autism spectrum disorder, children with learning disabilities, and dyslexia as well. Overall, the "DIAB SMART" game represents an innovative and valuable tool for diverse pediatric health needs.

Introduction

Type 1 diabetes, characterized by the body's inability to produce insulin due to an autoimmune attack on insulin-producing cells, necessitates lifelong insulin treatment. In contrast, type 2 diabetes, more common and linked to age and lifestyle, involves insulin resistance, and may progress to medication or insulin. [1-2] In Hungary, the incidence of type 1 diabetes among children doubled from 1989 to 2009, with an annual standardized rate of 12.5 per 100,000 people. [3] Despite the availability of modern tools, children diagnosed with type 1 diabetes must adhere to rigorous routines, encompassing meal plans, blood sugar monitoring, and insulin administration. Collaborative efforts among healthcare professionals play a pivotal role in ensuring effective treatment. The attainment of successful self-management is crucial for regulating blood sugar levels and averting complications, demanding support from both the medical community and civil society. The development of "serious games" seeks to aid children in adjusting to their new way of life [4]. Our primary objective was to design a straightforward and user-friendly app to cater to the needs of children with learning disabilities and dyslexia as well.

State of the Art

Our process began with a literature review to identify similar games for diabetic children. We then consulted a pediatric nutritionist and selected the development platform. The longest phase involved actual development. Finally, we conducted thorough testing with both adults and children to ensure the game's effectiveness. We found the following papers and video games.

Lieberman [5] showed fourteen video games that were circulated between 1992 and 2011, but none of them were suitable for preschoolers. The game in Pouw's pa-per [6] was developed for elementary school students.

Lazem et. al. [7] reviewed 18 articles describing the designing and evaluation process of diabetes games from the technical, methodological, and theoretical points of view. They conducted a search from 2010 to May 2015. Despite the fact that some of them were developed for children, none of them for pre-school-aged children, and some of them are not available in English.

The Carb Counting of Lenny[SM][8] can be downloaded from AppStore. Although it is recommended for the age group 4+, the user interface still contains some text information and is only available in English. In addition, the average score given by users was 2.9 out of a maximum of 5 points.

MyDiabetic game [9] is a very complicated game, but this complexity may be frustrating to our target group. The game is useful for older children and not for pre-school-age children because it shows as many aspects of diabetes as it is possible. The game was developed under the umbrella of 3 years of research. Unfortunately, the game is also not translated into the Hungarian language, therefore it is not avail-able for our target group.

Rewolinski et al. [10] have reviewed nine studies. Their investigations show that there are significant differences in game-based interventions, knowledge, behavior, and participation. In serious game interventions, knowledge outcomes are the most important, while in gamified/serious game interventions, behavioral outcomes are the most obvious. The findings also showed that the theories used in game development were inconsistent, and the quality of the evidence throughout the study was moderate to low. Although the reviewed 9 studies prove the potential for game-based tools to excellently improve the self-management of type 1 diabetes, it is recommended a broader and more stringent research parameters be used for further research before radically changing the practice. Their paper also discussed the potential impact of clinical and educational nurses on the use and research of game-based interventions. They state that gamification interventions, which primarily have knowledge behavioral and engagement objectives, may help with the time of diagnosis and with disease self-management.

Certainly, there is a wealth of applications and games tailored for preschoolers available, such as "Diabetes Dash," "Jerry the Bear," and "Carb Counting with Lenny the Lion." In our development process, we thoroughly analyzed several existing games with the aim of creating a user-friendly and accessible experience, drawing inspiration from these established offerings.

Methodology

Software

This section shows both the game for children and the editor for parents. Subsequent paragraphs, however, are indented.

True/false quiz game

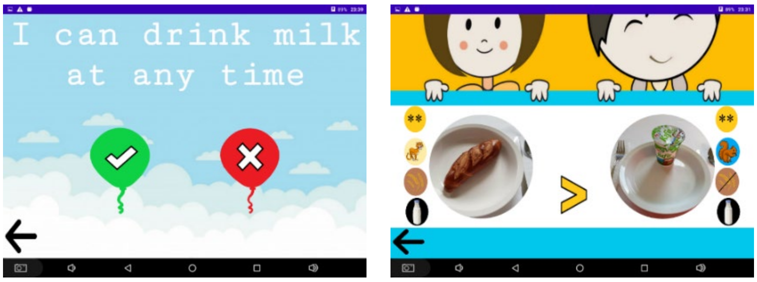

Figure 9-1: The "true(false quiz" (left and "Which game" (right) screenshots

The starting data contains 53 statements (in Hungarian) and sound files. In this lay-out, a random statement appears to the user, and the appropriate sound file is play-ing. (Fig.1.) The statement characters appear one by one. The user's task is to choose the right answer (True or False).

Which food has more / fewer carbs? game

The application shows the user two food images randomly from the database values. The application randomly also chooses to set the value on the left and the right site. The user's task is to choose which contains less carbohydrates. The user needs to select the appropriate relational sign (Fig.2).

Take it to your plate game

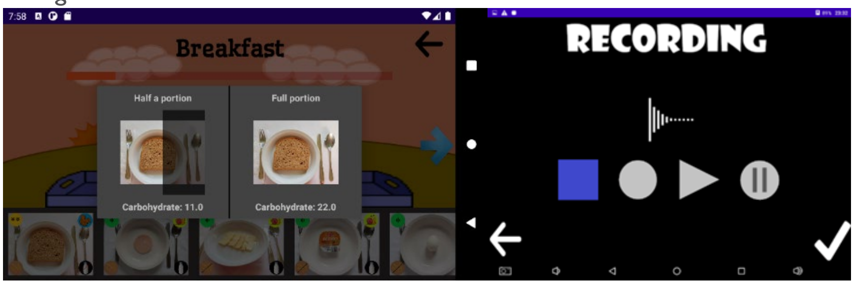

Figure 9-2: "Plate game" (left) and "Editor" (right) screenshot

This game helps the user count whether the required amount of calories for a selected meal is met or exceeded based on its ingredients. The selectable foods are shown on the bottom side of the screen, in a scrollable list. (Fig. 2) These can be dragged by long clicking them and dropped onto the plate in the middle of the screen which prompts the user the option to select a half- or full-calorie value for the current food. After choosing it, the calorie will be added to the progress bar at the top of the screen. Already picked foods can also be removed from the plate by dragging and dropping them over the bottom list.

Editor

We have created an editor for each game/function, which gave the opportunity for the parents to customize the game for their children's needs.

System Usability Scale

The previous section describes the functions of the developed serious game "DIAB SMART" and its editor. We have asked pre-school aged children, adult people: parents, and pediatric dietitians for testing the newly developed game and its editor. For this testing, we have used the System Usability Scale (SUS) [11], with our modified questions. The adoption of SUS brings several benefits, as it is an established industry standard. Key advantages include ease of use and scalability in administration to participants, applicability to small sample sizes, yielding reliable results, validity in effectively distinguishing between usable and unusable systems, and simplified calculation of scores' results. The test participants assigned rankings from one to five to each of the 10 questions, based on their level of agreement. The calculation involves the following steps: for odd-numbered questions, subtract one from the given score, for even-numbered questions, subtract the given value from five, sum up these new values, and multiply the total by 2.5. This sequence of calculations yields a final score out of 100 [12]. Such a methodical approach ensures a comprehensive assessment of usability, allowing for a quantitative evaluation of the user experience with "DIAB SMART" and its editor.

Results

Our software underwent testing by 9 adults and 3 children, who completed the System Usability Scale (SUS). Two modified System Usability Scale questionnaires were used in the testing phase: one for children and one for adult people. The maximum score is 100 in the System Usability Scale calculation method. The results of the evaluation were interesting, the parents' score was 87 and the children's score was 83. We can say that both the parents' and children's scores are "Excellent" based on the System Usability Scale calculation method. (SUS score above 80.3, the letter grade is "A", and the adjective rating is "Excellent".) Although children were much more assessed rigorously and critically. The cumulative survey result, at 85, indicates a high level of software usability, reflecting positive feedback from both adult and child participants.

Conclusions

A software, a serious game, “DIAB SMART” was developed for pre-school-aged children who have been newly diagnosed with type 1 diabetes. The main goal of the game is to teach newly diagnosed little children with type 1 diabetes to manage the forbidden and allowed food and its carbohydrate amount. Moreover, an editor was developed for parents. This game was designed using a user-centered design process. It means that children and their parents and diabetes experts were involved in the design process. The "DIAB SMART" game is based on the children’s needs and conceptions and is implemented based on the knowledge of pediatric dietitians. It contains not only games for children but also a database with photos and data of several foods and meals. After the development process, the game and its editor were evaluated for their learning effectiveness and usability. The "DIAB SMART" newly developed game is an innovative game because it is useful for children who suffer from other diseases too e.g., sensitive to gluten or lactose. Moreover, children with autism spectrum disorder or other learning disabilities can also use it easily because the game was designed to be user-friendly.

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10. Bridging the Higher Education Gap: Exploring the Integration of Accessibility and Universal Design in Higher Education Curricula

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Abstract

Curricula shape students' awareness, priorities, and values and act as political documents that reflect societal expectations. Additionally, they reveal what society expects, including the 'hidden curriculum'[10], which refers to unwritten attitudes and expected behaviors.

Accessibility and universal design are crucial for independent living and participation in various aspects of society. Although accessibility and universal design have a proven positive impact on business and society, these principles are often not integrated into core higher education curricula. Currently, only a few elective courses cover these topics. This higher education gap hinders inclusion, innovation, and the realization of the potential of digital inclusion.

The Erasmus+ ATHENA project analyzed the curricula of study programs across different fields of knowledge in four European countries to determine whether and how accessibility and the universal design approach were incorporated.

The findings will be used to advocate for increased inclusion and diversity within higher education. Furthermore, these characteristics will serve as a basis for formulating recommendations to integrate accessibility and universal design principles into higher education curricula.

Introduction

A modern education system requires the integration of accessibility and universal design principles into higher education curricula. Universities must fulfill their role as agents of change by providing students with essential knowledge and skills in these areas. This reflects society's demand for greater inclusion and equality, the demand for accessibility experts on the labor market, and the recognition that accessibility is an economic and commercial advantage. Universities are key contributors to this transformation. By incorporating accessibility and universal design into higher education curricula, universities can effectively teach essential skills and awareness that benefit society as a whole.

The ATHENA project explores whether and how accessibility and universal design principles are already included in higher education curricula.

State of the Art

Accessibility and universal design as teaching content in higher education curricula is rarely addressed and research on the integration of these principles is limited. However, accessibility of studies, accessibility of universities and accessibility of course con-tent are addressed and are gaining importance: There is a growing body of literature on how to facilitate the inclusion of students with disabilities in universities and ensure that they have equal access to education. Fleet[3] highlights the importance of universal design in addressing barriers for disabled students on university campuses. Furthermore, Burgstahler[2] provides a comprehensive guide for creating fully accessible college and university programs, covering physical and technological environments, curriculum and instruction, and student services. These studies collectively emphasize the significance of incorporating accessibility and universal design principles in higher education curricula.

Nevertheless, research in the area of incorporating accessibility and universal de-sign principles into higher education curricula is lacking. What little exists suggests a significant gap in practice, with accessibility and universal design education being infrequently incorporated into higher education. Nishchyk[7], and Kawas[4] highlight the lack of accessibility education in technical specializations, such as computer sci-ence, and the need for faculty professional development in this area. Moreno[6]and She[9] further emphasize the importance of standards and accessible strategies in online learning.

Both Lazar[5] and Velesco et al.[11] focus their research on the skills and knowledge required for accessibility in ICT and have developed curricula based on this, pointing to the need for accessibility experts in industry, as there is a need for accessible products and services, which is also seen as a large market to be developed. Bohmann[1] posits that graduates of ICT programs with accessibility training, will perceive accessibility as an inherent aspect of the design process and professional workflow. When accessibility in the digital realm becomes a standard and integral part of business, digital technology will finally realize its potential to facilitate life, rather than becoming yet another obstacle to it.

However, there is currently no inventory or research on how accessibility and universal design are already being incorporated and taught in higher education across disciplines to ensure that future generations are equipped with knowledge for an inclusive society. The ATHENA project addresses this research gap.

Methodology

In a first step, the fields of higher education in the countries of the participating academic partners Austria, the Czech Republic, Cyprus and Spain were systematically selected using the ISCED classification system[12]. The aim was to identify educationally and socially relevant domains based on criteria such as suitability of study programs and potential economic, political and social impacts. The following do-mains were identified along with sub-domains: 1) Education, 2) Arts and Humanities, 3) Social Sciences, Journalism and Information, 4) Business, Administration and Law, 5) Information and Communication Technologies, 6) Engineering, Manufacturing and Construction, 7) Health and Welfare and 8) Tourism and Services. Each of these main domains contains a number of sub-domains, all of which were assessed for their relevance to accessibility and universal design. This selection of domains and their sub-domains formed the basis for the following tasks.

Using corpus linguistics and keyword searches, 21 curricula in each country were identified that met the criteria despite country-specific challenges. The identified curricula and syllabi were analyzed for accessibility and universal design principles.

A qualitative analysis of the collected curricula was then conducted to identify how the study programs incorporate accessibility and universal design into their curricula and how accessibility and universal design are constructed and conceptualized within the selected domains. This research question is approached through the development of a thematic coding scheme. This scheme encompasses key aspects such as disability construction, the population of reference/beneficiaries, requirements, and the form and type of reference in the curricula (mandatory course, mainstreamed in different courses, elective course, small seminars, etc.).

Findings

The analysis of 84 curricula revealed that different academic disciplines approach the topic of disability in different ways. The following section offers a brief overview of the main patterns observed in the data across countries and domains[1].

- In the domain of Education, the use of assistive technology plays a pivotal role in facilitating the accessibility of learning materials for students with diverse abilities. Inclusive pedagogy, which adapts teaching methods to accommodate different learning styles and needs, is gaining importance. This is evidenced by the growing importance of guidelines and standards for inclusive education.
- In the domain of Arts and Humanities, there is a clear emphasis on sensory accessibility, particularly through features such as audio description and subtitling. This focus is evident in the attempt to make cultural and artistic content more accessible to people with visual and intellectual disabilities.
- In the domain of Social Sciences, journalism, and information, universal design is becoming increasingly relevant in ensuring that information and communication are accessible to a diverse group of individuals, including those with disabilities, the elderly, and those from diverse backgrounds. The use of assistive technologies to enhance the accessibility of information and communication is also emerging as a crucial area of focus.
- The Business, Administration and Law curricula prioritize equality, diversity and social justice. This focus on accessibility has grown in importance with an increasing emphasis on gender and diversity. International standards such as the Convention on the Rights of Persons with Disabilities are referenced in order to emphasize the importance of alignment with global accessibility guidelines.
- Information and Communication Technologies (ICT) curricula are characterized by a strong emphasis on user-centered design, usability, and human-computer interaction. This is done in order to create digital products and services that are inclusive and diversity friendly.
- The domain of Engineering, Manufacturing, and Construction place a strong emphasis on the principles of universal design, particularly in the context of the design of public transport and buildings. Additionally, the importance of digital accessibility and personal autonomy is also evident.
- In the context of Health and Welfare curricula, accessibility appears to focus on the respect of the rights and well-being of people with disabilities, in line with national and international standards.
- Ensuring physical accessibility was observed to be an emphasis in the domain of Tourism and Services.

In summary, the curricula can be categorized into two groups: those with an explicit focus on inclusion and accessibility, such as curricula from teacher training or health assisting engineering, and those that address these issues through selected courses, both compulsory and elective. Those within the domains of Education, Social Sciences, Arts and Humanities, Business, Administration and Law tend to emphasize accessibility in relation to diversity, human rights and social inclusion. In this context, accessibility and universal design are often grouped together with other legal and social requirements such as gender equality, linguistic rights, sustainability, etc. On the other hand, disciplines like Information and Communication Technology; Engineering, Manufacturing and Construction and Health and Welfare focused on technology-enabled inclusion.

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[1] A detailed description of the results can be found in the transnational report "ATHENA . Bringing Accessibility and Design for All into Higher Education" [8].

The study found that curricula generally prioritized social diversity, occasionally addressing specific dimensions like gender and migration, but tended to discuss disability in a broad sense, with a predominant focus on visual, hearing, or motor impairments. Accessibility and universal design were depicted with significant variation across domains and disciplines. While the analysis was limited to curricula containing relevant concepts, it suggested that accessibility and universal design were present in certain university curricula, albeit in limited ways and with diverse interpretations.

Overall accessibility and universal design were portrayed with significant variation across the different domains and disciplines, as evident in the curricula that were analyzed. Given that the curricula that were analyzed only included concepts relevant to accessibility and universal design if they were present in the samples that were selected, it is not possible to make any claims as to how widespread such an emphasis might be across curricula and across countries. It can be argued with relative certainty that accessibility and universal design appear in certain university curricula, but in limited ways and with varying meanings.

Conclusions and Further Work

These findings demonstrate the uneven integration of accessibility in university curricula, revealing variations across academic domains, countries, and institutions. While certain disciplines, such as Education, emphasize inclusive pedagogy and assistive technologies, others, such as Information and Communication Technologies, prioritize digital inclusivity. The findings also indicate that accessibility and considerations for people with disabilities are often implicitly incorporated into curricula, typically under the broader themes of diversity and human rights.

The next step in this project will be to develop tangible recommendations on integrating accessibility and universal design as teaching content into higher education curricula. This will be achieved through multiple focus groups in each participating country with higher education and accessibility experts as well as members of the target groups from various subject areas as well as, based on the results obtained. For five higher education degrees easy-to-adopt sample modules will be developed through co-design sessions with educational leaders. This enables easy replication across higher education institutions.

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Abstract

Blind people or people with low vision (B/LV) rely on acoustic cues when using navigation guides. However, the auditory sensation is imperative for road traffic orientation as well. Since this sensory channel can quickly become overloaded, it is evident that another sensory perception, like the haptic channel, should be considered for navigation commands [6]. Thermal-tactile biofeedback has shown great potential in delivering messages without requiring special attention [1-3, 5], thus reducing cognitive workload. Further research is needed to consider how this target group could perceive thermal information and to what extent it can support B/LV users' navigation [1]. We have developed a prototype where B/LV were provided with warm and cold signals through Peltier elements in the lumbar region based on obstacle detection results from a camera in the head area. The main focus was estimating the absolute perception threshold and a general standard biofeedback configuration, the users' reaction behaviour and acceptance, and comparing the two signal variants. Additionally, we conducted a user experiment with eight B/LV individuals, which showed promising results. [12]

Introduction

White canes do not adequately protect B/LV in the head and back areas, as their detection radius primarily focuses on the front of the body and the ground. Modern technologies offer the potential to expand this "field of vision" or detection radius, yet they encounter challenges in accurately recognising static or dynamic obstacles. Recent advancements aim to enhance user protection by improving the precision of risk predictions. Thermal biofeedback is a novel approach, particularly in the field of B/LV navigation and belongs to tactile sensation. The human body contains more cold than warm receptors [4]. Therefore, cold stimuli are perceived more rapidly than warm stimuli [1, 5, 8]. Leveraging this physiological characteristic, cold perception is utilised to issue stop signals. The face harbours the highest concentration of cold receptors (per cm^2), followed by the chest and kidney areas with a very dense distribution.

In contrast, the stomach area (see blue area in Figure 1) exhibits an average distribution, while the upper and lower extremities have the lowest [4]. Based on these findings and the additional user-body experiment outlined in [12] lead to the focus of this body part for further research. On the one hand, a prototype at the lumbar region employing thermoelectric modules directs users along an optimal evasion path based on obstacle detection using warm directional signals. On the other hand, a cold stimulus is initiated as a stop-warning when obstacles are immediately approaching. Besides providing excellent tactile resolution, a further advantage is the hands-free operation.

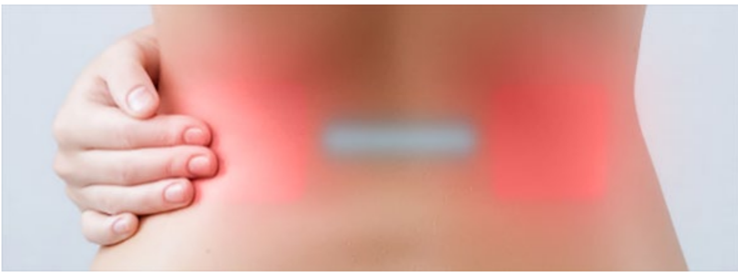

Figure 11-1: Thermal-tactile biofeedback in lumbar region (warm signals for directional instructions and the cold mode for stop commands) https://www.experto.de/praxistipps/rueckenschule-fuer-zu-hause-gesunder-ruecken-gesunde-haltung.html%20 last acc. November 1, 2023 [edited].

Related Work

Haptic feedback offers rapid responses, as it is directly connected to the users [6]. Thermal perception is generally influenced by factors such as body parts and age. In terms of gender-specific differences it is mentionable that women tend to exhibit higher thermal sensitivity compared to men. [1, 13-14] Prior studies demonstrated that participants prefer cold stimuli due to their ease of recognition and pleasantness [1]. Particularly, thermal-tactile feedback outperforms vibrotactile feedback when applied to a white-cane grip or wristband, leading to higher accuracy [5, 1] and shorter stimulus detection times [5]. Research has also indicated that thermal information can reliably indicate a direction, further supporting its utility [1, 5, 7]. In simulated driving tasks, utilising thermal navigation feedback on a steering wheel has demonstrated superior performance compared to cutaneous push and audio feedback methods [2].

In contrast to acoustic or vibrotactile feedback, utilising thermal information offers numerous advantages such as robustness, privacy [9, 6], strong emotional associations [10-11], suitability for noise-sensitive environments [6, 3], and reduced perception limitations in natural turbulence [1]. Previous studies have shown user preference for compression haptic devices over vibration for communicating touch [20]. Building on these findings, there has been a push for further exploration into providing haptic feedback using pneumatically actuated inflatable airbags capable of delivering pressure and thermal cues to one or multiple body parts [19]. Although results from studies utilising this technology [18-19] have demonstrated promising potential for enriching interaction experiences, several limitations remain, including constraints related to thermal sensation range, weight considerations, and reliability. Moreover, additional user studies are needed to explore warm and cool thresholds as well as just noticeable differences (JND) [18].

Prototype

In the field of obstacle detection, no distinction was made between dangerous and harmless objects. To serve as a "third eye," a Pixy2 CMU (2.1) camera, PixyMon2 object recognition software [15], and an Arduino UNO microcontroller were used. Only 3 balloons served as hazards and were detected along the route. The environmental data collected was then transmitted to a Raspberry Pi 4 (model B 4GB RAM) for further processing. Two L298N motor drivers with a 9V power supply operated the thermal control of piezoelectric actuators. On/Off pushbuttons were used to record the duration of perception during the threshold estimation stage of Trial 0. Additionally, two flexible components [16] (depicted as grey actors in Figure 2) made of silicon and cloth covering were utilised for side navigation. In contrast, a ceramic rod component [17] was employed to transmit stop commands. Due to various material properties, different adaptation times to skin temperature were observed. Notably, the ceramic module exhibited a faster adaptation coefficient than the silicon element, impacting users' perception, especially during rapid sequences of repeated stimuli. To ensure comparability of users' absolute perception thresholds, it was crucial to consider both the current skin and actor temperatures concerning stimulus duration, as well as the defined stimulus breaks in between. For threshold estimations, temperature curves were measured using five sensors connected to a separate Arduino UNO. The first three sensors refer to Peltier elements (for left, stop, and right commands), while the remaining sensors were used to monitor actual skin and room temperatures (refer to Chart 1) [12].

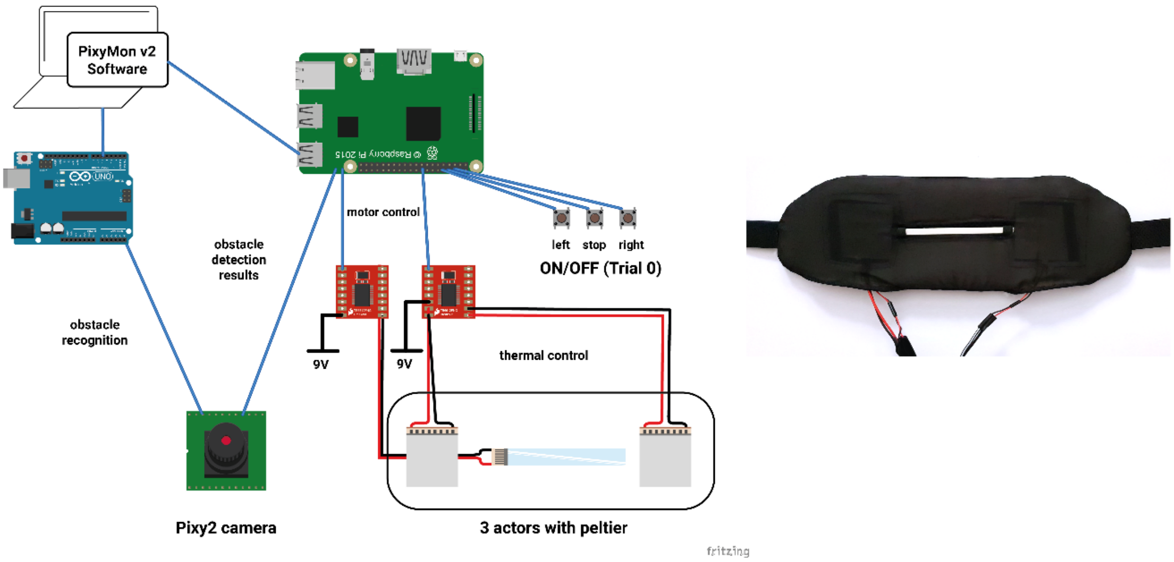

Figure 11-2: Prototype components: Pixy2 CMU (2.1) camera, PixyMon2 software, Arduino UNO, Raspberry Pi 4, L298N motor drivers with 9V power supplies, Pushbuttons, TEC-1-04008 Thermoelectric Cooling Module (light blue) and DK-TEM ES-02 Module (grey) [by fritzing.09.3b] [edited].

Methods and Analysis

The user experiment is divided into three sections: Trial 0 for threshold estimation and Trial 1 and 2 for the anti-collision walking experiment. Additionally, two interviews were conducted at the beginning and end of the experiment to gather users' demographic information, current mood, and subjective assessments.

Trial 0 – Threshold estimation

During Trial 0, users were introduced to thermal-tactile biofeedback to familiarise them with the system. The users' absolute perception threshold was then estimated using the method of limits. Ten discrete stimuli were presented for each command (left, right, and stop), with a minimum 2-second break between each stimulus. The duration of perception for each stimulus was measured using a pushbutton. Due to time and organisational constraints, participants completed all three trials sequentially in one experiment, and the final standard configuration based on the established average value was evaluated later and not considered for Trials 1 and 2. As a result, a fictive configuration was tested, with a scheduled perception time of 2.74 seconds for stop commands and 3.10 seconds for direction signals [12].

Trial 1 and 2 – Anti-collision walking experiment

An anti-collision walking experiment was conducted during Trials 1 and 2. Each user began from the same starting position, and camera calibration was performed for accurate detection, along with adjustments to the obstacle height to match each user's forehead height. The main difference between Trials 1 and 2 lay in the method of information transmission, serving as the primary basis for comparison. In Trial 1, signal transmission occurred upon detection of every recognised object, whereas in Trial 2, the signal was repeated once with a 1.5-second break upon detection. Evaluation of users' reaction behaviour and collision incidents relied solely on observational data. Subsequently, users' mental load was assessed using the NASA RTLX scale for Trials 1 and 2 [12].

Figure 11-3: Anti-collision experiment with three balloon obstacles. The participant wears the prototype consisting of a camera cap and textile belt with three integrated Peltier modules to provide left, stop, and right commands. [12] p 171

Participants

Eight B/LV participants (7 male and 1 female) aged between 36 and 70 years (mean = 44.38, SD = 12.40) were recruited for the study. One participant had prior involvement in the user-centric development process of a previous prototype and had tested a similar thermo-tactile device on various hand positions in an earlier stage. Among the participants, three out of eight were congenitally blind, while half of them could perceive movements and lights, with the remaining being entirely blind. [12]

	AMOUNT OF PARTICIPANTS			
BODY SIZE	(3) 160-170 cm	(4) 171-180 cm	(1) >180 cm	
BODY WEIGHT	(7) <100 kg	(1) =>100 kg		
MEDICATION & HEALTH	(0) diabetes	(1) high blood pressure	(2) blood thinning medication regularly	(2) smokers
SPORT ACTIVITY	(1) not athletic	(4) several times a week	(3) once a week	
SUBJECTIVE TENDENCY	(7) not tend to get cold	(1) tend to get cold		
	(3) freezing quickly in cold rooms	(5) not freezing quickly in cold rooms		
	(2) tends to sweaty hands	(6) not tend to sweaty hands		
	(5) favoring thick gloves in winter	(1) favoring thin gloves in winter	(1) not wear any gloves	(1) not have a favorite
CURRENT MOOD	(1) fantastic	(1) moderately good	(6) good	
NAVIGATION TOOLS	(3) mobile phone (google maps)	(1) blind square app	(1) apple watch	

Figure 11-4: Evaluated participants' data. [12] pp 67-72

Preliminary Results

Trial 0 – Threshold Estimation Results

The standardised configuration necessary for reliable perception involves a duration of 3.39 seconds for stop commands (ΔThaut/Peltier -0.50°C) and 3.86 seconds for directional signals (ΔThaut/Peltier +1.04°C). However, not all ten discrete stimuli could be allocated for calculating stop warnings due to technical issues encountered in six cases, one of which was attributed to perceptual factors. Due to a technical malfunction in the right thermal module, the results of three participants on directional instructions relied solely on the left Peltier element. The directional cues exhibited smoother fading within stimulus sequences concerning their stimulus quality. During testing, two participants reported perceptual irritations, claiming they perceived thermal stimuli even when the prototype was offline. The cooling process of a stop command is depicted by the blue line in data visualisation (Chart 1), while the light blue bars represent the duration of users' perceptions when they recognised the applied cold stimulus. This report also highlights the necessary temperature difference in relation to the initial temperature. Furthermore, additional temperature values from other sensors, such as room and skin temperature, are presented for inactive directional Peltier elements. [12]

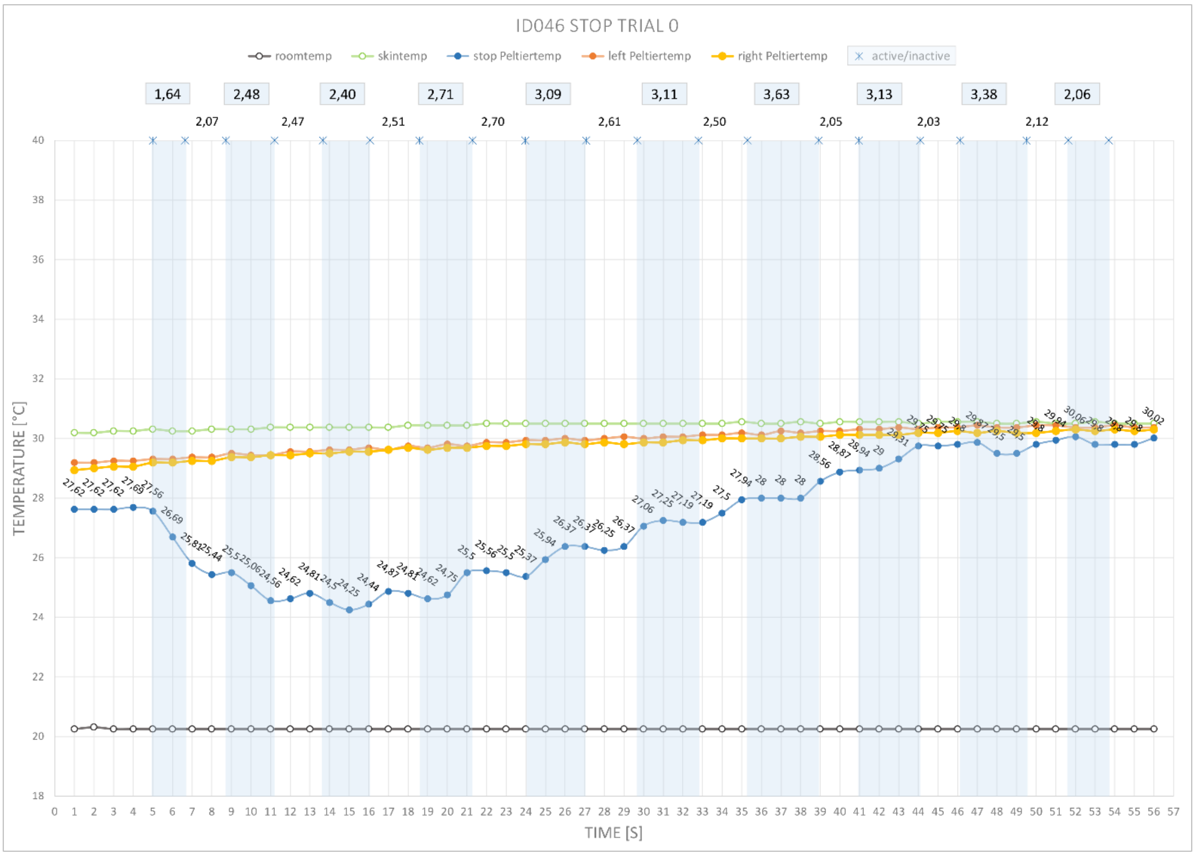

Figure 11-5 Chart I: Visualisation of the recorded cooling process of an active stop command by participant ID046 (blue line). Light blue bars demonstrate the user´s perception duration and required difference in relation to the outgoing temperature. [12] p 75

Trials 1 and 2 – Anti-collision Walking Experiment Results

In comparing congenitally blind participants with those who lost their sight over time, no discernible differences were observed in reaction and perception behaviour. However, due to the inability of most participants to distinguish between signal variants in Trials 1 and 2, no meaningful comparison could be made between the two trials. Among the three users who could differentiate between signal variants in Trial 2, one preferred Signal 1 for its calming effect, while others favoured the more frequent signal repetition within a 1.5-second break, perceiving it as providing a higher sense of security. As already mentioned, the NASA RTLX evaluation was conducted exclusively for Trial 1 due to the circumstances. Chart 2 visualises the final NASA RTLX index evaluation, indicating an overall good result attributed to low ratings across mental demand (38.13%), physical demand (35.63%), temporal demand (18.75%), effort (45.00%), performance (18.75%), and frustration level (33.75%). Further examination revealed that despite variations in reaction times during threshold estimations (Trial 0) and regardless of the transmission method, all participants were able to stop in front of obstacles in time, solely relying on thermal perception reactions. This finding suggests that the fictitious configuration was suitable for reliable stopping, as the main causes of collision synchronisation issues were identified as camera tracking, gait speed, and thermal-tactile biofeedback. Closer observation of user behaviour also highlighted the significant impact of walking speed, body alignment, and bending movements on information transfer. Additionally, upon removal of the prototype, slight skin redness was observed in one participant. [12]

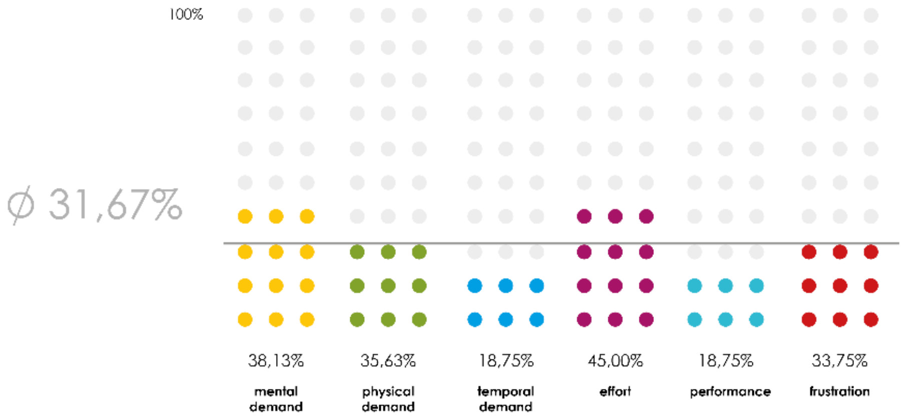

Figure 11-6: Chart 2: Final evaluation of NASA RTLX index based on Trial 1 user assessments. An overall average good result was achieved due to low ratings. [12] p 84

User Feedback

Overall, the prototype did not reach a high level of acceptance. For example, two individuals reported sweating in combination with body movements, while two participants criticised the assessment period as being too short. One participant suggested reconsidering the approach, pointing out that existing navigation aids typically use signals to indicate sources of danger rather than displaying alternative routes. Additionally, two participants suggested a faster stimulus fading, as there is a risk of perceiving two sequential signals as one due to residual temperature. The direct skin contact with the rod cooling module was rated as unpleasant by 4 participants, and two users expressed a desire for further customisation options to adapt to different seasons. One participant expressed concern about potential distraction, while another was unimpressed, noting that the application did not protect against all sources of danger, particularly downward gradients. Detailed comments on thermal-tactile biofeedback from participants are highlighted in Figure 7 [12].

COMMENTS OF PARTICIPANTS
I like the way of transmitted information. But I have doubts as if it is reliable in everyday life.
I like it because the signal is not noticeable to others. Due to the direct body reception, it is very easy to feel. I am positively surprised how well the temperature information is perceptible.
I really enjoyed the temperature navigation.
Testing the prototype was very interesting.
It was a really exciting experience to be navigated with temperature information.
Being navigated with the assistance of temperature is totally exciting.
I am surprised how quickly temperature information can be realised.
I associate the stop signal with a cool towel - I am pleasantly surprised.

Figure 11-7: Listed thermal tactile comments of participants. [12] pp 80-81

Discussion & Conclusion

This paper introduces an orientation system prototype for individuals who are blind or have low vision (B/LV) by utilising thermal-tactile biofeedback as an input channel for information. To accommodate individual user perception thresholds, a final standard configuration was derived from threshold estimation (Trial 0). This configuration, determined to ensure reliable perception, requires 3.39 seconds for stop commands (ΔThaut/Peltier -0.50°C) and 3.86 seconds for directional signals

(ΔThaut/Peltier +1.04°C). In the anti-collision walking experiment, a temporary fictitious configuration proved suitable for this small target group. The overall evaluation of the NASA RTLX index, based on Trial 1 signals, yielded an average good result, attributed to low ratings across various dimensions. Upon examining users' perception reactions, it was found that the stop signal elicited a timely and reliable response. All participants were positively surprised by thermal-tactile biofeedback. However, certain limitations were identified, such as real-time synchronisation issues with camera tracking, gait speed, and thermal-tactile biofeedback, which emerged as the primary causes of collisions. Technical defects in motor drives also highlighted concerns about the robustness and performance of thermal modules, which is another research issue. The intended comparison of two signal variants demonstrated a too minor recognisable difference. In the future, a medical study is required to determine the limitations to which the skin can tolerate temperature information and whether there is a risk of impairment for long-term uses. The realisation that directional cues offer better fading within stimulus sequences underscores the potential benefits of standardised use of silicone Peltier modules. These flexible thermal modules demonstrate a more suitable adaptation coefficient for this application, potentially leading to a larger information area for stop indications. Overall, the prototype shows promise in protecting the head area from hazards such as hanging boxes, chest-height traffic signs, and forest branches. However, none of the participants could envision the current prototype being used in pedestrian zones or everyday traffic. Moving forward, a wireless solution and outdoor experiments are deemed necessary for further development and practical application [12].

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12. Development of An Assistive Tool for Screen Reader Users Who Utilize Icons Without Alternative Text

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Abstract

This study explores the challenges faced by visually impaired individuals using screen readers in the workplace and proposes the development of an assistive tool to address these challenges. Interviews with five screen reader using workers revealed the need for operating icons without alternative text and the lack of measures users can currently take to address this challenge. Thus, we have created a development plan for an assistive tool that enables screen reader users to operate icons without alternative text through image recognition and AI. In the future, we plan to develop a prototype, conduct additional interviews with five more screen reader users and evaluate the prototype with all 10 respondents.

Introduction

The development and widespread adoption of Information and Communication Technology (ICT) have the potential to further promote the social inclusion of people with various disabilities, including those with visual impairments, wheelchair users, and individuals with developmental disabilities [1]. For example, digital data can be converted into accessible formats for individuals [1], and online classes or remote work can reduce the burden on those facing mobility challenges [2]. Enabling people to acquire information and express themselves without relying on others is crucial for the protection of basic human rights, dignity, and the formation of identity as equal members of society.

However, the prioritization of designs that are easily understandable and operable for people without disability, coupled with a lack of consideration for accessibility, can result in the latest ICT becoming a social barrier for individuals with disabilities [1]. For instance, the visual design of apps or websites and specifications based on mouse interactions make access difficult for people with severe visual impairments. Although there are cases where accessibility improvements have been made or updates of screen readers (assistive technology for blind and low vision people that converts text on screen into speech) and keyboard operations have become available after a certain period, simultaneous access to the benefits of new technology as sighted people is often limited.

Based on these social circumstances, we conducted research to determine the challenges and needs of screen reader users during their office work, with the aim of proposing information access assistive tools as potential solutions.

In this paper, we had questionnaire and interview surveys with five screen reader using workers. The potential needs they have and causes of challenges they faced were determined by extracting key words and phrases from the responses and classifying them into primary issues and secondary issues. We narrowed down to one need that was considered to be the most necessary and urgent, and devised a development plan for tools to address it.

Previous Research

In recent years, surveys conducted by employment support organizations in Japan have revealed various challenges and needs regarding the use of ICT by blind and low vision people in work environments.

In a study titled "Research on Various Challenges for Improving Occupational Access for Visually Impaired Individuals" (2018), when asked what kind of equipment development was necessary to broaden the scope of tasks, 63.1% of the 122 respondents answered that improving screen reader functionality was essential [3].

In the results of the "Survey on ICT Support Situation in the Employment Environment of Visually Impaired Individuals" (2023), respondents were asked whom they sought assistance from when visual support devices like screen readers could not be used in the workplace and whether the issue was resolved [4].

Among 95 respondents who had never received assistance, only 15.8% reported, while the rest had sought assistance from supervisors, colleagues, IT departments, job coaches, or screen reader manufacturers. The outcomes of seeking assistance were as follows: successfully resolved: 23.5%; partially resolved or unresolved: 70.4%; unresolved: 3.7%, Other: 2.5%.

As for tools that could not be resolved with assistance, various work systems, OA software, Windows, communication tools, and remote workplace environments were mentioned. These tools are essential regardless of job duties or positions. Despite colleagues and technical experts being familiar with the operations, there were still challenges that cannot be resolved, highlighting a significant issue.

Similarly, several surveys conducted by researchers and developers of assistive technologies (ATs) have also highlighted challenges faced by screen reader users.

In the paper titled "The challenges in adopting assistive technologies in the workplace for people with visual impairments," interviews were conducted with five blind and low vision participants, each with over 20 years of work experience [5]. The participants discussed the considerable independent learning required regarding accessibility, compatibility, staying updated with the latest information, and troubleshooting to utilize AT effectively in the workplace. Among the accessibility issues reported by participants, the most common revolved around screen readers being unable to interpret images, diagrams, and graphs. This included specific formats and styles such as text boxes, flowcharts, and editing fields in Word, as well as the inability to read PDF files. Regarding web accessibility issues, concerns were raised about page layouts, unlabeled buttons, mouse-over actions, and pop-ups.

In the study titled "Rich Screen Reader Experiences for Accessible Data Visualization," the authors proposed design prototypes that enable interactive reading, a benefit of data visualization, accessible to screen reader users, and evaluated them with 13 screen reader users [6]. Among the future challenges that were highlighted, two were notable: the need for appropriate non-visual alternatives provided by visualization authors; and the complexity of operations required by screen readers to achieve the interactive engagement sighted people execute with data visualization through visual filtering.

Methods

The questionnaire surveys and interview surveys were conducted with five screen reader users who have work experience. To develop a more useful assistive tool for blind and low vision screen readers, respondents were recruited through snowball sampling methods. They met the following criteria: they were screen reader users, manipulated computers without seeing, conducted work tasks on a computer and had not received any special training on computer or screen readers.

The questionnaire asked for the respondents for their basic information and job description. It also asked them to list the support devices they used, experiences of difficulties caused by not being able to read or operate, and how those situations were handled.

The 30-minute interviews were conducted via Zoom using semi-structured interview methods. Based on the responses to the questionnaire, interviewees were asked specific questions about the systems and software they utilized at the workplaces and experiences of difficulty reading or operating them to speculate on the causes.

We transcribed the interview responses, extracted key words and phrases, and divided them into primary issues faced during work and secondary issues resulting from those primary issues. Subsequently, the causes of the primary issues were categorized into the following three groups: 1. Technical issues with the screen readers, 2. Technical issues with character/image recognition, and 3. issues due to lack of accessibility awareness. Those that were difficult to categorize due to reasons such as not being able to assume the exact cause were classified as "other."

To see the tendency of needs, each primary issue underwent both quantitative analysis, such as measuring the total number of mentions, and measuring the number of associated secondary issues, as well as qualitative analysis to identify related comments, including secondary issues.

Results

Demographic Information

The breakdown of the five respondents is as follows; Age: 3 in their 20s, 2 in their 30s; gender: 4 females, 1 male; classification of physical disability certificate: 4 with Level 1 (indicating blindness), 1 no response; text usage: 4 using braille, 1 using enlarged text, and all 5 using standard text via screen readers; industries: 1 public servant, 1 systems engineer, 1 administrative clerk, 1 salesperson, and 1 teacher.

The primary issues were classified into the three cause groups as follows. The number in parentheses indicates the number of respondents that mentioned the issue.

- Technical issues with screen readers: Irregular tables (3) and compatibility between screen readers and systems or browsers (1)
- Technical issues with image/character recognition technology: Illustrations/diagrams (2), stickers/reactions (2), image menus (2) and icons without alternative text (3)
- Issues due to lack of accessibility awareness: PDFs (4), visual layout (3), map displays (1), calendar displays (3), mouse operations (3), digital textbooks (1) and niche systems (1)
- Other: Furigana (1), Reading order of vertical writing (1), image verification (1) and Filling in MS word borders (3)

Irregular Tables (3). Irregular tables are tables with irregular structures, such as tables in which some cells being merged or the numbers of cells per row varies. In Japan, this structure is often observed not only in tables but also in input fields of documents created in MS Word. The reason irregular tables become a primary issue is that moving between rows and columns is not always straightforward, making it difficult to reach the desired cell, and thereby complicating the understanding of the overall structure and content.

Compatibility Between Screen Readers and Systems or Browsers (1). The compatibility between the web-based human resources management system used at this respondent's workplace and screen readers is poor. As a result, she cannot input data by herself. As secondary issues, the respondent experiences a psychological burden of having to ask colleagues to input data for her, as well as the psychological burden of knowing that her colleagues know her personal information. She is hesitant to try operating it by herself because if she failed operating, it might possibly cause inconvenience to the entire workplace. Currently, as a coping approach, she creates application forms in Excel and submits them to her immediate supervisor. It decreases the psychological burden of disturbing colleagues' work and information disclosure can be limited to a specific individual.

PDFs (4). The primary issues are that PDFs are unreadable or incomprehensible for screen reader users. Many documents, such as materials created and distributed for meetings, legal documents, various research findings published by the government, and teaching materials for teachers, are in PDF format. PDF files can contain both textual information and images. Some PDFs consist solely of text, while others, such as scanned documents, may contain images of text. Some PDFs consist solely of textual information, allowing you to select and copy text, as well as search within the document. On the other hand, other PDFs exist solely as images, similar to scanned documents, and you cannot select and copy text from them. In these cases, OCR is needed to extract the text from the images. However, there are cases where even, after OCR, the text remains garbled and unreadable, where the distinction between images and text cannot be made resulting in garbled text, or where the layout is distorted and read in an incomprehensible order.

As secondary issues, there were concerns such as the overwhelming majority of materials being in PDF format, making it impractical to have them all read by someone else; being unable to deepen one's own knowledge of the job as desired; and being unable to create tasks by extracting teaching materials tailored to the level of the students as other teachers do. Both respondents expressed strong desire to access and select on their own in order to improve the quality of their work and expand its scope.

Illustrations and diagrams (2). Visualized expressions such as 4-panel comic format, images of tables, and graphs are often used because they can convey complex information or a large amount of data in a short time to readers. However, for screen reader users, they are often completely incomprehensible because screen readers can only read the text included in the data or they read them as "image." One respondent mentioned that when circulars in the workplace are presented in the form of 4-panel comics or when meeting materials contain many inserted diagrams and charts, she generally does not attempt to read them.

Stickers/reactions (2). As primary issues, stickers cannot be read by screen readers. On iPhones, in particular it is challenging to determine who sent the reaction in a group chat. As secondary issue, there were opinions expressing anxiety and feelings of exclusion because the respondents could not participate in conversations, particularly greetings outside of work or invitations to colleagues' gatherings, which were conducted solely through stickers. Some respondents mentioned that they use stickers in their private conversations, especially those that contain large text in speech bubbles or in still image stickers, or speaking stickers, as they can understand the content. However, those stickers are often paid for, and some mentioned feeling uncomfortable asking colleagues to use them for their sake.

Image menus (2). They are found at the top/side of various websites. If there is no alternative text representing the features, it is inaccessible to screen reader users, which is particularly common on individually operated websites. As the secondary issue, screen reader users have no choice but to give up using the website. An enlarge user mentioned that she cannot distinguish menus and buttons from advertisements, and it makes her hesitate to use the website.

Icons without alternative text (3). The primary issues raised included only being read as an "image", making it difficult to understand the function of the icon, and sometimes encountering shapes whose function is difficult to guess. A respondent reported that more cases are observed in apps and software than on websites, where previously the functions of icons were read aloud, but after software updates, there are cases where they are no longer read aloud. As secondary issues, they could not grasp the function of the entire software, which would have allowed them to operate it themselves. As a solution, users search for a list of shortcuts for the software, identify the functions the software has from that list, and operate it by using shortcuts. However, if there are no corresponding shortcut keys provided for the icons, they have no choice but to not use the software.

Visual Layouts (3). Textbooks, package design proposals, and other materials that mix pictures and text or heavily use designed fonts are difficult for OCR to accurately recognize and read.

Map displays. In the respondent's workplace, the travel expense application system requires selecting the area, public transportation used, and facilities at the destination on a map. As a measure, she creates an Excel application form or ask a colleague to input on her behalf.

Calendar Displays (3). Human resource management systems and scheduling tools often feature screens that allow users to select dates and times from within a calendar. As the first primary issue, even though they can navigate to the desired slot using the tab key, it cannot be selected with the space bar or the enter key. The second primary issue is that to confirm which slot other colleagues have selected, they need to check each slot sequentially, which is visually easy on the screen but time-consuming for screen reader users. Additionally, some tools fail to accurately read symbols such as circles or triangles chosen by the selectors to indicate priority for the slots. As a secondary issue, some respondents mentioned that while remote work is generally practiced, there are occasions when they need to come to the office to handle calendar input tasks such as vacation requests. As another secondary issue, it is cumbersome to grasp the desired dates and times for all participants, leading to the inconvenience of having to delegate meeting scheduling tasks to other colleagues.

Mouse Operations (3). Most websites and applications are designed with the assumption of mouse operation, and many sighted people primarily navigate computers through mouse operations. On the other hand, screen reader users operate computers using keyboards, making extensive use of shortcut keys and accelerator keys. Thus, when learning how to navigate the same websites or tools as sighted colleagues, or when asking for guidance on how to operate them over the phone during remote work, the following issues can arise: not knowing keyboard shortcuts corresponding to mouse operations, unintentionally expanding mouse hover menus while exploring the websites, and an inability to control the expansion or collapse of mouse hover menus, resulting in their inability to comprehend items within the hover menus. As a secondary issues, first, it takes time to understand and operate the necessary sites and tools for work. Second, even when operating the same tools remotely, conversations may not synchronize. Third, screen reader users can be misunderstood by sighted colleagues as having low computer literacy just because they cannot perform operations for mouse users.

The respondents cope with those issues as follows. They search for a list of shortcut keys for the tool and divide tasks so that they can be responsible for the part that can be done with keyboard operations. One respondent mentioned that he could perform his tasks using alternative methods. For example, since bulletin boards for writing departmental announcements are difficult to use with a screen reader, he uses email or chat tools.

Digital Textbooks (1). A respondent working as a teacher at a school for the blind stated that she believes that selecting and incorporating digital textbooks with the highest compatibility with screen readers would be effective, but without purchasing them, it is not possible to compare digital textbooks and screen readers. She suggested that a mechanism should be developed that ensures the availability and accessibility of digital textbooks that are reliably usable with screen readers, including measures for visual layouts, or confirms usability and accessibility in students' computer environments before a purchase is made.

Niche Systems (1). With regard to user systems such as groupware, human resources management systems, etc., when issues arise with screen reader reading or operation, they can be difficult to resolve. This is because external specialists such as job coaches cannot access the tools, making it challenging to provide appropriate support. Additionally, as only a limited number of users utilize them, progress in accessibility improvements is also slow.

Furigana (1). Furigana is the Japanese term for small kana characters, usually hiragana or katakana, placed above or alongside kanji characters to indicate their pronunciation. It is commonly found in texts with specialized or academic content intended for readers, including children, such as on museum websites. In text with furigana, screen readers read both the kanji and the furigana, causing the same word to be repeated suddenly, which can be confusing. The respondent mentioned wanting the screen reader to skip the kanji and only read the furigana in parts where furigana is provided.

Reading Order of Vertical Writing (1). Vertical writing refers to the style of writing where the text runs vertically from top to bottom, usually from right to left, as seen in traditional Japanese and Chinese texts. However, according to the respondent, vertically-written e-books on Kindle are not read in the correct order.

Image Verification (1). If authentication via images is not possible, the only alternative method is to listen to English words. Respondents argued that alternative methods not dependent on the user's language proficiency are necessary.

Filling in MS Word Borders (3). In Japanese documents, it is common to indicate fill-in fields by enclosing them with borders in MS Word. However, borders can be difficult to discern on screen readers, and the visual effects or intentions of the borders may be unclear to screen reader users. As a result, the respondents may inadvertently disrupt the formatting while filling in the document in MS Word. Rather than overexerting themselves, they prefer to request input assistance from the beginning, such as creating the current form as text data, to minimize the recipient's effort. However, everyone still agreed that being able to fill it out themselves is the most desirable option.

Discussion

In conclusion, support for operating icons without alternative text would be the most crucial and urgent need owing to the large number of related comments including secondary issues associated with it and because there are no measures that users can take on their own. Furthermore, although this study could not offer a solution to this problem, it strongly demonstrated that there was a need to raise awareness of accessibility.

In order of highest number of classified issues, the three cause groups were issues due to lack of accessibility of awareness, technical issues with character/image recognition, and technical issues with screen readers. Among the issues, the number of secondary issues was highest for (number of secondary issues in parentheses): icons without alternative text (8), stickers/reactions (8), mouse operations (7) and PDFs (6).

The three issues (icons without alternative text, mouse operations and PDFs) raised by multiple respondents are considered important and urgent issues for screen reader users. They have aspects that could be resolved by improving the accessibility awareness of providers of apps, websites and PDF documents. Regarding icons without alternative text, it can be said that the issues arise owing to the lack of alternative text provided by the app or website provider; this is also true for mouse operations where the provider should provide keyboard shortcuts, and for PDFs, where the document creator could use Adobe Acrobat's accessibility features [7], add explanations for data visualizations themselves, or provide documents in a format before PDF conversion.

With regard to mouse operations and PDFs, some technical solutions are available, although they depend on users' knowledge and awareness, and there is still room for improvement and usability issues. For example, the JAWS screen reader has a feature called the JAWS cursor that can be used to operate a mouse cursor and a feature that can be used to recognize text from PDFs, although their accuracies are not sufficiently high. Additionally, for PDF creators, the Adobe Acrobat's accessibility features mentioned earlier can be used. However, regarding icons without alternative text, there are no user-side measures that can be taken at all.

Development Plan

We recommend the following approach to application development to ameliorate the main issue identified in this study.

With regard to specifications, the application should be developed for Windows, considering that the application is intended for use during office work and that Windows holds a 70.78% market share in Japan (as of February 2024)[8]. It is logical to initially target Windows computers, which are presumed to have a large user base. Additionally, all five respondents use Windows computers for their work.

With regard to its operation, when a user encounters an icon without alternate text, they can navigate to the icon using the Tab key, press a specific shortcut key to infer the function of the icon, and display the inference result as text. Upon pressing the shortcut key, the image of the icon is captured and subjected to image recognition. Based on the captured image, AI infers the function of the icon using learned data of visual features and functions of icons.

Although this method cannot accommodate icons that cannot be focused on using the Tab key, it will be considered as the next step. For now, the focus will be on icons that can be focused on using the Tab key. The application will be developed using Win32API on Python.

Future Works

In the future, we plan to focus on the following three areas. First, we intend to develop a prototype of the assistive tool to operate icons without alternative text. Second, we plan to conduct additional interviews with five more screen reader users and use the insight gleaned from these interviews in development of the prototype. Presently, as the number of respondents is biased towards females and those in their twenties, we will need to recruit more males and respondents aged thirty and above. Third, to evaluate the prototype with all respondents and expand functionality, we would ask the participants to utilize some icons without alternative text selected beforehand for the test through the assistive tools. If possible, they could try the icons that they actually could not operate with a screen reader. Based on their feedback, usability improvements and functionality expansions such as making icons operable even if they cannot be focused by the Tab key, and ensuring compatibility with operating systems other than Windows would be performed.

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13. Digital Twin Development for Extraocular Muscle Prosthesis Surgeries and Assistive Technologies: A Systematic Literature Review

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Abstract

This paper shows a systematic literature review (SLR) of various information and communication technologies (ICT) that assist in extraocular muscles (EOM) prosthesis implant surgeries. EOM prosthesis is a type of assistive technology which needs minimal invasive surgery to implant. There are different methodologies to do a systematic literature review. We have used Kitchenham's methodology to do a systematic literature review. This SLR is started from the various research questions, followed by definitions, keywords, database selection, developing query for research, specification of exclusion and inclusion criteria, search process, data extraction with exclusion and inclusion criteria, and data analysis and results of the research questions. People who have extraocular muscle difficulties or who are missing extraocular muscle due to trauma, a condition at birth, or disease. They need a prosthesis implant as eye muscle. The goal of this research work is to find the various ICT technologies like medical imaging, algorithms for personalize 3D geometrical modeling, and biomedical simulators to diagnose and assistive technology solutions to EOM problems and assist surgeries of EOMs such as EOM prosthesis implant surgeries. There are only 46 publications fulfill the criteria for inclusion. Additionally, the goal is to find different constraints, drawbacks, and open areas that will allow a new model to be proposed. This SLR is the first in the development of doctorate research in which the digital twin of eyes for EOM surgeries and assistive technology is proposed.

Keywords: Systematic Literature Review · Prosthesis · Assistive Technology · Personalize 3D Geometrical Modeling · Biomedical Simulators · Digital Twin

Introduction

Extraocular Muscles [1] help in the movement and alignment of eyes. Any problem in EOM can lead to different visual problems including double vision, visual confusion, monocular vision, eyestrain, headaches, and abnormal head posture. Strabismus and nystagmus are major problems that are related to problems in EOMs. We can differentiate assistive technologies into two types: Invasive-assistive technologies which required minimum invasive surgery like cochlear implant and non-invasive assistive technology which don't require any surgery like screen readers. EOM prosthesis can be consider as invasive assistive technology. EOM prosthesis implant needs high accuracy to achieve significant improvement. We believe that development of a digital twin for extraocular muscle prosthesis surgeries and assistive technologies can significantly enhance the precision and predictability of these procedures by providing a patient-specific, real-time model. This technology not only serves as an effective training tool, allowing surgeons to practice before actual surgery, but also facilitates research by providing a platform for testing new surgical techniques and prosthesis designs [49, 50]. Furthermore, it aids in patient communication and allows for continuous post-surgery monitoring [49,50]. While existing biomedical simulator [32-39], and medical imaging technologies [1-16] provide valuable tools for extraocular muscle surgeries, we believe that the addition of a digital twin can offer further advancements in precision, predictability, training, research, patient communication, and long-term care. It represents a significant step forward in the integration of digital technology in the field of ophthalmic surgery.

Systematic Literature Review with Kitchenham's Methodology

We have used Kitchenham's methodology [47] to do a systematic literature review. We have selected this methodology because it contains all the necessary components for conducting a search for information on the chosen topic.

Table 13-1: Systematic Literature Review with Kitchenham's methodology

	Aspect	Description
1	Research Questions	1. What imaging modalities and data sources are essential for constructing Digital Twins tailored for Strabismus Surgeries? 2. What medical image databases exist for addressing EOM issues, particularly in the context of Strabismus? 3. What are the current diagnostic image processing and neural network algorithms available for detecting Strabismus? 4. What components constitute the 3D geometrical models utilized in EOM simulators? 5. How can the eye be quantified using medical imaging? 6. What frameworks and algorithms are available for converting medical imaging into three-dimensional geometrical models, facilitating diagnosis and simulation? 7. What mathematical models are employed in EOM simulations to enhance understanding and training?
2	Keywords	Prosthesis, Diagnose, Medical Imaging, Eye Medical Image Dataset, Algorithm, medical image to 3D geometrical Model, NURBS, B-Spline, Quantification of Muscles, Biomedical Simulators, Assistive Technology, Rehabilitation technology, EOM (Extra Ocular Muscles), Strabismus and Nystagmus.
3	Databases	6 recognized databases (ACM, Google Scholar, IEEE Xplore, SCOPUS, Science Direct, Web of Science) selected for their relevance.
4	Develop Query for Search	Original lengthy query modified into 7 smaller queries for effective database search considering limitations of certain platforms. 1. ("Biomedical Simulation" OR "Extraocular Muscle" OR "Strabismus" OR "Nystagmus OR "Prosthesis") 2. ("Image" AND "Diagnose" AND "Extraocular Muscle") 3. ("Image" AND "Quantification of muscle" AND "Extraocular Muscles") 4. ("Biomedical Simulation" AND "Extraocular Muscle") 5. ("Medical Imaging" AND "3D Geometrical Model ") 6. ("Assistive Technology" AND "Extraocular Muscles" OR "Strabismus" OR "Nystagmus") 7. ("Digital Twin" AND "Medical Image")
5	Exclusion & Inclusion Criteria	Defined criteria for including and excluding papers based on relevance, written in English language, availability, and duplication. Evaluation conducted through title, abstract, and detailed reading stages. We have included papers from 1975 – 2024.
6	Search Process	We have used Mendeley research paper management platform and spreadsheet to organize the research papers.
7	Data Extraction	There are only 46 publications fulfill the criteria for inclusion out of 4265 papers.

Data Analysis and Results

RQ 1: What sorts of imaging and data can be helpful to build Digital Twin with a focus on Strabismus Surgeries?

Analysis: To construct a Digital Twin for Strabismus Surgeries, a diverse range of imaging modalities and data sources prove instrumental: We found that Magnetic Resonance Imaging (MRI)[1]: It helps to find soft tissues, extra ocular muscles, and diagnose different types of strabismus, Computed Tomography (CT)[2]: It helps to find the Orbital Traumatology and Orbital Fractures, X-Ray[2]: X-ray helps to find the Orbital Fractures, Anterior Segment Optical Coherence Tomography (AS-OCT)[3]: Applications currently available are still limited to identifying limbus-muscle insertion distance and anterior segment changes following strabismus surgery, Color Fundus Images: To examine the impact of strabismus surgery on retinal vessels calibers with the help of color fundus images [4], Ultrasound Biomicroscopy (UBM) and AS-OCT [5] may be helpful in identifying the position of EOMs which could also help to create a preoperative surgical strategy, especially in people who have had strabismus surgery in the past.. Additionally, Photographs of Patients [6-10], Eye Tracking Data [11], Cover Test Videos[12-13], Retinal Birefringence Scanning [14] and Prism Cover Test (PCT) [15,16] measurements are a fundamental tool for diagnosing different types of Strabismus, allowing clinicians to assess the degree of ocular misalignment.

RQ2: What kind of medical image databases are there for EOM issues?

Analysis: We need data to develop a 3D model for digital Twin. Additionally, we need data to diagnose the different kinds of strabismus and quantification of important elements of these 3D models like Eyeballs and Extraocular muscles. Therefore, there is a need arise to collect the required data from strabologists. We tried to contact different strabologists with the help of emails and phone calls. We find that there are EU regulations are there on sharing medical data, which makes it difficult for the strabologists to share data with us. We are trying to find a different database that can be helpful for us to develop a digital twin. Currently, we find one MRI database of humans that also includes Eyeballs and EOMs [17]. Additionally, we have Digital Imaging with a Camera (photographs of patients/ non-patients) that may further help us to develop desired digital twin [18-24].

RQ3: What are the current diagnostic image processing and neural network algorithms for finding Strabismus?

Analysis: Strabologists generally used [25-26] 'Prism cover Test (PCT) or also Golden standard', 'Hirschberg Test', 'Krimsky Test', 'Unilateral Cover Test, and ' Alternate Cover Test' to diagnose Strabismus. We have founded 8 research papers based on face photographs. Khumdat et al. (2013) [7] developed an algorithm for strabismus detection based on the central cornea light reflex ratio, utilizing an automatic detection model. The dataset consisted of 103 images, and the model achieved an accuracy of 94.2%. Almeida et al. (2015) [6] employed a Support Vector Machine (SVM) algorithm to detect ocular misalignment using the Hirschberg reflex. Their study included a dataset of 200 photographs, resulting in an accuracy of 88% for Esotropia, 100% for Exotropia, 80% for Hypotropia, and 83% for Hypertropia. Lu et al. (2018) [9] conducted a classification study using a Convolutional Neural Network (CNN). The training set contained 3409 images, including 701 with strabismus and 2708 without, while the testing dataset comprised 2276 images, with 470 indicating strabismus and 1806 not. The study reported an accuracy of 93.9%. Jung et al. (2019) [10] also utilized an SVM-based model for strabismus detection. The training dataset included 300 strabismus photographs and an equal number of normal photographs, with a testing set containing 50 images of each type. The accuracy achieved was 95%. Figueiredo et al. (2021) [27] explored the use of deep learning for classifying different gaze positions in strabismus patients. They employed a ResNet-50 architecture pre-trained on ImageNet and tested it on photos of 110 patients, achieving an accuracy range of 42 to 92%. Zheng et al. (2021) [8] applied a Faster R-CNN model to localize regions of interest in photographs for strabismus detection. The training and validation sets used 3829 photographs without strabismus from 3021 subjects and 3197 photographs with strabismus from 2772 subjects. For testing, 277 photographs were used, and the model achieved a 95% accuracy. Huang et al. (2021) [29] utilized a pretrained CNN-based face detection model, combined with Otsu's binarization and the HSV color model, for strabismus detection. The testing involved facial images of 30 strabismus and 30 non-strabismus patients, reporting a sample mean of normal and strabismus images as (1.073 ± 0.014) and (0.039), respectively, and a sample standard deviation of (1.924 ± 0.169) and (0.472). Huang et al. (2022) [28]

investigated a meta-learning approach on a pre-trained public dataset with additional image processing techniques for strabismus classification. They further employed SVM for classification, testing on facial images of 30 strabismus and 30 non-strabismus patients. The study achieved an accuracy of 0.805, sensitivity of 0.768, and specificity of 0.842. Each study contributes uniquely to the field of strabismus detection, showcasing the evolution of diagnostic techniques and the increasing accuracy of machine learning models in medical image analysis. We have found 3 research papers based upon Eye movement data: Viikki et al. (2001) [30]: This study utilized electrooculography to record eye movement data and employed a decision tree classification method. The dataset included 137 patients with either central or peripheral lesions, and the algorithm achieved an accuracy range of 88.0% to 91.0%. Chen et al. (2018) [11]: Eye movement data were recorded using an eye tracker in this research. Classification was performed using a Support Vector Machine (SVM) and Image Net, along with convolutional neural network architectures such as AlexNet, VGG-F, VGG-M, VGG-S, VGG-16, and VGG-19. The testing dataset comprised 42 images, including 25 without strabismus and 17 with strabismus. D'addio et al. (2020) [31]: In this study, eye movement data were captured through electrooculography. The researchers applied Random Forests and Logistic Regression Tree Algorithms to analyze the eye movement data of 20 nystagmus patients. The investigation focused on the relationship between various nystagmus parameters and the variability of eye positioning. We have found 2 research papers based on cover test videos: Yang et al. (2013) [12]: This study utilized full-face infrared photographs captured with a video camera, incorporating a wavelength filter (occluder). The researchers employed a 3D Strabismus photo analyzer to examine the images. Their dataset included photographs of 90 patients, categorized into 30 esotropia, 30 exotropia, and 30 orthoptic cases. Valente et al. (2017) [13]: The researchers in this study harnessed the digital movement of eyes recorded during the cover test. They developed a classification system based on the automated deviation of an eye. The dataset for this study comprised data from 15 patients with exotropia, and the algorithm achieved an accuracy of 93.3%. We have also found a research paper based on retinal birefringence scanning: In a 2017 study, Gramatikov [14] utilized retinal birefringence scanning, recorded via a pediatric vision screener, and analyzed the data using MATLAB's neural network toolbox. This approach effectively detected ocular misalignment, achieving a sensitivity of 98.5% and a specificity of 96.2%. We have found 2 research papers based on prism cover test measurements. But we don't find any strabismus diagnosis algorithm based on medical images. In the scientific domain, Fisher et al. (2007) [15] and Chandna et al. (2009) [16] have developed diagnostic algorithms for vertical strabismus using PCT measurements: Fisher et al. (2007): Utilized PCT measurements for a training set of 160 individuals, with a separate validation and test set of 120 people. They employed Levenberg–Marquardt back-propagation for network training, achieving a perfect accuracy of 100%. Chandna et al. (2009) [16]: Also used PCT measurements for vertical strabismus, applying an Artificial Neural Network (ANN) for classification. Their study involved a training dataset of 160 patients and a testing dataset of 43 patients, resulting in an accuracy of 94.4%. These studies highlight the effectiveness of PCT measurements and neural network-based approaches in the accurate diagnosis of vertical strabismus.

RQ4: What are the components of a 3D geometrical model employed in these simulators that could be useful?

Analysis: We have found 8 different simulators that focused on strabismus surgeries: SQUINT (1984) [32], Orbit™ (1995) [33], Eyelab (2000) [34], SEE++ Kid (2009) [35], Qi Wei Model (Only Research Work) (2010) [36], Open Sim (2016) [37], Open Sim (2018) [38], Qi Wei Model (2022) [39]. If we do the union of all the components of these simulators then we have Eyeballs of left and right eye, Muscle Pulleys and extraocular muscles (Superior rectus, Superior Oblique, Medial Rectus, lateral rectus, inferior rectus and inferior oblique muscles of both eyes.)

RQ5: How can eye muscles and eyeball be quantified with the use of medical imaging?

Analysis: We have found 7 different research papers based on the quantification of the eyeball and eye muscles. Wei et al. (2014) [36]: This study focused on the quantification of the eyeball, providing metrics for its dimensions and volume. Xing et al. (2015) [40]: Investigated the accuracy of automatic segmentation of extraocular muscles (EOM) against manual segmentation, highlighting advancements in image processing techniques. Asakawa et al. (2003) [41]: Utilized cine phase-contrast magnetic resonance imaging to quantify skeletal muscle motion, offering insights into the dynamic aspects of muscle movement. Demer et al. (1994) [42]: Quantified the extraocular (EO) muscles in cases of paralytic strabismus, aiding in the understanding of muscle atrophy and its clinical implications. Kono et al. (2002) [43]: Conducted a quantitative analysis of the structure of the human extraocular muscle pulley system, which plays a crucial role in eye movement coordination. Sylvestre et al. [44] (1999): Performed a quantitative analysis of abducens neuron discharge dynamics during both saccadic and slow eye movements, contributing to the knowledge of neural control in ocular motility. Robinson et al. (1975) [32]: Provided a quantitative analysis of extraocular muscles and squint, establishing foundational data for the development of corrective surgical procedures. These studies collectively enhance the precision of medical imaging in quantifying ocular structures and contribute to the refinement of diagnostic and therapeutic strategies in ophthalmology.

RQ6: What are the various frameworks and algorithms available for converting medical imaging into a three-dimensional geometrical model (NURBS/ B-Splines Modeling) for better Diagnosis and Simulation? Analysis: In the pursuit of achieving more precise and comprehensive diagnostic and simulation tools for Strabismus surgery, a range of frameworks and algorithms have been analysed for transforming medical imaging into intricate three-dimensional geometrical models. This analysis offers insights into select algorithms employed for this purpose: Qi Wei's Algorithm (2014) [36] encompasses a sequence of steps beginning with the preprocessing of images, followed by segmentation, boundary registration, B-Spline surface fitting, and concluding with sub-division surface fitting. This algorithmic flow ensures a comprehensive approach to model creation. Fazanaro et al.'s NURBS Parameterization (2015) [45] initiates with input processing that involves reading and extracting data from input files. Subsequent stages include point cloud formation, NURBS reconstruction with PCA integration for refinement, bounding box estimation based on eigenvectors, and surface quality refinement to enhance the NURBS surface. Zhang et al.'s Vascular NURBS Modeling (2007) [46] commences with image processing techniques such as contrast enhancement and segmentation. It proceeds with iso-contouring and geometry editing, path extraction, skeleton-based meshing, solid NURBS construction, and isogeometric analysis for simulation applications.

RQ7: What kind of different mathematical models available for simulation?

Analysis: Geometrical models such as the String Model, introduced by Krewson in 1950 [48], and the Tape Model, formulated by Robinson in 1975, provide fundamental representations of ocular mechanics. Additionally, Pulley Models including the SEE-KID model [48], SEE-KID active Pulley Model [48], and Orbit Model offer more intricate perspectives on eye movement coordination. In terms of Kinematic Models [48], the Muscle Force Model aims to replicate muscle behavior based on length and innervation, while the Hess-Lancaster Test assesses binocular functions using separated images for each eye. These models and tests are integral components of the SEE++ simulator, facilitating comprehensive study and diagnosis of ocular conditions.

Conclusion and Future Scope

Our systematic literature review underscores the transformative potential of digital twins in revolutionizing precision, predictability, training, research, patient communication, and long-term care in extraocular muscle (EOM) prosthesis surgeries. Moreover, integrating digital twins into the development of assistive technologies presents promising opportunities, such as binocular glasses, to address monocular vision defects. Our proposed smart glasses utilize sensor technology to detect normal eye movement and a camera to capture images aligned with predicted movement of the affected eye, projecting them onto the affected side to restore binocular vision. This innovative approach offers a non-invasive solution to enhance depth perception and improve the quality of life for individuals with monocular vision defects. Further research and development in this area hold immense potential for advancing both surgical and assistive interventions in ophthalmology.

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14. Post-COVID Sign Language Instruction by the Deaf: Perspectives from Hearing Sign Language Learners

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Abstract

COVID-19 has proposed many challenges in the educational field. Many face-to-face language classes had to be switched to online classes. For Japanese Sign Language (JSL) classes, Deaf instructors had to cope with the change. Yet it was an opportunity for Deaf sign language instructors to start another form of teaching. This study looks at the hearing JSL learner's perspectives on online sign language learning. An online questionnaire was conducted to hearing JSL learners. 27 learners responded to the survey. The survey asked the respondents about their background information and their views towards online classes. This can provide insights into how this form of learning style could continue and become another form of teaching style in the Post-COVID era.

Introduction

COVID-19 has brought many changes in the form of language classes. Many schools could not conduct face-to-face language classes and these classes were conducted online. In universities, classes were conducted online synchronously or asynchronously. Language classes are different from other classes in that interaction is crucial part of the education. Many tools such as Zoom, Google Meet, Microsoft Teams have become known to the public and are now used in the educational settings. Concerning the Deaf, use of technology and online tools provided them with more options. They could use functions such as auto-captioning and spot-light functions. These were very convenient in online meetings. Auto-captioning could be used with remote sign language interpretation, it could be a supplementary tool to gain sufficient access to spoken information. The accuracy of the auto-captioning was not so high in the initial stage but now with many updates and many different software, the user can choose and try many different methods that works the best for them. In online meetings with a sign language interpreter, the spot-light functioning could help the Deaf see who the speaker is in the meeting. In actual face-to-face sign language interpretations when the conversation becomes overlapped and complexed, it is sometimes difficult for the Deaf to figure out who is the speaker, but most online conferencing tools has functions to indicate who is speaking. COVID-19 became an opportunity for the Deaf in Japan to have better access to information in their workplaces.

In the educational settings such as language classes, the pandemic was an opportunity for the Deaf to start online classes for hearing sign language learners. Many Deaf started online classes and hearing sign language learners took these online classes. Now all classes have returned to normal and hearing sign language learners can learn sign language in a face-to-face setting. This study looks at the post-COVID online sign language instruction and how the hearing students who took the sign language classes feel about online classes conducted by the Deaf. A survey was conducted to analyze the hearing learners' views towards online sign language classes. It can also give some hints on how online sign language classes can continue to be popular in the post-COVID era. This study is conducted by two researchers. One is a Deaf sign language instructor and the other is a hearing sign language interpreter. This can provide both insights from the teacher and learner's perspective in the analysis.

Sign Language Instructions by the Deaf

For sign language instructions, it is important to understand that JSL has a different grammar to Japanese. When hearing people teach sign language using both spoken and signing simultaneously, it is Signed Japanese and not JSL. The World Federation of the Deaf (2023) proposed a position paper that states that "States Parties should take all necessary steps to ensure the capacity and capability of deaf people to serve as cultural and linguistic models, teachers and disseminators of their national sign languages including through the establishment of appropriately resourced sign language teacher training courses and teacher training courses for deaf people", on March 2023 [1]. This paper emphasized that sign language is the language of the Deaf and it is recommended that the Deaf teach the hearing, their own language. This position paper was presented amid COVID-19 and had influence on the Japanese Deaf community resulting in many Deaf people starting online classes for sign language learners and interpreters. For hearing sign language learners, they could not practice sign language in their homes so online sign language classes were useful to keep up their signing skills.

Online Sign Language Instructions

Before COVID-19, Japan was slowly adapting to the global trends for a more ICT based-form of learning. According to the Ministry of Internal Affairs and Communications (2021), in the educational setting, GIGA School Vision "to develop a high- speed and large-capacity communication network integrally with provision of a terminal to every student", was to start from the AY 2023 [2]. Yet this plan was moved forward due to the spread of COVID-19. In higher educational settings, as of April 23, 2020 about 90% of universities postponed the regular classes and in July 1, 2020, all universities conducted face-to face and remote classes. Japanese educational institutions could not suddenly make a huge leap from face-to-face to completely remote and COVID-19 was a challenge for higher educational institutions.

For online sign language instruction, Gournaris (2022) states that compared to spoken language instruction, the modality is different in American Sign Language (ASL) and the following factors needs to be taken into consideration: the use of space and facial expressions. These are crucial parts of sign language grammar, and it applies to all sign languages of the world [3]. In Gournaris (2022)'s study, a semi-structured interview was conducted to students taking ASL classes online using Zoom, during the pandemic. In the interview, a student mentioned that it was difficult to ask a question online than in face-to face classes. Some students mentioned that exposure to ASL decreased during the pandemic. Alshawabkeh et al. (2021) looked at both the instructors' perspective and deaf students' perspective on online classes in the university in UAE. Sign language interpreters are necessary form of information access for the deaf students and in the study, a deaf student mentioned that when internet speed was slow, sign language from the students to the interpreter was slow, disjointed, and often misunderstood [4]. There are many common problems such as internet speed and intelligibility of the language in all online language classes but for sign languages, gaining visual information is essential in the understanding of sign language grammar.

Background of the Sign Language Class

The online classes offered by the researchers started in 2020 as a pilot and in 2021 the online classes started officially. In the initial pilot stage, students could choose to participate in a quick tutorial on how to use Zoom offered by the researcher before the beginning of the class. Students were taught how to change the view from speaker view to gallery view. For those students who were not accustomed to the use of Zoom, it was recommended that they just use the speaker view to watch the Deaf instructor during class. From the year 2021, total of 74 students have taken the online classes. The online classes are conducted 3 times a week on Monday 13:00~15:30, 16:00~17:30 and Friday

19:00~20:30 (from the year 2024 Friday classes were moved to Monday classes). The 3 classes are for advanced JSL learners. Since this class is not a university class, students can continue taking the classes for as long as they wish to. Students can choose 2 styles of learning: observer and full-time student. Full-time student can attend all classes and must have their cameras on and participate in the class. If there are too many full-time students in the class, it is difficult for the students to see the interaction between the instructor and the students so the maximum number of full-time students for each class is 6. Figure 1 shows an image of the actual class with the instructor in the top center and display of the iPad using a smart phone on the left corner and 6 windows of 6 full-time students.

Figure 14-1: Picture showing the layout of the Zoom display during the class

Observer students can view the classes with their cameras off. The classes are synchronous classes, and the video recording of the classes are sent to the full-time students after each class. The video recordings are converted to YouTube and the YouTube URLs with limited access are sent to the full-time students. During the initial stage of the online sign language class, some students had trouble turning their microphones/cameras on and off but as the classes proceeded, most students became accustomed to the style of learning. If a student had problems with the microphones and camera, a message using the Zoom messenger was sent to them and all the students were able to fix the problem on their own. As of the year 2023, little support is necessary concerning internet access and the use of Zoom. Table1 is an example of a lesson plan in one of the classes.

Table 14-1: Table showing an example lesson plan

Time	Content	Objective	Tool
3~5 days before the class	Zoom link for the class is sent to the students	To inform the students about the up-coming class	E-mail
20 minutes	A short talk by the instructor about news related to the Deaf and sign language	Warm-up for the learners to watch and understand the signs To provide latest information to the learners	Show another display using a smart phone and a tablet device (Zoom)
5 minutes	Explanation of the class	To help the learners understand the objective of the class	Zoom
3 minutes	Watch a video of a Deaf signing	To give time for the learners to understand the content	Show another display using a smart phone and tablet device (Zoom)
6 minutes	Show parts of the video in slow motion and in normal speed	To indicate which part of the video will be used for translation practice	Show another display using a smart-phone and tablet device (Zoom)
10 minutes	Give students time to type in the Japanese translation	To check individual understanding of the content	Messaging on Zoom
20 minutes	Give feedback to the students	To check the answer	Messaging on Zoom
3 minutes	Show the video again	To show the video one last time to the student	Zoom
10 minutes	Ask students for questions	To have some time for the students to reflect on what they learned in the class	Zoom
Summing up	Wrapping up the class and emphasizing important points	To state the main points of the class	Zoom
After the class	YouTube link and the messaging chat files are sent to the students	To help the students review what they studied	Email, Microsoft Word file converted to pdf file and Zoom recordings converted to YouTube

In the sign language classes, videos of the Deaf are used. Different applications were used in the initial stages of the class, but it was found that the most effective way to present a video in the classes was to use 3 devices. A laptop to show the instructor signing, a smartphone camera to show a video or a picture that is being displayed on another tablet device. Figure 2 shows the setting of the devices.

Figure 14-2: Picture showing the setting of the devices

Methodology

Online survey was conducted to the students who took the online classes offered by the researchers, using google form. The google form link were sent to all students (both full-time and observer students). The survey consisted of 20 questions (16 close-ended and 4 open-ended questions). 27 participants taking the sign language classes responded to the survey (26 female and 1 others). The age distribution of the students is shown on figure 3. The background of the students reflected the situation of sign language interpreters in Japan. The respondents were mostly female, and their age was over 30s. 48.1% of the respondents were in their 50s. In the survey conducted by the Information and Culture Center for the Deaf in 2019, out of 1863 certified sign language interpreter, 1687 were female. 89.5% of the certified sign language interpreters are female [5]. As for age distribution, out of 1884 respondents, 10 people were in their 20s, 107 people were in their 30s, 336 people were in their 40s (17.8%), 674 people were in their 50s (35.8%), 614 people were in their 60s (32.6%), 133 people were over 70s. Although in this study there were only 27 respondents, the age distribution seems somewhat like the survey conducted towards the certified sign language interpreters with the large number of sign language interpreters in their 50s and 60s. The detailed background of the students will be discussed in the next section.

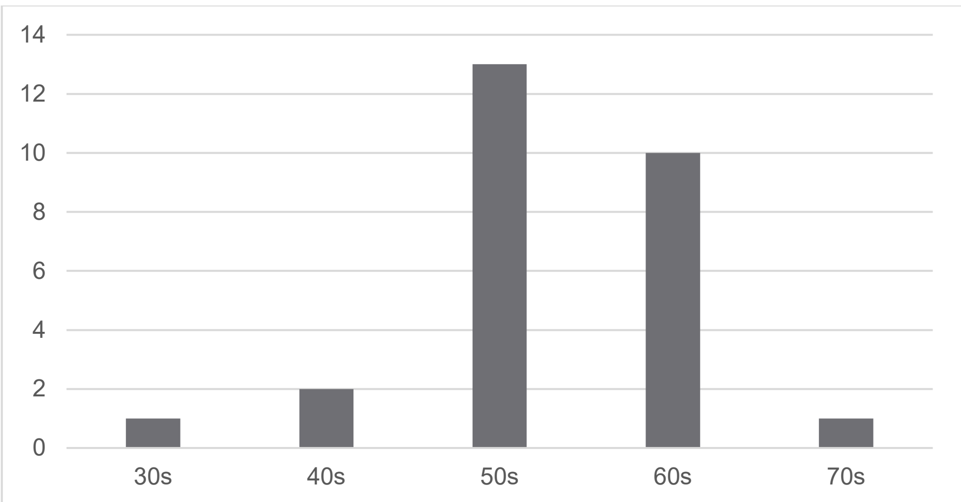

Figure 14-3: Bar graph showing the age distribution of the students (N=27)

Results and Discussion

From the survey there were several interesting findings. The first part of this section will look at the background of the students and the latter part will analyze the responses to the open-ended questions concerning online sign language classes.

As for the location of the students, 12 students were from Tokyo, 7 students were from the Kanto-region (3 from Kanagawa, 1 from Saitama, 1 from Tochigi, 1 from Ibaraki and 1 from Chiba). The remaining 8 participants were from areas far from Tokyo: 3 from Okinawa, 1 from Kagoshima, 1 from Aomori, 2 from Hyogo and 1 from Fukushima. It was thought that in post-COVID era, students in Tokyo will return to face-to-face classes but the results show that over 70% of the respondents were from the Kanto-region. The years that the students' studied JSL were all over 5 years and the longest was 25 years. As for license, 12 respondents were certified sign language interpreters, and 24 respondents were interpreting in their local municipalities. In Japan, there is a national certification for sign language interpreters, but many interpreters do not take the test for the certification and work as a community interpreter in their local municipalities.

For online software, it was found that most participants (20 out of 27) had some experience in using video conferencing software platforms. The platforms that the participants were familiar with were Zoom (27 people), Microsoft Teams (5 people), Google Meet (11 people) and Webex (1 person). All respondents selected Zoom since the software used in the sign language class was Zoom. The years that the participants received online sign language instruction was less than 4 years indicating that COVID-19 may have caused the learners to the use of video conferencing software to receive sign language instruction.

The devices that were used for Zoom were laptop computers (24 people), desktop computers (4 people), tablet devices (5 people), smart phones (8 people) and TV monitors (4 people). For students learning sign language online, it is important that they can see the signs clearly. The portability of the camera is important because your hands and upper part of your body must be seen on the Zoom display. A few hearing learners have problem setting the camera and when they are concentrating on watching the videos, they tend to forget about setting the camera so all the manual movements and facial expressions can be seen on your Zoom display. For hearing people during online meetings, the angle of the camera is not so important if you can hear the speaker's voice. For hearing sign language learners, the first thing they must do is to set the camera so that everyone can see their signing.

As for computer literacy and internet literacy, 19 respondents stated that they learned to use the software by themselves. 2 answered that their family taught them how to use the software, 1 answered that they learned it at work, 1 answered that they learned it from a friend and 1 answered that they learned it in the tutorial given in the beginning of the sign language class. This indicates that none of them received a formal training in video conferencing tools. This result shows that no specialized technical skill is necessary. For internet access, 4 used a portable Wi-Fi, 9 used wired Wi-Fi and 20 used wireless Wi-Fi. As for internet speed, 20 responded that they had good access and 6 responded that sometimes they had bad internet connection. Stability of internet connection was not related to the types of Wi-Fi access.

The second part of the analysis will look at the students' open-ended response. As for the good points of online sign language instruction 24 responded to the question. Most of the students stated that they can save time on transportation, and they find it convenient that they can take the classes wherever they want to. 3 students mentioned that they can utilize the video recording after the class and can review what they learned in the previous classes. 1 student mentioned that Zoom can show the faces of the instructor and the students so you can see the signs clearly. This answer is unique in that sign language is a visual language and for second language learners it is sometimes difficult to understand the signs when looking at the signer from the side or the back. In a face-to-face classroom setting, it is important to arrange the chairs so that the students can see the instructor but in online classes this is not necessary. In regular classes where sign language is taught, a large lecture room is not suitable unless there is some sort of TV monitor for students sitting at the back of the class. Several students responded that they wanted to learn from a particular instructor, and it was easier to learn from the instructor on Zoom. For student in areas far from Tokyo, online sign language classes can give them more options and they can learn from popular Deaf sign language instructors in Tokyo.

As for the negative points of online sign language instruction, 4 respondents thought that face-to-face classes were more effective communication-wise. 1 respondent felt that it was difficult to ask a question online than in face-to-face classes. The greatest number of responses (7 responses) were to do with internet connection and internet speed. The internet connection varies from person to person, and this has big influence on the online instructions. 2 respondents mentioned that since the actual signs are 3 dimensional, sometimes it is difficult for them to understand the signs on the screen which is 2 dimensional. The Deaf instructors' ways of signing can help to solve this problem. For some signs the instructor can change the direction of their body so that the learners can see from different angles.

The final part summarizes the further requests from the learners. There were 2 requests in the survey concerning the teaching methodologies. 1 request was to use more slow-motion functions frequently so that they can check the signs being used in the videos. Another request was to do with the labeling of the signs. Although JSL has different grammar to Japanese, for better understanding of the learners, signs in the utterance of a Deaf signer can be labelled. For example, the labels Pt1/Name [raised eyebrow/head shake] /RE/N. Pt1 stands for pointing in the first person i.e. pointing to oneself. "Name" is the actual sign for name and the movements in brackets show the grammatical facial expression accompanying the sign. The capitalized alphabets indicate the Japanese manual alphabet. There are many conventions in labelling and one word does not correspond to one sign but for the learners, to distinguish what signs are being used, labelling is an effective way to understand the meaning of the signs. In the online classes labelling is sometimes used to check everyone's understanding using the messaging function on Zoom. Depending on the learners' level of JSL the use of the labels may be effective. For example, in classes where the students level vary, advanced level students can decide to not look at the messaging tool on Zoom with the labels and beginner level students can look at the message tool to see the labels.

This study was a survey to find out the students' views towards online sign language instruction after the pandemic. It was found that although many preferred to receive sign language instruction face-to-face, there are still needs for online sign language instructions. Online sign language instruction can save the students time to travel to the classes and can save the effort to make accommodations in the room so that all learners can see the signer. There is no need for training when using Zoom and it can create more opportunities for the Deaf to start an online class. There are negative points such as internet access and speed, but this can be solved by repeating the signs and checking the students understanding during the instruction. For the observer students, they can just watch the video and use it as a supplementary form of learning. Online sign language instruction can give more opportunities to both the instructor and the learners.

For further study, it is necessary to do a more large-scale interview to both hearing learners and Deaf sign language instructors. Also, studies need to be conducted to find out effective ways to show signs on a 2-dimensional screen. The pandemic caused the sign language learners to accommodate to a new form of sign language instruction and post-COVID era will be a time for opportunity and development of a new style of online sign language instruction.

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15. AVATA-AAC: an AAC-based Digital Therapeutic to Improve Communication Skills in Children with Autism Spectrum Disorder

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Abstract

Autism spectrum disorder (ASD) is a neurodevelopmental disorder that affects social interaction and communication skills. The purpose of this study was to develop a digital therapeutic application (AVATA-AAC: Amusing Verbal and Alternative Communication Tools for Children with ASD - Augmentative and Alternative Communication) to improve the communication skills of children with ASD. We evaluated the effectiveness of the application in improving vocabulary acquisition and AAC-based communication skills, with four children between the ages of 3 and 5 who had ASD and single-word level speech. The social validity of this digital therapeutic was also evaluated by assessing its acceptability to caregivers.

Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental disorder that affects social interaction and communication skills [1]. Children with ASD exhibit a wide range of symptoms and signs, and effective interventions require consideration of individual differences. Augmented and Alternative Communication (AAC) helps improve communication skills for people with language disability. AAC can be used as an effective tool for language acquisition of children with ASD [2].

Accessible digital therapeutics are increasingly recognized by parents as beneficial in supporting their children with special needs, particularly in educational settings. For children with ASD, who frequently struggle with language learning, the use of digital therapeutics tailored to their needs presents a valuable opportunity. Such digital therapeutics, especially those that include visual and auditory aids, have the potential to significantly improve language skills. By using these digital therapeutics, we can better support the communication development of children with ASD [3].

The purpose of this study was to develop a digital therapeutic application (AVATA-AAC: Amusing Verbal and Alternative Communication Tools for Children with ASD - Augmentative and Alternative Communication) to improve the understanding and learning of target vocabulary and AAC symbols within various contextual scenarios. The focus of this study is children with ASD aged 3-5 who are at the single-word speech level. We conducted a user study with four children to evaluate the effectiveness of the application in improving vocabulary acquisition and AAC-based communication skills. We also evaluated social validity of this digital therapeutic by assessing its acceptability to caregivers.

Design Implication

In this study, we conducted interviews with speech-language pathologists and analyzed applications for children with ASD to derive guidelines for the development of AAC-based applications to improve communication skills in preschool children who have difficulty with spoken language.

Two speech-language pathologists with more than 20 years of experience providing speech-language therapy to children with ASD were interviewed about the communication goals, intervention activities, intervention strategies, progress assessment, and reinforcers commonly addressed in speech-language therapy for children with ASD. Because children with ASD have deficits in social communication skills, it was found that establishing joint attention for interaction is important in early intervention. In terms of intervention activities and goals, the preferences of children with ASD vary widely, but the inclusion of language goals focuses on places and activities that children with ASD frequently encounter in their daily lives at a young age. Intervention strategies include modeling, imitation, and reinforcement.

An analysis of current applications for improving communication skills in children with ASD found that most focus on social communication skills, and there are very few applications for children with ASD who have difficulty communicating verbally or have low communication skills [4]. The interviews with speech-language pathologists and the analysis of existing applications were used to finalize the concept of the app that we would like to develop in this study.

Structure and Protocol of AVATA-AAC

For effective communication learning in children with ASD, the development of joint attention skills is essential [5]. AVATA-AAC consists of two main parts: Joint Attention and AAC-based Communication Learning. For a structured progression in the learning experience, it is important for children to complete the Joint Attention part before advancing to AAC-based Communication Learning. Picture 1 shows the flow of this application.

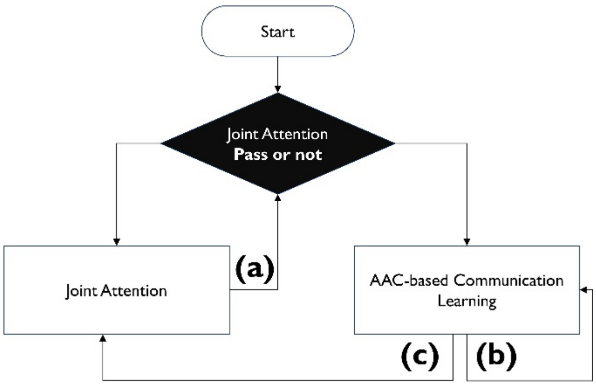

Figure 15-1: AVATA-AAC Two main parts and protocol

When a child starts the application, it first checks whether the child has completed Joint Attention part. If not, the child is required to repeatedly engage in joint attention exercises (Picture. 1(a)). Upon completing this part, the child then progresses to the AAC-based Communication Learning part. The child can choose and perform the AAC-based learning scenarios they prefer (Picture. 1 (b)), and they can also revisit and practice Joint Attention at any time (Picture. 1 (c)).

The Joint Attention Learning part focuses on developing skills such as pointing, showing, and gazing [5]. In this part, children engage in activities where target objects are presented on a screen, without specific instructions. Activities are categorized into three themes based on the child's target actions. Each theme includes a range of scenarios. Children can select scenarios that interest them and engage in activities to develop skills such as pointing at objects, sharing attention with caregivers, and focusing attention. These structured activities play a crucial role in enhancing the child's communication and interaction abilities.

Table 15-1: Overview of Joint Attention themes with descriptions and detailed scenarios

Theme	Description	Detailed Scenarios
Theme 1	finding and selecting a hidden object	Vehicles, Dinosaurs, Sea Creatures, Hide and Seek, Bubbles, Balloons
Theme 2	selecting a target object and confirming its auditory response	Zoo, Concert, Road Traffic, Farm, Household
Theme 3	choosing an object and then watching how it interacts with an animal nearby	A Puppy & An Apple, A Cat & A Milk, A Fox & A Grape, A Pig & A Chicken, A Yellow Duck & A Bread

AAC-based Communication Design

The AAC-based communication learning part is designed to teach target vocabulary in various scenarios, guided by an agent's instructions. These scenarios are categorized into three places: 'My Home', 'My Town', and 'Kindergarten'. Each place offers specific scenarios appropriate to that place, as shown in Table 2.

Table 15-2 : Scenarios by location

Place	Detailed Scenarios
My Home	'Eating', 'Dressing Up', 'Taking a Bath', 'Brushing Teeth', 'A Birthday Party', 'Our Family', 'Getting Ready for Bed', 'Bathroom', 'Living Room', 'Entrance', 'Refrigerator', 'Our Body'
My Town	'Shopping', 'Crossing the road', 'Going to the hospital', 'Going to a hair salon', Transportation', 'Fruit Shop', 'Bakery', 'Restaurant'
Kindergarten	'Coloring', 'Playground', 'Zoo', 'Classroom', 'Kindergarten bus', 'Weather', 'Making a Christmas Tree', 'Feelings', 'Describe', 'Musical Instruments', 'Social Expressions', 'Puzzle Play'

The learning process comprises three activities. Picture 2 displays scenes from each activity in the 'A Birthday Party' scenario at 'My Home'. In Activity 1, children choose a target object on the screen following the agent's directions (Picture. 2 (a)). This activity facilitates the understanding and learning of the target vocabulary. In Activity 2, children select an AAC graphic symbol that corresponds to the words spoken by the agent (Picture. 2 (b)). This activity assists in learning AAC symbols. In Activity 3, children observe character animations on the screen and select the AAC communication expression symbol that matches the agent's question (Picture. 2 (c)). This activity supports the learning of AAC communication symbols.

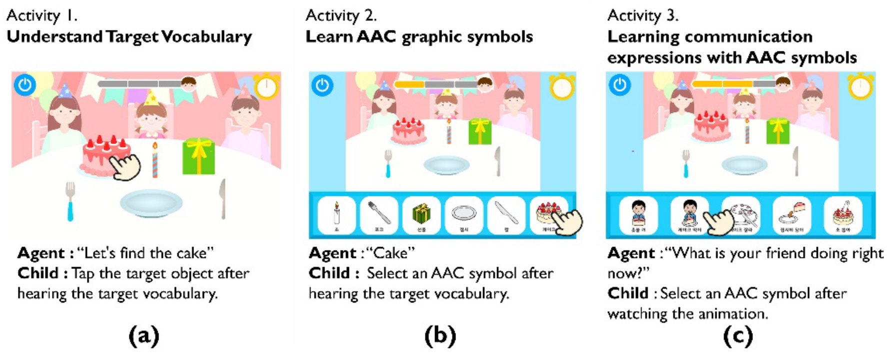

Figure 15-2: AAC-based Communication Activity Structure

These activities provide opportunities for children to improve their communication skills in a variety of situations. AAC-based communication learning helps children understand and use AAC graphic symbols in different contexts, improving their overall communication skills.

Prompting Children's Responses and Scoring System

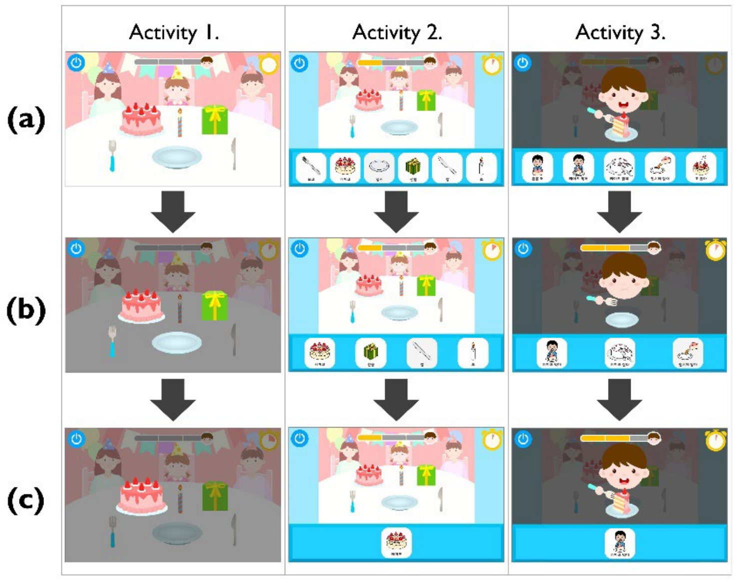

Figure 15-3: Prompting system

AVATA-AAC uses a prompting system to encourage correct responses from the child during activities. The First Prompt displays all target objects and uses visual effects to focus the child's attention (Picture. 3 (a)). If the child doesn't react or responds incorrectly, the Second Prompt is triggered, reducing the number of selectable target vocabularies to three (Picture. 3 (b)). A correct response leads to the next word, but if the child still doesn't respond or makes an error, the Third Prompt is triggered, leaving only the correct answer as a selectable target vocabulary (Picture. 3 (c)).

Additionally, AVATA-AAC includes a scoring system that records the children's performance in each activity, storing this information as data on their progress. This data is used to assess and analyze the child's level of language learning and their improvement over time.

User Study

Participants

This study involved four children who were diagnosed with autism spectrum disorder (ASD) and were between the ages of 3;3 and 5;0 years (M = 46.25 months, SD = 9.50). The children met the following criteria: (a) Participants were between the ages of 3 and 5 years old; (b) They were diagnosed with ASD by a pediatric psychiatrist according to DSM-5 criteria; (c) They had a total score of 30 or higher on the Korean Childhood Autism Rating Scale (K-CARS 2); (d) Parents were assessed with the Korean Child Development Inventory (K-CDI) and the total developmental score was in the delayed development range; (e) The delayed language development was assessed using the Sequenced Language Scale for Infants (SELSI) or the Preschool Receptive and Expressive Language Scale (PRES); and (f) The vocabulary was limited to 140 or fewer expressive words, and the expressive language development was evaluated at the single-word level using the Korean MacArthur-Bates Communicative Development Inventories (K M-B CDI). All procedures were approved by the institutional review board of the university (No. 230821-7A), and consents were obtained prior to the start of the study.

Procedure

A pre-test was conducted to select participants who met the inclusion criteria for the study. They were then asked to use the AVATA-AAC digital therapeutic for a minimum of 20 minutes and a maximum of 40 minutes per day, at least four times per week, for a total of eight weeks. The program was designed to limit the child's continuous use of the application to the maximum time per day. Parents were given login information and instructed to allow their child to use the AVATA-AAC app in a quiet area of the home at least four times a week. The AVATA-AAC app automatically progresses through programmed activities based on the child's engagement and responses without the presence of a caregiver or therapist. However, in this study, a speech-language pathologist visited the home twice a week to monitor the child's use of the AVATA-AAC app. After 8 weeks of AVATA-AAC use, a post-test was conducted which included the same tests as the pre-test.

Results of improving communication skills in children with ASD

To evaluate the effectiveness of the AVATA-AAC app in enhancing communication skills among children with ASD, we compared their pre- and post-test results. Table 3 shows that three out of four children had lower scores on the post-test for autism severity compared to the pre-test. Regarding language skills, three of the children showed improvements in both receptive and expressive language development, with the exception of Child D. In addition, all of the children showed an increase in the number of words in their receptive and expressive vocabularies on the post-test compared to the pre-test.

Table 15-3: Summary of pre- and post-test results

Participants Age (years; months)	A (3;9)		B (3;3)		C (3;5)		D (5;0)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
K-CARS2	36	36	33.5	31	37	31.5	46.5	43.5
Receptive language	19	23	24,	29	16	18	12	12
Expressive language	25	26	27	27	13	15	12	12
Receptive vocabulary	121	408	435	518	162	180	176	182
Expressive vocabulary	32	225	135	300	5	7	20	26

K-CARS2=Korean Childhood Autism Rating Scale (CARS)-2nd edition [6]; Receptive & expressive language=Age equivalents (month) on the Sequenced Language Scale for Infants (SELSI) [7] or Preschool Receptive-Expressive Language Scale (PRES) [8]; Receptive & expressive vocabulary= number of vocabulary words on the Korean MacArthur-Bates Communicative Development Inventories (K M-B CDI) [9].

Social Validations

A social validity assessment was conducted with the parents of participating children to evaluate the effectiveness of AVAT-AAC in improving communication skills in children with autism. The speech-language pathologist responsible for monitoring the use of the AVATA-AAC app met individually with each child's mother after the post-test to conduct the assessment. The questionnaire used to assess social validity was revised based on a previous study [10]. The questionnaire now encompasses sub-questions regarding intervention goals, methods, outcomes, preferences, and recommendations. It comprises 11 items that are rated on a 5-point scale. To evaluate the effectiveness of the intervention, mothers were asked to rate their child's responses before and after 8 weeks of AVATA-AAC activities on a scale from 1 (not at all) to 5 (very much).

The intervention goals were rated an average of 4.50 (SD = 0.64) by the study participants' mothers. The methods received an average rating of 4.41 (SD = 0.79), while the intervention outcomes were rated an average of 4.67 (SD = 0.47). The preference received an average rating of 4.00 (SD = 2.00), and the recommendation an average of 4.25 (SD = 0.50). Overall, the social validity score was 4 or higher. Table 4 shows the results of the social validity ratings provided by the parents of the study participants.

Table 15-4: Results of Social validity

		A' mother	B' mother	C' mother	D' mother	Mean (SD)
1	Intervention goals	5.00	5.00	4.33	3.67	4.50 (0.64)
2	Intervention methods	5.00	4.34	5.00	3.33	4.41 (0.79)
3	Intervention outcomes	5.00	5.00	4.67	4.00	4.67 (0.47)
4	Preference	5.00	5.00	5.00	1.00	4.00 (2.00)
5	Recommendations	5.00	4.00	5.00	5.00	4.75 (0.50)

Conclusions and Possible Next Steps

This study presents AVATA-AAC, a digital therapeutic designed to improve communication skills in children with ASD who have difficulty communicating in spoken language. The intervention strategies are customized based on user responses. The effectiveness of AVATA-AAC in improving communication was examined in four children with ASD. Additionally, a social validity evaluation was conducted for their mothers.

The results of the study indicate that the use of the AVATA-AAC app had a positive impact on reducing the severity of ASD and improving communication skills in children with ASD. It can be concluded that providing differentiated facilitation strategies based on the child's on-time responses, with minimal intervention from SLPs contributed to the improvement of the child's communication skills. Despite these positive findings, there remains to be done.

After 8 weeks of using the AVATA-AAC app, Child D demonstrated an increase in the number of vocabulary words he understood. However, there was no improvement in other aspects of receptive and expressive language development. Additionally, his mother rated him low on the social acceptability scale. The child scored particularly low on the preference scale, highlighting the significance of considering the child's preferences in communication interventions. Therefore, future development should include differentiation strategies based on the child's preferences.

Due to the diverse social communication skills of children with ASD, customized intervention strategies should be applied based on the severity of their condition and their strengths and weaknesses. Additionally, intervention goals should be expanded in the future. The study's significance lies in its examination of the feasibility of developing digital therapeutic and their effectiveness in improving children's communication skills with minimal therapist intervention.

Acknowledgements

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16. Facilitators and Barriers of Academic Achievement in University Students with Dyslexia: Systematic Review

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Abstract

While there is a significant amount of literature on dyslexia in children, research on adults, particularly university students, is somewhat limited. It is worth noting that despite having a high IQ and training, adults with dyslexia often experience persistent symptoms such as low reading fluency and low orthographic competencies. Additionally, individuals with dyslexia may encounter challenges in text production and proofreading. Individuals with dyslexia may face persistent difficulties that can negatively impact their school performance, resulting in higher repetition rates and lower grade point averages (GPA) compared to their peers, despite their strong motivation to learn. This systematic review aims to examine the factors that may hinder or support the academic success of individuals with dyslexia as a distinct group of learners. The literature was systematically searched to identify variables related to the persistence of symptoms, new assessment tools, comorbid conditions as a potential barrier to studying, and support (including personal, device, and strategy-based support). This paper discusses the implications of these findings for learners and universities.

Keywords: Dyslexia, university students, support, achievement, performance

Introduction

Dyslexia is a condition that can impact one's ability to recognize words accurately and fluently, decode text, and spell correctly [1]. Additionally, individuals with dyslexia may face challenges with reading comprehension, which can limit their reading experience, vocabulary development, and overall knowledge acquisition [2]. Dyslexia is a term used to describe various reading and spelling disorders, whether they occur alone or in combination. It is important to note that this definition excludes difficulties resulting from brain damage, such as aphasia. According to Moll et al. [3], the prevalence rate of dyslexia among children in German-speaking countries is approximately 5-8%. There is robust evidence for persistence in symptoms of dyslexia from early schooling through adolescence [6, 25–27] into adulthood [28, 29]. While there is literature concerning adult dyslexia in general, literature about university students is scarce. According to prevalence data from the UK, a relatively small percentage of children (1.38-1.51%) begin or complete higher education [4]. It is believed that many students either choose not to pursue further education after their schooling or that there is a high dropout rate in the academic pathway. It is crucial to consider the core symptoms, related symptoms, and any coexisting conditions dedicated specifically to university students. Consequently, it is important to analyze barriers and support for a better understanding of access to higher education.

Study Aims

This literature review investigates symptoms of dyslexia in students at university level, as little is known about the further symptoms experienced by this population beyond the core symptoms of lower reading fluency and difficulties with orthographic spellings that typically arise during the first school years [1]. In this specific case, it is worth noting that dyslexia is often accompanied by other disorders. Studies have shown that comorbidity rates between specific reading difficulties and other neurodevelopmental disorders can range from 11% to 70% [3]. It is important to consider the presence of comorbidities, as they might influence the severity of dyslexia problems over time and further modulate the symptoms of learning disorders in the dyslexic population. It is worth noting that comorbidities tend to persist or worsen in adults, including university students. In addition to their learning difficulties, which require support during childhood, university students may experience secondary symptoms such as heightened anxiety and diminished self-esteem [5]. In general, individuals with dyslexia may require additional support from their families and professional assistance throughout their educational journey [6, 7].

To summarize, the current literature review intents a) to analyze the range of symptoms in the specific group of university students in and beyond core symptoms as well as possible ways assessment, b) to find symptoms and comorbidities influencing academic achievement and c) to define support mechanism.

Method

This systematic review is intended to provide an overview of all articles that were found in a systematic search process with certain inclusion and exclusion criteria and were subsequently assessed with the aim of addressing the objectives (see above). The procedure of the present analysis of the papers is orientated towards the guidelines of the systematic review *TRANSPARENT REPORTING of SYSTEMATIC REVIEWS and META-ANALYSES* (http://www.prisma-statement.org/).

Search Strategy, Inclusion and Exclusion Criteria

Five databases were analysed using the search platform EBSCO: APA Psycinfo, ERIC, Psych an Behavoral; Psyndex, MEDLINE. The period was defined as within the last 20 years (since 2003) and only peer-reviewed publications were used. To answer the research questions, the following search terms were used: dyslexia AND (reading or writing or spelling) AND (higher education or college or university) AND (academic achievement or academic performance or academic success) NOT (children or child) NOT (mathematics or numeracy or numbers) NOT primary school NOT teacher.

The search yielded a total of 50 articles. For the purpose of this research, only a subset of articles were included, after excluding duplicate publications (n=1), studies in non-English languages (n=1), articles dealing with acquired dyslexia due to medical causes or medical reports (n=3), and non-empirical articles (n=2). As a result, 43 publications were considered for this study – These studies are all listed in a table, which can be found in the appendix. A further 17 articles were excluded because they focused on children and/or adolescents rather than adults, and one article did not include a focus on dyslexia; the remaining 24 articles were analyzed. The initial analysis included all remaining articles, regardless of their sample size, procedure, effect sizes, and other criteria. The detailed procedure can be found in the PRISMA chart in the appendix. The 24 articles were from 12 different countries, with the majority being conducted at universities.

Categorization and Evaluation of the Articles

The remaining publications were then entered into a table (see appendix) and categorized according to the following 5 categories derived from the research questions.

- Symptoms & persistence into adulthood: Are persistent or changing symptoms described into adulthood? Are these the focus of the research?
- Assessment: Does the article examine approaches of assessment (new assessment, feasibility, validation, etc.) or is an assessment the primary topic of the study?

- Performance during academic studies: Does the article address externally observable performance and outcomes?
- Comorbidities: Are comorbidities with dyslexia in the focus of the present study?
- Support: Is there a focus on facilitators (regardless of the type of support)?

The articles underwent an evaluation process based on the quality of their methods, content, and usefulness in relation to the study. Additionally, the assignment necessitated the categorization of the articles. The evaluation system utilized a traffic light system with three categories: green for suitable/good yellow for partially suitable/expandable, and red for unsuitable. Quality of Method was rated by sample size and population basement. Lower quality was defined by small or minor representative samples or simple types of measurement. The quality of content was rated by the novelty value of the information about academic achievement of university students suffering from dyslexia.

The categorization and evaluation were conducted independently by two raters. The agreement between the raters was calculated using Hemmerich [8]. The interrater correlation, calculated with Cohen's Kappa, was 0.7 for the evaluation of the methods, and 0.72 for the evaluation of the content. The ratings are available in the table in the appendix.

Results

Evaluation

As shown in the figure in the appendix, of the remaining 24 articles, 12 were unanimously rated green by both raters in terms of *methodology*, 6 were rated yellow in relation to the methodology and none were rated red.

Regarding the *context and benefit for this review*, 16 were unanimously rated green (appropriate), 2 were rated yellow (partially appropriate) and none of the remaining 24 were rated red. The following categories have been agreed upon. It is important to note that an article has been assigned to a category if it primarily focuses on topics that can be assigned to that category.

Symptoms and Assessment

The subject of 14 articles was the continuation of symptoms into adulthood. The text mentions a range of symptoms, including low discrimination ability, poor reading skills [12], persistent difficulties in reading and writing, anxiety about reading [9], weak reading and spelling skills of unknown words despite good IQ [16], difficulties in text production [17], and having fewer learning strategies [15]. Additionally, it was observed that poor reading skills were stable [13] and like those found in children [14]. In terms of assessment, a one-minute reading test was evaluated for its validity and test-retest reliability, demonstrating positive results [21]. The Adult Reading Questionnaire (ARQ), a tool for assessing individual risks and identifying reading and spelling difficulties [3], was tested in Norway and found to be effective [22]. Furthermore, the Writing Quality Scale (WQS) was found to be a useful tool in the UK for identifying writing difficulties with sufficient interrater reliability (k=0.67) [23]. In addition, a tool for measuring reading fluency was validated [24].

Comorbidities

Three articles were consistently categorized as reporting comorbidities by both raters. The comorbidities found to be in focus for dyslexia were abusive alcohol use, Developmental Coordination Disorder (DCD), and Attention Deficit/ Hyperactivity Disorder (ADHD). Moreover, according to research, university students with dyslexia tend to exhibit higher levels of impulsivity and negative drinking motives [9].

Barriers and Support for Academic Achievement

Academic achievement was analyzed in 6 articles, 4 with surveys (retrospective) of inhomogeneous sample sizes ranging from 12 individuals with dyslexia to above 2000. One study [30] focused on prevalence data of a cohort sample in UK. Just one article assessed performance with standardized assessment scales [19]. Furthermore, the text highlights the importance of noting that reading anxiety can have an impact on performance at university [13]. It has been observed that individuals with dyslexia tend to achieve lower grades and experience less academic success in university [15]. Despite completing their studies at similar rates, students with dyslexia tend to receive lower grades and repeat courses more frequently [4]. According to research, self-efficacy has a positive correlation with the use of learning strategies among students with dyslexia [18]. Additionally, it has been noted that rapid automatized naming, which is a core cognitive feature of dyslexia, can predict academic achievement [19]. The topic of university performance and achievement is covered in five articles.

It has been suggested by sources that individuals with dyslexia may benefit from increased access to technological support [10]. Additionally, autocorrection systems have been found to be helpful for those with dyslexia in writing content [20]. Emotional and personal/social support is also considered to be a crucial factor for individuals with dyslexia, as noted by experts [7]. Although the systematic review primarily focused on remediation, only three articles were found to be directly related to remediation and support for students with dyslexia. Some articles briefly mention support centers or contact points at universities that offer aid to students in various areas, including dyslexia (e.g., [20]); however, these centers are not the main subject of the articles.

Discussion

In contrast to the extensive literature on dyslexia in children, research on adults, particularly among university students, is limited. There is robust evidence for persistence in symptoms of dyslexia from early schooling into adulthood [28, 29]. Despite having a good IQ [16], practice and motivation, dyslexic university students continue to experience core problems from childhood, such as low reading fluency and orthographic competencies [12, 13] and they still perform worse on various writing and reading tasks, apart from reading comprehension, compared to matched control groups (for a comprehensive review see [28]). In addition to the core symptoms, individuals may experience challenges with text production [17] and text checking [20]. Explicitly for university students they have difficulties with note-taking, essay organization and written expression. These difficulties, which manifested themselves in different patterns, were also observed in these students in earlier educational phases [30].

Additionally to dyslexic specific symptoms, a couple of articles highlight increased levels of anxiety in university students diagnosed with dyslexia compared to peers without learning difficulties [11, 31] combined with lower self-esteem [32]. However, there are also contradictory results regarding differences in anxiety levels [33], which can be seen as a need for further research.

Students may need to demonstrate determination and perseverance to overcome these challenges. According to Bergey et al. [15], it has been observed that students with dyslexia tend to have higher repetition rates in courses and lower grade point averages and lower academic achievement as compared to their peers without dyslexia. However, it is noteworthy that both groups have similar completion rates. This indicates that students with dyslexia may require additional support and resources to successfully complete their studies. Consecutive or comorbid conditions may be present in childhood or in the specific group of students with dyslexia, such as fear of reading [13] or compensating for lower self-esteem through alcohol consumption [9].

It is important to note that despite having good learning motivation and intelligence, these students may require additional support to successfully complete their chosen course of study. Based on the literature, we have summarized three levels:

A) Awareness and recognition of persistent symptoms is important, as core symptoms may persist and be compounded by additional difficulties related to studying. Effective testing procedures are necessary, and further assessment tools should be developed to address students' learning strategies and difficulties in demanding tasks, including reading and writing.

B) It is important to be aware of and recognize comorbidities and accompanying symptoms that can make learning with dyslexia even more challenging. Some common conditions that may interfere with learning, like ADHD [24]. As such, it may be beneficial for dyslexia assessments to include screening for these conditions. Comorbid conditions of people with learning disorders are well known in children [3] but less analyzed in the specific population of university students. High prevalent comorbidities as depression are not analyzed yet, but others are highlighted, like abusive alcohol drinking. More studies about highly occurring comorbid conditions are needed.

C) Information should be provided regarding available support options for learning and examination conditions. Additionally, awareness should be raised about potential learning strategies and technical aids.

Conclusions and Possible Next Steps

The aim of this study was to search for literature specifically focused on academic achievement in university students with dyslexia. Dyslexia is a persistent condition that can make learning and academic performance more challenging. As the concomitant symptoms can persist into adulthood and may even worsen, the gap between neurodiverse and neurotypical individuals tends to widen the further one progresses along the educational pathway. While core symptoms are like those found in childhood, additional symptoms beyond the core symptoms and comorbid disorders can be distressing for studying. Therefore, it is important for students to be aware of symptoms, comorbidities, and support systems.

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17. Words Unleashed: A Systematic Literature Review Study on to Use of Current Assistive Technology for Adults with Dyslexia

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Abstract

This systematic literature review (SLR) explores the topic of assistive technology (AT) for adults with dyslexia, to investigate the gap in research beyond the focus on children. Dyslexia, a neurological condition affecting reading and writing abilities, presents challenges that AT aims to tackle. Through a comprehensive and systematic search across multiple databases, the review identifies various AT solutions and categorizes them. However, it highlights a scarcity of studies systematically evaluating AT effectiveness specifically for adults, indicating a critical area for future research. Still, we aimed for identifying facilitating factors and hindering factors for the effective use of AT discussed in the analyzed papers. Additionally, this work concludes that existing research is primarily centered on children, and therefore identifies a need to extend understanding to adult contexts such as professional life and higher education.

Introduction

A significant proportion of the population is affected by dyslexia, which is a neurological condition that affects a person's ability to read, write, and spell. It is a specific learning disability often characterized by difficulties with accurate and/or fluent word recognition and poor spelling and decoding skills [1, 5, 6, 27]. AT can provide tools and solutions that help alleviate the challenges associated with reading and writing. These technologies aim to increase accessibility, support comprehension, and improve the overall learning experience for persons with dyslexia [1, 17]. "While direct instruction reading programs aim to remediate reading skills, research suggests that assistive technology (AT) can effectively accommodate reading, writing, and spelling difficulties so those with dyslexia can access their education" [18]. AT for reading and writing have the potential to support the writing skills of persons with dyslexia. Despite this potential, they often do not make full use of these features, and there is a lack of comprehensive research that addresses the relevant technological features [19]. Therefore, this paper addresses the following research question: What assistive technologies are reported in the literature to support adults with dyslexia (and its synonyms) in their every day (work) or educational lives?

State of the Art

The existing literature primarily focuses on children and their learning processes within the school environment. Several literature reviews have explored this area, as evidenced by references such as [7, 8]. However, there is a noticeable gap in research concerning dyslexia across all age groups. The main focus of the majority of studies lies on children and under-age students, e.g. [6, 11, 13, 24]. Only a few studies have addressed this issue, and even fewer have specifically examined dyslexia in adults within their professional lives, vocational education and training (VET), higher education, or leisure activities. Notable exceptions to this trend include studies referenced in [1, 7, 22]. Furthermore, our state-of-the-art analysis for systematic literature reviews (SLR) in this area revealed another potential issue despite the focus on a different target group: Some studies did not appear to have been conducted systematically. This lack of a systematic approach can lead to several disadvantages: Traditional literature reviews often suffer from bias and subjectivity due to researchers' selective sourcing, leading to potential cherry-picking and limited scope. In addition, these reviews require more transparency in methodology, which hinders reproducibility and may miss relevant studies, thus posing challenges for replication and comprehensive understanding. In summary, while existing literature reviews offer a solid foundation for our specific focus on "AT for adults with dyslexia," they exhibit certain limitations. These include a lack of a systematic approach with associated drawbacks, focusing on different demographics or contexts, or being too outdated for our purpose. Therefore, to address these gaps, we conducted a SLR to provide a more comprehensive understanding of the topic.

Methodology – Systematic Literature Review

The SLR is a method used to categorize and capture extensive sources of information on a specific topic. This method aims to use the results of the literature search in an analytical way to address a specific research question [30]. This SLR is based on the guidelines for performing Systematic Literature Reviews in Software Engineering [12]. For the SLR, a search query was created that centered on the topics of dyslexia and AT and excluded children, training/ therapy and aphasia[2]. Wildcards and Boolean operators were used to obtain the search results (with minor alteration to the syntax depending on the search engine):

```
"query": {(dyslexia OR dyslexic OR "reading disorder" OR
"reading disorders" OR "spelling disorder" OR
"spelling disorders") AND ("assistive technology" OR
"assistive technologies") AND NOT children AND NOT therapeutic
AND NOT therapeutical AND NOT training}
"filter": {E-Publication Date: (01/01/2014 TO 02/29/2024)}
```

The databases selected for the study include Web of Science, ACM Digital Library, Springer eBooks, and IEEE Xplore. Inclusion and exclusion criteria were applied based on language (English, German), journal peer review status, full-text availability, study and publication type, a clear focus on AT and dyslexia, the paper's impact factor, and the study's classification in computer science or engineering.

For the SLR itself, the final search query initially yielded a total of 189 results. However, after applying our exclusion and inclusion criteria, we refined the results down to a total of 20 relevant findings. The table below breaks down the results for each individual search engine.

Table 17-1: Systematic Literature Review Results

Name of Database	Results (total)	Results after pre-screening	Paper analyzed
Web of Science	43	20	8
ACM Digital Library	54	1	1
Springer eBooks Computer Science	63	4	3
IEEE Xplore	29	5	3
Total	189	30	15

There are several reasons why certain studies were excluded from the review. Studies that did not specifically focus on AT and dyslexia were excluded, as these topics were outside the scope of the research interest. In addition, studies that focused solely on web accessibility or universal design, rather than AT, were also excluded. Duplicates were also removed from our analysis to ensure data accuracy. Specifically, we identified and removed duplicates from several databases, including IEEE (5 duplicates),

[2] Aphasia arises from damage to specific areas of the brain responsible for language functions [21].

ACM (5 duplicates), and Springer (1 duplicate). This process helped to streamline our research and eliminate redundant information.

Summary of Results - Dyslexia and Assistive Technology in Literature

Target Group

The analyzed papers covered a range of target groups within the dyslexia community. The breakdown by category shows three main target groups in the analyzed literature: Several studies targeted the general dyslexic population and various AT tools and strategies applicable to a wide range of dyslexic individuals, including Srivastav & Agarwal (2015) [28], Alsobhi et al. (2014)[3], Di Gregorio et al. (2022) [9], Evtimova und Nicholson (2021) [10], and Renaud et al. (2020)[26]. A significant portion of the research focused on students with dyslexia. Lerga et al. (2021) conducted a broad literature review encompassing AT used by students from primary school to university. Mossige et al. (2023) [19] and Alsobhi et al. (2015) [2] also investigated AT for students with dyslexia, though specific age groups weren't mentioned in Mossige et al. (2023) [19]. Finally, Patnoorkar et al. (2023) [24] specifically targeted learners with dyslexia. Poobrasert und Phaykrew (2021) [25] targeted Thai students with learning disabilities (LD) who struggle with writing, though not necessarily limited to dyslexia. Vangeli's work [29] addressed learners with dyslexia, but without specifying age or educational level. Two studies focused specifically on university students with dyslexia. Pařilová & Remšíková (2018) [23] conducted user experience research with dyslexic university students, while Baeck et al. (2023) [4] studied a group of nine adolescent dyslexic students.

Identified Assistive Technologies

After conducting a thorough review of the selected papers based on the predefined and previously described criteria of the SLR, we have categorized various ATs into four groups, each tailored to address specific needs encountered by individuals with dyslexia. While many tools can be used by children with dyslexia, we have only included AT in the list that, based on our research, is also suitable for adults in educational as well as other contexts.

Reading Support

- Text-to-Speech (TTS): Literature deals with examples for software that reads text aloud are Kurzweil 3000 [14], Read&Write, IDEAL eBook reader [24], ClaroReader, OribiSpeak [19]
- Read-aid tools: Improve reading patterns, e.g. Read-aid tool [2]
- Eye-tracking technologies: Identify reading patterns, e.g. Dyslexia Explorer [24]
- Text Modification Solutions: Change text appearance for better readability, e.g. Text4All, IDEAL eBook reader, MultiReader, DysWebxia [9]
- Web Accessibility Tools: Customize websites for reading ease, e.g. Firefixia [9]
- Audiobooks [4]

Writing Support

- Speech-to-Text: Dictate text instead of typing [4], e.g. AppWriter [19]
- Word Prediction: Suggests words as you type [25]
- Spell Checkers: Identify and correct spelling errors [25,26]
- Pictures for Vocabulary Building: Learn new words through pictures [25]
- Grammar Checkers: Improve grammar and sentence structure [19]

Learning and Organization

- Adaptive e-learning systems: Personalize learning materials, e.g. DAELMS [14]
- Virtual Learning Environments (VLEs): Improve writing efficiency [2,24]
- Mind Mapping Software: Organize thoughts and information [25]
- Note-taking Apps: Organize notes and information [3]
- Calendar Apps: Manage time and tasks [3]

Other

- Phonological Awareness Education Software: Improve phonological skills [14]
- Games: Enhance reading and writing skills through play, e.g. DysEggxia, iLearnRW [24]
- Password Managers: Assist with password creation [26]

Facilitating Factors for an Effective Use of Assistive Technology

Personalization and Accessibility

Tailored applications, such as those designed specifically for individuals with dyslexia, can significantly enhance accessibility. These applications offer customizable features like adjustable fonts and layouts, catering to individual needs [14, 19]. Conducting user preferences testing is crucial for tailoring AT. By identifying individual preferences, it becomes possible to customize the technology effectively [23]. Ensuring smooth transition across devices is essential for helping users familiarize themselves with new functions seamlessly [4]. Reducing reliance on reading and spelling can be achieved through the implementation of graphical passwords and other alternatives, lessening the burden for dyslexic individuals [10]. Incorporating an inclusive design process by involving dyslexic users in the design of applications ensures that the technology effectively enhances their reading skills [29].

Use of Assistive Technology

Comprehensive training is essential for enabling students to effectively utilize AT, as it equips them with the necessary skills and knowledge [14]. Additionally, continuous support is crucial to ensuring the sustained effectiveness of AT, emphasizing the need for ongoing assistance and guidance [4]. Moreover, the implementation of assistive writing tools, including spellcheckers, autocorrection, and word prediction, serves as invaluable aids in text production for dyslexic individuals, significantly enhancing their writing process [20]. Furthermore, targeted design of AT specifically tailored to address dyslexic challenges, such as incorporating text-to-speech functionality to assist with reading difficulties, further enhances the efficacy and usability of these tools [24].

Supportive Learning Environment

Ensuring the availability of digital course materials is crucial in facilitating access for dyslexic individuals, as it provides them with alternative formats that cater to their needs [3, 15]. Moreover, granting permission to use AT software during classroom sessions and offering options for leaving the room to utilize specific functions (like TTS or STT) can greatly support dyslexic learners in their educational endeavors [4]. Additionally, the personalization of learning environments to accommodate various learning styles, including the integration of multi-sensory approaches, proves beneficial for dyslexic students, enabling them to engage more effectively with the material [2, 24].

Hindering Factors for an Effective Use of AT

Inadequate Software Design Process

One key issue is the inattention to the diverse types of dyslexia, as developers may overlook varying presentations when designing e-learning applications, potentially leading to a mismatch between user needs and available tools [3]. Additionally, issues such as poor interface design, technical bugs, and lack of functionality contribute to the frustration and decreased adoption of AT tools [29]. Furthermore, the limited scientific evidence on user needs and effective design principles presents a significant challenge, making it difficult to develop AT solutions that truly address the challenges faced by dyslexic users. Combined with insufficient user involvement in the design process, this can lead to AT tools that do not align with the needs and preferences of dyslexic individuals, highlighting the importance of direct user engagement in the development process [29]. And in general, an incomplete understanding of dyslexia can hinder progress, resulting in AT solutions that fail to adequately address the core difficulties experienced by individuals with dyslexia [29].

User Interface Challenges

Generic e-learning applications, not tailored specifically to the needs of dyslexic individuals, may present obstacles that hinder their effectiveness, potentially impeding the learning process [14]. Moreover, while TTS technology can offer valuable support, overreliance on this feature for young learners with dyslexia may not foster the development of active reading skills effectively [14]. Additionally, inconsistent support for accessibility features across different reading devices and applications poses a significant challenge, making it difficult for users to seamlessly access AT solutions [16]. Furthermore, a lack of awareness of existing AT functionalities, coupled with fragmentary support in utilizing these tools, further exacerbates the issue, limiting the potential benefits for dyslexic students [4]. Moreover, abrupt transitions between devices with different AT features and privacy concerns associated with STT technology in classroom settings add additional layers of complexity, potentially disrupting the learning experience and restraining workflow for dyslexic users [4].

Limitations of Specific Assistive Technology Tools

Spellcheckers, while intended to assist with spelling errors, can inadvertently demoralize students with dyslexia due to the constant identification of mistakes, potentially undermining their confidence [19]. Features such as flashing word suggestions and autocorrection mechanisms can introduce distractions and hinder writing fluency, particularly for users with attention difficulties [20]. Additionally, challenges with word prediction and autocorrection functionalities, including difficulty in selecting the correct word and the cognitive load associated with managing these features, can hamper writing speed and flow [20]. Furthermore, the cognitive load of word completion may not necessarily lead to increased typing speed, further complicating the writing process for dyslexic individuals [19]. Moreover, mis-corrections by autocorrect features can cause confusion and embarrassment, prompting many users to disable the function altogether [19]. The overemphasis on spelling correction within AT features can also disrupt writing fluency, particularly for students struggling with spelling, further complicating the learning process [20]. Additionally, challenges with optical character recognition accuracy and variations in TTS quality pose additional barriers for dyslexic users, hindering their access to vital information [9].

Future Research Areas in the Field of Assistive Technology for Dyslexic People

In addition to the other areas of investigation, we also analyzed future research areas or research gaps mentioned in the papers.

For security, authentication, and password management, it is crucial to understand how dyslexic individuals cope with password management in real-world scenarios. Additionally, adapting password managers to better support dyslexic users, possibly through features like tailored password suggestions and alternative input methods, can significantly improve accessibility. Investigating ways to make multi-factor authentication systems more accessible for dyslexic users and exploring alternative authentication methods such as musical clips or multisensory environments are areas interesting for research [26].

Emphasizing open-hardware AT as a promising avenue allows for customizable features that adapt to users' changing needs and preferences. This approach holds potential for enhancing the accessibility and effectiveness of assistive technology for dyslexic individuals [24]. Of course, this seems like a desirable path for other user groups and AT in general.

Moreover, there is a notable gap in knowledge regarding the specific needs of adults with dyslexia and how AT can best support them. Future research should prioritize exploring assistive technology solutions tailored to this under-represented population to ensure inclusivity across all age groups. [24]

Investigating practical coping strategies that dyslexic individuals currently employ for managing passwords and other everyday tasks can provide valuable insights for designing effective assistive technology solutions. Understanding these strategies is essential for developing user-centric approaches that truly meet the needs of dyslexic users. [26]

Exploring design quality issues identified by dyslexic users and validating the effectiveness of existing interaction design guidelines are important steps. Involving dyslexic individuals actively in the design process through participatory methods fosters inclusivity and ensures that solutions are truly user-centered. Additionally, evaluating the potential of interventions to support students' use of speech-to-text (STT) technology and examining whether specific writing tools can enhance writing fluency are crucial for advancing assistive technology for dyslexic individuals. Incorporating AI, augmented reality (AR), or game-based learning into future developments can further enrich educational processes for dyslexic students. [4, 14, 20, 29]

Conclusion

The systematic literature review has yielded interesting results, revealing numerous types of ATs for adults with dyslexia discussed in the literature. The first step of our study was to determine the state-of-the-art of AT for adults with dyslexia. Our SLR and its iterative approach have shown a predominant focus on dyslexia research among children in the early stages of education. After adjusting the search query to match the research question, it became clear that there is an existing research gap in AT for adults. Consequently, there is a need to explore the use of existing AT solutions, primarily trialed with school-age children, for adults with dyslexia in diverse settings such as their professional life, higher education, or VET. The current state of research shows that AT is a promising approach to supporting adults with dyslexia in their daily life and improving their literacy skills. While our research has revealed a set of facilitating and hindering factors for the effective use of AT, future research should focus on further investigating the effectiveness of these technologies and developing innovative but scientifically proven solutions to overcome the challenges faced by people with dyslexia, aligning with our plans for the next steps in our journey and taking our finding of chapter “future research and further development” as basis.

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18. Exploring AR, VR, and Educational Robotics for Inclusive Mathematics Education for Dyslexic Students

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Abstract

Dyslexic students often face challenges in comprehending mathematical concepts. Numeracy issues in dyslexia include symbol confusion, digit reversal, problem-solving challenges, slow calculations, and spatial perception difficulties, leading to a significant gap in learning outcomes. Inclusive learning approaches that cater to the specific needs of dyslexic students are essential to promote their mathematical understanding and engagement. The authors investigate the traditional inclusive learning approaches and explore the potential integration of augmented reality (AR), virtual reality (VR) technologies, and educational robotics (ER) to support dyslexic students with mathematics education. AR and VR in education have shown promising results in enhancing student learning experiences across various domains. By creating immersive and interactive environments, these technologies have the potential to enable dyslexic students to explore mathematical concepts in novel and engaging ways. ER integration can complement AR and VR experiences by providing tangible and interactive tools, bridging the gap between the physical and digital worlds. By leveraging AR, VR, and educational robots, educators can create an inclusive and supportive learning environment, promoting active participation and knowledge retention among dyslexic students. The paper also highlights the significance of professional development for educators, aiming to provide educators with essential knowledge and skills to effectively implement these technologies in the classroom and cater to the diverse needs of their students. By integrating current research and best practices, the paper aims to advance inclusive mathematics education to promote equitable learning opportunities to support all students in a holistic way for mathematics education.

Keywords: Dyslexia, Mathematics, Inclusion, Immersive environments, Virtual Reality (VR), Augmented Reality (AR), Educational Robotics (ER).

Introduction and Background

Dyslexia is a learning disability that hinders a student's learning ability. It affects their reading, spelling, and writing but can also impact the understanding and processing of mathematical concepts [3, 15, 19]. The prevalence of dyslexia varies significantly based on the definition used in research studies, with estimates ranging between 4% to 17% and an internationally agreed average worldwide estimate of 10% [30].

Dyslexia's impact on mathematical learning extends beyond reading difficulties, presenting significant barriers to inclusive mathematics education [43]. Dyslexia can sometimes make it harder for students to process sounds and put their thoughts into writing [43]. As a result, they may face challenges when trying to show their understanding through written assignments or exams. For dyslexic students, remembering mathematical facts can sometimes be a real challenge, and they might use less effective strategies [24], making them uneasy and hesitant when learning or answering questions. On top of that, some may find it hard to grasp the concepts of the number system, leading to a lack of 'number sense'. If these difficulties are not addressed early on, they can continue to impact their lives in a significant way [24]. The lack of suitable accommodations and support further highlights the importance of fostering inclusivity in mathematics education [46].

Educators support students with Specific Learning Disabilities (SLD) using tailored resources such as engaging activities with visual aids, hands-on projects, and interactive experiments [38]. These interactive approaches enhance comprehension and boost confidence in dyslexic students. Information Communication Technology (ICT) tools have aided dyslexic students [18]. Integrating ICT tools creates an inclusive learning environment, enabling students to overcome challenges and increase their confidence and motivation. Extensive visual aids in the learning process have been found to benefit dyslexic students [54]. VR/AR are additional tools that can support dyslexic students in their educational journey [7]. ER can be presented as learning about robots or learning with robots as educational tools. This paper focuses on the second approach, exploring how mathematics education can be enhanced through interaction with robots. ER offers promising opportunities to enhance inclusivity in mathematics education for dyslexic students. By engaging with tangible, hands-on robotic activities, dyslexic students can experience a multi-sensory learning approach that taps into their visual and kinaesthetic strengths, complementing traditional text-based methods.

Mathematics Teaching Methods for Dyslexic Students

Dyslexic students include a diverse group with varied characteristics, requiring targeted support at different educational levels [56]. In the primary school environment, dyslexic students are in the early stages of literacy development, necessitating early identification and intervention [12]. At the secondary level, dyslexic students face more complex academic demands and subject-specific content. Accommodations such as extended exam time, assistive technology integration, and individualised education plans become crucial to facilitate their academic success [12]. By understanding the challenges dyslexic students face at each level and employing appropriate interventions, educators can foster a supportive environment to help these students achieve and succeed academically. In order to create an inclusive learning environment for dyslexic students in mathematics, educators need to implement effective teaching strategies and utilise assistive technologies.

Conventional Approaches in Mathematics Education

One key challenge in mathematics education is relying heavily on traditional teaching methods. These methods may involve text-heavy explanations, a rapid pace, and a focus on memorisation of mathematical procedures [32]. For dyslexic students who struggle with processing written information and have difficulties recalling sequences and procedures, these conventional teaching approaches can be overwhelming and frustrating [29]. Consequently, dyslexic students may fall behind in mathematics, leading to a lack of confidence in their mathematical abilities and disengagement from the subject.

Visual Aids and Manipulatives to Enhance Understanding

Visual aids and manipulatives influence dyslexic students' understanding of mathematical concepts, and there is a link between dyslexia and visual-spatial talents [29, 49]. While some studies suggest strengths in visual-spatial thinking for dyslexic students, discrepancies exist due to varied definitions and assessment methods [55]. Educators should accommodate different learning styles by providing multiple representations of mathematical concepts and facilitating a deeper understanding of students' learning abilities or skills. Dyslexic students may excel in 3D spatial thinking connected to mechanics and complex visualisation, but conflicting views exist, with some studies showing lower scores on nonverbal spatial tasks [10, 22].

Breaking Down Complex Problems into Manageable Steps and Encouraging Verbal Expression

Complex mathematical problems can be overwhelming for dyslexic students, making it essential for educators to break them down into manageable steps, which allows students to focus on one component at a time, reducing cognitive load and promoting better knowledge retention [60]. This approach includes providing clear and structured learning materials, offering feedback that emphasises effort and improvement, and encouraging students to have more autonomy and choices in their learning process [24, 42, 43].

Encouraging dyslexic students to engage in verbal expression and discussion enhances their grasp of mathematical techniques. Group discussions allow students to articulate their thoughts and reasoning, allowing them to reinforce their understanding of concepts through active participation [40]. The collaborative nature of group discussions fosters a supportive learning environment where students can learn from each other's approaches and insights.

Assistive Technology for Dyslexic Students in Mathematics

The transformative process of adopting assistive technologies, particularly in empowering students with disabilities to unlock their utmost capabilities, entails a diverse array of specialised tools precisely designed to meet the diverse requirements of students with learning or sensory disabilities. These tools encompass a spectrum of solutions, ranging from fundamental aids like screen readers for vision-impaired students [8] to ubiquitous smartphone calendar applications, assisting students with specific cognitive challenges in organising their academic timetables.

Text-to-speech (TTS) software is a robust aid for dyslexic students in accessing and producing mathematical content. This software allows students to listen to mathematical instructions, problems, and explanations, providing an auditory reinforcement of the material. Additionally, the speech-to-text (STT) application enables dyslexic students to express their mathematical ideas and responses using spoken language, which can be especially beneficial for those with difficulties in writing or spelling [13, 31].

Exploring Multimodal Learning in Mathematics for Dyslexic Students

Early detection of dyslexia plays a crucial role in facilitating timely support during critical learning stages. By leveraging eye-tracking technology, valuable data can be collected from young students with dyslexia, aiding in the early identification of reading difficulties [5]. Eye-tracking studies suggest that analysing eye movements during reading can help design dyslexia-friendly interfaces and efficiently identify children at risk of long-term reading difficulties by detecting differences in eye movements between dyslexic and non-dyslexic individuals [36, 37]. In mathematics, students with dyslexia may experience challenges with understanding mathematical symbols, sequencing numbers, and solving word problems [29, 52]. Some established strategies for dyslexia and mathematics education include multimodal approaches, structured explicit instruction, and cognitive training [21]. Multimodal approaches involve engaging multiple senses, such as touch, sight, and hearing, to reinforce learning. For dyslexic students, this can mean incorporating tactile elements, visual aids, and auditory cues in the mathematics learning process. Structured explicit instruction entails breaking down complex mathematical concepts into smaller, more manageable steps, providing clear explanations and ample practice opportunities. Cognitive training focuses on enhancing cognitive functions such as working memory, attention, and processing speed, which can indirectly improve mathematics performance.

AR/VR Technologies

To effectively engage dyslexic students in mathematics, educators can adopt innovative teaching methods incorporating AR/VR technologies. These approaches offer a hands-on, interactive learning experience that caters to the diverse learning needs of dyslexic students, providing them with a multimodal and engaging platform to grasp mathematical concepts. Moreover, research has shown that utilising VR has improved attention skills in dyslexic children, indicating the potential for positive outcomes in their learning [44]. Using haptic feedback and spatial sound in AR/VR enhances dyslexic students' engagement by providing tactile interactions, kinaesthetic learning, and 3D auditory guidance. Dyslexic students may benefit from AR/VR immersive environments, where they can interact with and manipulate 3D models, facilitating a deeper understanding of subjects such as geometry. This multisensory approach, combined with real-time collaboration, personalises the learning experience, fostering inclusive education for dyslexic individuals [20, 50]. Embracing these immersive technologies can lead to remarkable improvements in dyslexic students' academic outcomes.

Reading skills are essential in comprehending mathematics curriculum, which is one of the major problems dyslexic students have. In a recent study, the researchers examined the effects of the Virtual Reality Rehabilitation System (VRRS) on dyslexic children. While VRRS has been applied to improve cognitive and language deficits in patients with neurological impairments, its impact on children with dyslexia remained unexplored. Thus, the study aimed to evaluate the effectiveness of VRRS as an intervention for children with dyslexia. The results showed a significant improvement in word-reading skills, suggesting that VRRS can lead to enhanced outcomes through active exploration, increased engagement, and the provision of motivation and enjoyment via VR [33].

Educational Robotics (ER)

ER involves the integration of robots and computational tools into the learning process to foster a deeper understanding of mathematical concepts and enhance the overall learning experience for students [59]. Research has indicated that robots have the potential to facilitate students' problem-solving skills and foster their understanding of mathematics [6, 17]. It can offer significant new educational benefits at all levels [16]. As dyslexic students learn best through observation, demonstrations, diagrams, or hands-on activities [6], it is important to explore the potential of ER to support the learning process. Robots usually have multiple sensors, such as sound, light, distance and colour. They can be programmed to assist teachers in presenting mathematics curricula in an interactive and customised format. Incorporating robots in the learning process positively impacts dyslexic students, offering interactive experiences and ample time for tasks, capturing their attention, and enhancing their overall learning experience [23, 41].

Robots could offer real-time feedback, adaptive challenges, and interactive simulations [47], fostering a deeper engagement and motivation for dyslexic students and optimising their mathematical skills and confidence. For example, LEGO Mindstorms EV3 robots can provide interactive and dynamic platforms for students to explore mathematical concepts, enhancing their understanding of abstract topics through concrete, real-world applications [2, 26]. Additionally, the collaborative nature of robotics activities promotes social interaction and teamwork, which can further support dyslexic students' learning experiences. The combination of experiential learning, visual aids, and social engagement in ER creates an inclusive and effective learning environment [4, 59] that caters to the diverse needs of dyslexic students in mathematics education. To address the visual and spatial difficulties experienced by dyslexic students, the ROBIN project [45] provides empirical evidence that the robot-maze activity is a beneficial exercise; by employing screen-guided robot navigation and physical robot imitation, the intervention proves to be effective in enhancing the visual-spatial skills of dyslexic students.

Recognising The Needs of Dyslexic Students in Mathematics

It is essential to recognise and address the unique needs of dyslexic students in mathematics to create an inclusive learning environment. Understanding how dyslexia affects their mathematical learning helps educators and policymakers develop evidence-based strategies that enhance mathematics education for these students, fostering a more supportive and inclusive setting.

Challenges Faced by Dyslexic Students in Mathematics

AHEAD [1], an Irish organisation supporting persons with disabilities, identified common challenges dyslexic students face in mathematics, such as organising information, comprehending word problems, and recalling procedures [20, 52]. These challenges emphasise the importance of inclusive mathematics education that considers the unique needs and strengths of dyslexic students. By acknowledging the specific challenges faced by dyslexic students and tailoring teaching strategies to meet their needs, educators can take proactive steps to foster inclusivity in mathematics classrooms. In a recent study, researchers developed an AR content to teach English vocabulary to dyslexic students. The study findings revealed that students with dyslexia acknowledged the challenges they face in memorising English vocabulary but expressed a positive outlook on the potential of AR technology to assist them in this regard [25]. Considering the integration of English concepts within mathematics, such AR-based content shows promise for effectively teaching mathematical concepts to dyslexic students as well.

Impact of Mathematics Anxiety on Dyslexic Students

Mathematics anxiety is a negative emotional response to numbers and mathematical equations. For dyslexic students, this anxiety is even more pronounced, affecting their ability to work with numbers and solve mathematical problems, ultimately hindering their overall learning experience in mathematics [9]. VR and AR can offer interactive visualisations of mathematical concepts, making them more concrete and easier to grasp [53, 58]. VR and AR can create a safe space for students to practice without fear of making mistakes [11]. Students who feel less judged and anxious about errors are more likely to explore and learn from their mistakes, leading to better mathematical comprehension. Integrating gamification elements into VR and AR mathematical applications can make learning enjoyable and less stressful for dyslexic students [39]. Additional mathematics-specific applications also offer customised exercises, visualisations, and step-by-step guidance, catering to students' learning needs. These applications often incorporate gamification elements, making the learning process enjoyable and motivating for dyslexic students. One significant advantage for students is that their mistakes go unnoticed by others, allowing them to enjoy the process of striving for personal improvement. Such applications include Maths Tricks, Maths Workout, and Maths Pieces (Maths puzzle game). With these applications, students can explore the intricacies of numbers and patterns at their own pace, making learning a fun and engaging experience. Students can monitor their progress and work towards achieving their best performance in a supportive and private environment [57].

Impact of Memory on Dyslexic Students

Having a strong short-term and working memory is essential for mental arithmetic. A student with weak short-term and working memories may struggle with mental mathematics, emphasising the importance of good memory skills for overall mathematics performance [27, 30]. Mathematical calculations and problem-solving require a cognitive process, often involving sequential steps. As a result, working memory (short-term memory) plays a significant role in children's mathematical progress [27]. AR/VR can serve as promising tools in supporting dyslexic students facing memory-related challenges. These technologies enable the creation of memory-enhancing games and exercises that address the learning needs of dyslexic students. Dyslexic students may struggle with spatial awareness and orientation. VR simulations can help them practice and improve these skills, which are essential for memory and learning [14].

Supporting Dyslexic Students in Mathematics Education: Strategies and Considerations

Continuous assessment is crucial for supporting students who encounter difficulties, especially dyslexic students. Technology's flexibility, providing the ability to adjust screen colours and fonts, makes it highly suitable for use on computers and interactive whiteboards by dyslexic students [24]. In a recent project [51], researchers developed a mobile app with the specific aim of enhancing the reading, comprehension, and mathematical skills of dyslexic children. Throughout the initial phase of the application, they actively gathered invaluable feedback and faced challenges related to font selection, text layout, and an excessive number of alternative answers. Therefore, these adjustments play a significant role in developing educational materials tailored to the needs of dyslexic students. Insufficient training may cause teachers to lack the required skills to teach mathematics to dyslexic students effectively [28]. As a result, they end up depending heavily on mathematics textbooks for both content and teaching methods [34]. So, it is necessary to provide comprehensive and specialised training for all teachers (including mathematics teachers) that helps them close the achievement gap for dyslexic students. For instance, the National Council for Special Education in Ireland provides essential support for students with dyslexia in the education system. They offer valuable factsheets to second-level schoolteachers, helping them understand dyslexia's impact and ways to aid and support [35].

Another promising option involves using VR and AR technologies to immerse teachers in simulations replicating dyslexia-related challenges. By experiencing first-hand the obstacles dyslexic students face, educators can gain deeper insights and develop more effective teaching strategies tailored to their needs. Teachers often need help implementing differentiation strategies in their classrooms for various reasons. First, they need more time to plan and prepare lessons tailored to each student's needs. Second, some teachers may feel they lack the necessary expertise to address the diverse learning needs of their students [28]. One critical area that needs attention is preparing Individual Iducation Plans (IEPs) to create a more inclusive and supportive learning environment. These plans are personalised for students with diverse learning needs, and teachers need proper training on creating, implementing, and assessing them effectively [35]. VR can provide a multi-sensory learning environment for dyslexic students [31], offering a different approach to exploring information. VR can be a powerful tool for teachers to differentiate dyslexic students, offering personalised and immersive learning experiences that cater to their learning needs. Through VR experiences, students can engage with content using multiple senses, including visual, auditory, and sometimes tactile elements [14].

Conclusion

This paper highlights the challenges dyslexic students face in understanding mathematical concepts, leading to numeracy issues and probably mathematics anxiety. It also explores the integration of AR/VR and ER to support dyslexic students in their mathematics education. AR/VR technologies create interactive and immersive environments, while ER provides tangible tools, bridging physical and digital learning. This paper underlines the importance of professional development for educators to effectively implement these technologies, promoting inclusive mathematics education and equitable learning opportunities for dyslexic students. The authors investigate the possibility of developing inclusive mathematical learning materials by leveraging the capabilities of AR/VR with ER. The main objective is to design a mathematical interactive content (educational game) that meets dyslexic students' learning needs, ensuring their inclusion in the learning process. Overall, the research contributes to the field of inclusive education and advocates for innovative teaching methods to benefit dyslexic learners and the broader educational community.

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19. Iteration and Co-design of a Physical Web Application for Outdoor Activities with Older Adults

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Abstract

Existing research and physical activity guidelines highlight the benefits of outdoor physical activities for ageing populations. There is potential for technology to facilitate outdoor activity through Physical Web infrastructure. We proposed that embedding Physical Web applications that are engaging and interactive in public open spaces as part of interactive wellness parks can encourage older adults to participate in physical activities outdoors and motivate rehabilitation. We have created an initial design prototype based on design requirements generated from a qualitative field study with 24 older adults to explore their perceptions, experiences, and routines of outdoor physical activities. In this paper, we present an initial prototype and findings from a co-design session with 12 older adults, eliciting their feedback on the design and their ideas for future design iterations.

Introduction

The world population is ageing at an increasing rate, and according to the World Health Organisation (WHO), the number of people aged 60 years and above outnumber children younger than five years [1]. As we age, we are more likely to experience age-related health conditions. Common age-related conditions among older adults include dementia, depression, osteoarthritis, hearing loss, and cognitive decline [7]. Research has shown that regular physical activities among older adults profoundly affect their well-being and can positively contribute to their mental and physical health [2]. This age group's lack of physical activities can result in a sedentary lifestyle [8]. Beyond the physical benefits, physical activities are essential in reducing the risk of cognitive decline associated with ageing and maintaining cognitive function. Additionally, physical activities improve sleep quality [9] and boost overall health and quality of life for older adults [3] Therefore, it is essential to develop community programmes that encourage older adults to engage in regular physical activities because, without adequate strategic planning, the healthcare burden associated with the increase in the number of older adults globally will significantly challenge the healthcare system. [4]

Several global initiatives for active ageing promote physical activities among older adults. According to the World Health Organization (WHO), active ageing is "the process of promoting health, social security, and social contribution of the elderly to promote their quality of life" [5]. Supporting older adults in regular activities is a crucial strategy to foster healthy and active ageing, a general strategy for maintaining physical and spiritual health [6]. There is wide support in the literature for the health benefits for older adults who engage in outdoor physical activity [10;12;11]. Benefits include increased participation in physical activity and the potential for increased social interactions. Creating outdoor mobility opportunities for older adults can improve their quality of life through increased opportunities for physical activity, promoting independence [13]. Therefore, the availability of outdoor spaces within communities of older adults is vital in promoting active ageing, physical activities, and social interaction.

Need for co-design.

Various applications are designed for outdoor physical activities as mobile technologies evolve. These applications include walking apps [14], wearables [15], and exergaming [16]. Research has found that these interventions significantly increased physical activity and reduced sedentary behaviour [17].

However, implementation of these technological interventions has encountered resistance and underuse by older adults [18]. The most common problems include a lack of accessibility and usability for older adults with limited digital literacy [30]. The explanation for these issues could be a lack of consideration for older adults' needs and preferences, and most of these technologies are commercially made for older adults but were not designed with them, nor were older adults involved in the technology development process. Campelo and Katz [19] and [20; 22] reported a positive perception of using technology among older adults despite a lack of familiarity with technology for physical activities. However, Ivan et al. [31] analyse the mutual relationship between ageist stereotypes and technology and conclude that technology, developed by young people with the youth market in mind, produces prototypes that are more difficult for older people to use. Therefore, there is a need to investigate more tailored and accessible applications for outdoor physical activities involving older adults in the design process through co-design. Co-design is a methodology where the user participates in the design process of an application or service as an active co-designer [23]. A codesign-based approach has great potential for the proposed physical web interface. By understanding older adults' needs, preferences, and lived experiences and applying them within an iterative design method, we can co-create an interface that meets their needs. Additionally, this can help with creating an engaging and inclusive design.

Digital Skills Divide Among Older Adults

As older adults become increasingly reliant on digital technologies that young people usually design without their participation, the ability to navigate new technologies has become essential for full participation in contemporary life. However, a persistent digital divide exists. Research has shown that older adults are not a homogenous group and should not be treated as such when designing technology for their needs [24]. While some older adults effortlessly integrate technology into their daily routines, others struggle to adapt, hindered by a lack of experience, interest, health, or access to resources [25]. Recognising the complexities within the older adult population is crucial in addressing these digital differences. There are many challenges in understanding exactly why the age-related digital skills gap appears among this demographic. According to Beneito-Montagut [26], individuals' prior technological experiences significantly influence their ease of navigating new technology. Research has shown that older adults who actively use technology during their professional lives often exhibit higher proficiency, having developed extensive digital skills. Many others in this age group proactively keep up with technological advancements out of personal interest or necessity. However, even experienced users may encounter challenges due to the rapid pace of technological change. Keeping abreast of the latest trends and adapting to new interfaces can be daunting, especially post-retirement, when access to technology may diminish [29]. In contrast, older adults with no prior exposure to technology face even greater barriers to accessing digital information. Motivation to acquire digital skills may be lacking, compounded by limited access to resources and distrust of online platforms [28]. It is crucial to recognise that most older adults, regardless of their past experiences, encounter difficulties in learning and engaging with digital technologies [29]. However, age-related physical, sensory, and cognitive impairments can further intensify these challenges and exacerbate the digital divide [27]. Age-related declines in vision, hearing, motor skills, and cognitive abilities can make it challenging for older adults to use digital technologies effectively.

Design Requirements

At the beginning of this research, focus group workshops were organised to understand the perspectives of older adults. This included their experiences and perceptions of outdoor physical activities and the kind of activities they will be willing to engage in outdoors. Based on the findings from workshops with twenty-four older adults [21]. The following users' preferences were identified for the initial prototype design: creating an outdoor application that older adults with minimal technology skill or interest can engage with (no accompanying app needed to be downloaded), group activities to support socialisation, dance, music activities, and walking. Two essential parts were considered for the development of the prototype. The first was user engagement, designing the outdoor activities for users to engage in, tailored to group or individual physical activities. Second, the technology and the hardware to develop that technology. Physical Web technology was used to create user interaction. The prototype consisted of a user interface with two options: users listen and dance to their favourite music or tour different historic trees around the Technological University Dublin, Grangegorman Campus, which was originally built in the 18th century. An embedded Physical Web user interface was created using components such as the Arduino Nano IoT, the DFPlayer and MQTT. A key characteristic of the Physical Web is that it allows users to access web resources such as multimedia files without requiring them to install a mobile app [32].

Initial Design of Prototype Based on Design Requirements

Dancing and Music Activities: The first activity is the user interaction with the smart post embedded with a QR Code as shown in picture 1-3. On scanning the QR Code, the user is presented with a webpage with the option of choosing the activities they are interested in. If the users pick music, they are asked to select the music they are interested in from the list of music. Subsequently, they can enjoy listening to music directly from the smart post, eliminating the need for their personal phones or downloading additional applications. Additionally, users have the freedom to dance to the music without relying on their mobile devices. The novelty of the interaction stems from the fact that the participants are listening from the artefacts in the physical environment rather than from their phones. However, the prompt to play the music is enacted from their mobile devices.

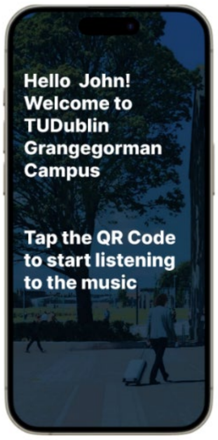

Figure 19-1: Web interface

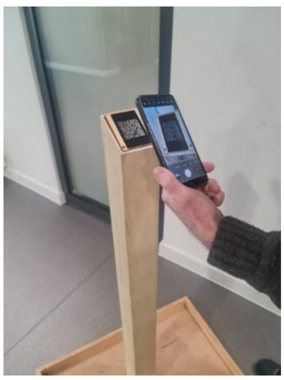

Figure 19-2: User scanning the QR code music.

Figure 19-3: Web interface to initiate the music

History Tours: Following the previous activity is the history tour experience. Upon selecting the history tour option from the web page, users can simply tap the QR code located on the artefact in the physical environment. This action presents them with two choices: they can either listen to the history of the place, which include details about the year it was built, story surrounding the place through the technology integrated around the building, or they can read the information via the web on their mobile phones.

Exploration and Co-design Session

A co-design workshop was organised with 12 older adults at the Technological University Grangegorman Campus in Dublin. This co-design session aimed to:

1. Explore perceptions and experiences of the group's outdoor activities.
2. Elicit feedback on the initial prototype presented above.
3. Use this initial prototype to ideate and iterate on the application design.

Method

Participants

Participants were recruited from a voluntary service organisation, which provides a range of social activities to the local older adult community in Dublin. Inclusion criteria for participating in the session were that they were over 60 years old, could give informed consent, and were willing to try out new technology and discuss their experience of engaging in outdoor activities. Twelve older adults took part in the workshop, with ages ranging from 60-100. Table 1.

Table 19-1: Participants' Demographic Table

P. No	Gender	Age Range	How often do you engage in Physical activity outdoors a week?	Do you currently have a working mobile phone?	Does your phone have internet?	What do you use your phone for mostly?	Have you ever used your phone to scan a QR code	Can you use the on-screen Keyboard on your phone to type?
1	Male	81-90	Everyday	No	No	Receive and make calls	No,	No
2	Male	81-90	Three Times	Yes	yes	Receive and make calls, send messages, social media, Google map	No	No
3	Male	81-90	Three Times	No	No	No Mobile phone	No	No
4	Female	60-70	Everyday	Yes	Yes	Receive and make calls, send messages, social media, Google map	Yes	Yes
5	Male	81-90	Three Times	Yes	No	Receive and make calls	No	No
6	Female	71-80	Everyday	Yes	No	Receive and make calls, send messages	No	Yes, slowly
7	Female	90-100	Everyday	Yes	No	Receive and make call	Yes	No
8	Female	85	Everyday	Yes	No	Receive and make call	No	Yes
9	Female	81- 90	Everyday	Yes	Yes	Receive and make calls, send text messages, social media	Yes	Yes
10		81-90	Female	Everyday	Yes	Receive and make calls, send messages	No	No
11	Female	89	Seldom	Yes	Yes	Receive and make calls, send text messages, social media, Google map	No	Yes, slowly
12	Female	81-90	Everyday	Yes	No	Receive and make calls, send text messages	No	Not

Participants travelled from their activities centre to the university for the workshop. They were divided into three focus groups. Demographic questionnaires were given to the participants to capture their age, how often they engage in outdoor activities, what kind of mobile phone they have, and what they mainly use their mobile phones for. The workshop protocol was developed to explore the initial findings with the participants, introduce the early prototype, and get feedback for further prototype iterations. The workshop lasted approximately two hours. The workshop was divided into two sections; the first was to explore the group's perceptions and experiences about engaging in outdoor activities. A semi-structured interview protocol included some questions from previous workshops under the following themes:

- Types of outdoor physical activities the participants currently engaged in.
- What activities would they prefer to do outdoors?
- Motivation, facilitators, and barriers to engaging in outdoor physical activities.

In the second stage of the workshop, participants were introduced to the Physical Web with explanations and a video showing how technology like QR codes can be used. The facilitators observed the participants' interactions to identify usability and accessibility issues experienced during the process. After the participants interacted with the prototype, feedback and ideas for the next iteration were collected. Participants' inputs were audio recorded, and the group facilitator also used Post-it papers to record participants' reflections.

Analysis

The focus group interactions were audio-recorded and transcribed verbatim. Two researchers reviewed each transcript to ensure the recorded and anonymised identifiable data was accurate according to Braun and Clarke's [33] inductive data analysis framework; post-its data were arranged according to the themes that emerged from the data.

Findings

Four major themes were identified in the data analysis: Ease of prototype use, First impression of the prototype, prototype improvement suggestion, Privacy, and security concern. A summary of these major themes and their subthemes is presented in Table 2.

Table 19-2: Summary of some of the overarching themes, sub-themes and quotes from the data

Major Themes	*Sub Themes*	*Quotes*
Ease of Use	*Limited Understanding of QR Codes functions*	*"Hard to understand", "Difficult to get how it works", "Beyond comprehension for older users", "Cannot be used without smart phone", "Where is the music coming from?"*
First Impressions and Experience of the prototype	*Impressive* *Perceived complexity and Age-Related barriers*	*"Love the experience", "Love the music features", "Love the interaction for outdoor activities", "It will help with social engagement", QR code outside will be good to get easy access to information, "We are too old to be bothered with new technology", "This is for young people", "Too complex for older people to understand*
Prototype Improvement suggestions	*Simpler interactions*	*"Make it easier to use", "For the music application, enable automatic playback minimal interaction", "Consider alternative forms of interaction like loyalty cards or tags", "Simplify with one-button operation", "Consider a smaller device or phone integration", "Enable automatic playback with minimal interaction", "Key holder idea or button for easier interaction"*
Privacy and Security Concerns	*Stolen data*	*"Who has access to our data?" "How is the technology made?", How secure is that thing?*

Ease of Use: A significant finding was the varied levels of understanding among participants regarding how QR codes functioned. Several participants who did not have smartphones found the process particularly challenging and expressed confusion and uncertainty about the mechanics of scanning QR codes. This confusion may stem from limited exposure to QR code scanning or difficulties in understanding the instructions provided, indicating a need for more intuitive and inclusive interfaces to enhance user comprehension and interactions. Another important aspect of ease of use is related to the novelty of hearing audio from the physical environment rather than through participants' mobile phones when they click play, highlighting a lack of familiarity with this technology. For many older adults in this cohort, this experience was unfamiliar and unexpected, leading to confusion and uncertainty about how to interpret the audio feedback. Some participants expressed surprise at hearing sounds emanating from the physical environment, highlighting a shift in their accustomed modes of audio interaction. This novelty factor may have contributed to initial hesitation or difficulty in engaging with the physical web application, particularly for those who were not expecting this mode of audio playback.

Impression of the Prototype: Despite the mixed reactions to the mechanics of how the prototype works, several participants reported enjoying the experience of interacting with the prototype. They appreciated the opportunity to engage in outdoor activities while leveraging digital technology to enhance their physical and social experience. For these participants, the technology provided an immersive way to interact with their surroundings, enriching their outdoor experiences and fostering a sense of enjoyment and fulfilment. However, while some of the participants described the interaction with the prototype as engaging, they perceived the technology as suitable for younger audiences as they could not be bothered to learn how to use it.

Prototype Improvement suggestions: The findings from the focus group workshop emphasise the importance of enhancing the usability and accessibility of the physical web application for older adults. Seven Participants highlight the necessity to "make it easier to use" through various suggestions and recommendations. Firstly, for the music application, participants suggested enabling automatic playback with minimal user interactions and inputs. This feature would allow users to enjoy audio content without the need for manual input, enhancing the user experience and reducing cognitive overload. Additionally, participants suggested considering alternative forms of interaction, such as loyalty cards or tags. These alternative methods would provide older adults with options beyond traditional smartphone interfaces, catering to diverse preferences and mobile and technological literacy levels. Another suggestion involved considering a smaller device or phone integration. Participants highlighted the importance of portability and seamless integration with existing devices, facilitating adoption and usage among older adults. Moreover, enabling automatic playback with minimal interaction was reiterated as a key enhancement. By reducing the need for manual input, older adults can engage with the physical web applications effortlessly, enhancing their overall user experience. Finally, the idea of incorporating a key holder or button for easier interaction was proposed. This physical addition would provide older adults with a tangible interface for accessing the features of the Physical Web application, further enhancing usability and accessibility. Furthermore, simplifying the interface with a one-button operation emerged as a prominent suggestion. By simplifying the interaction process, older adults would be able to navigate the Physical Web application more intuitively, promoting user interaction and satisfaction.

Privacy and Security Concerns: The fear of security issues emerged as a common theme among participants. Older adults expressed reservations about the safety of using QR codes, indicating a need for robust security measures and clear communication to address these concerns and build trust in the technology. Three of the participants raised questions such as "Who has access to our data?", “where is the data stored?” indicating a lack of understanding of the proposed system. Another aspect of concern was connected to the transparency of the technology's development process. One participant questioned, "How is the technology made?" expressing a desire for greater transparency and understanding of the underlying processes involved in creating the Physical Web application. Lastly, participants highlighted their doubts about the overall security of the technology, asking, "How secure is that thing?" This question reflects a vital concern about the integrity of the technology and its ability to safeguard users' information and ensure a secure user experience.

Discussion

The diverse levels of understanding among participants regarding QR code functionality highlights a crucial area for improvement in the design of the Physical Web application. Clearer instructions and more intuitive interfaces are necessary to address confusion and uncertainty, ensuring that older adults can easily navigate the technology [34]. By prioritising user comprehension, interaction and inclusivity, designers can enhance usability and promote greater adoption of technology among this older adult cohort. Participants’ belief that QR code technology is too complicated for older adults highlights the need for user-friendly design elements that cater to the diverse cognitive and technological literacy levels of this cohort of older adults [36]. Addressing age-related barriers requires simplifying interfaces, streamlining interaction processes, and providing alternative forms of interaction when needed. By making technology more accessible, inclusive, and intuitive, designers can overcome perceived complexities and promote inclusivity among older adults [35].

Participants’ concerns about data access, technology transparency, and security underline the importance of prioritising privacy and security measures in the design and implementation of applications. Addressing these concerns requires transparent and clear communication with users on where their data is stored and the strategies in place to protect their data. Also, it is important to limit the amount of data collected for such interactions. By instilling confidence and trust, designers can alleviate apprehensions and promote greater acceptance of the technology among older adults. Participants' difficulties in using the technology highlight the need for streamlined interfaces and intuitive interaction processes. Features such as one-button interaction and automatic playback with minimal interaction can enhance usability and accessibility for older adults in this cohort. Additionally, considering alternative forms of interaction, such as loyalty cards or tags, can provide users of Physical Web, especially those without smartphones, with options beyond traditional smartphone interfaces. By prioritising ease of use, designers can create a more inclusive and user-friendly technology that meets the diverse needs and preferences of older adult users.

Limitation

A limitation of this study is the small number of samples of older adults involved and their age range of 65-100, with most of the participants aged over 80. From a sample of 12 participants, only 3 participants reported using QR codes before the study, and most of the participants did not have a smartphone to scan a QR code. This sample may not fully represent the diverse population of older adults. The sample of the study limits the generalisability of the findings to broader populations of older adults with varying age groups, backgrounds, and digital experiences. Moreover, the study may not have fully reflected the specific contexts in which older adults would use the Physical Web application, which is in outdoor environments with varying levels of ambient noise or lighting conditions. This study was conducted in a study room with the older adults. Understanding the contextual factors like varying levels of ambient noise or lighting conditions that impact usability and engagement could inform more tailored design decisions. Lastly, our future iterative workshops will be organised outdoors to give the participants an environment to use the prototype. We will also include many participants with a diverse age range and digital skills and experience.

Conclusion.

The research aimed to codesign a Physical Web application with older adults to encourage outdoor physical activity. The study presented in this paper includes a focus group workshop exploring the initial prototype of the application with 12 older adults. Participants without smartphones face challenges using the application, and other participants find the QR code functionality difficult to understand, while others question the security of the QR code technology. Despite these challenges, most participants found the technology useful for outdoor activities. Future iterations of the design will focus on considering the feedback from the participants, redesigning the interface for clarity, and exploring different modes of interaction for those without smartphones. However, there is a need to ensure that the Physical Web technology remains usable, inclusive and accessible for all older adults.

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20. Student Perceptions About Age, Gender, Computer Literacy and Design Aspects: A Longitudinal Study

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Abstract

Studies done in different countries have found that beginning computer science students think older people are less likely to use computers. To understand the impact this may have on the designs conceived, some studies investigated the design aspects suggested for younger and older, women and men. We asked the same cohort of students the same questions about perceived computer literacy and design aspects at the beginning and end of their bachelor's degree to see if these views persist. Three runs of the questionnaire were done, each with more than 95 participants: a) first year students, b) shortly before or after graduation and c) students starting after the COVID-19 lock-downs (to check this was not a significant factor). Mixed methods were used to analyze the differences between the beginning and end of their studies. We analyzed if the stage in studies was a factor in their perceptions of computer use. We also compared the design aspects suggested at each stage, to see if more aspects of user experience were included for all people. Since many older people have limitations, we also evaluated whether the aspects mentioned covered the accessibility recommendations for older people. Although biases towards older people remain, graduates perceive less difference in the likelihood of regular use by young and old. Regarding design, aspects related to usability are mentioned more often for all ages. For older, less focus is put on large fonts alone and other aspects of accessibility are mentioned more often.

Introduction

Studies show that based only on a picture showing the approximate age of a person, students at the beginning their computer science studies think that older people are less likely to use computer systems regularly and are less expert with them than younger people [12,8]. That is concerning, as if older people are thought not to use systems, they may not be considered in the design process. In reality diversity increases as people age [7], and some older people are frequent computer users [5]. Thus, systems are needed to fit the diversity of needs.

The biases extend to the design features these students suggest for older people, so that the most common include *large fonts*, *large buttons* and *reduced features* [8]. Since for older people it is particularly important that systems be useful and not stigmatizing [18], these ageist views may lead to systems designed for older people that are not attractive to them. At the same time, it is important that usability is not neglected for younger users, as it is a factor in User Experience (UX), which in turn increases the chances of a project's success on the market [15].

Of course, many older people do have perceptual, physical and/or cognitive limitations [19], so that it is important the accessibility features be included in systems. However, the aspects recommended for older people go far beyond large interface elements [17].

For this study, we wanted to re-evaluate the perceptions of students at end of their bachelor's degree and compare these to results from a previous study at the beginning of their studies. This is important as there are few empirical studies about the attitudes of young people towards older people [13], and computer science graduates are likely to be among those designing the systems of the future. We hoped that their biases are diminished and expected that they are more aware of the importance of UX/usability and of the needs of older people in terms of accessibility.

To this end, a longitudinal study was done, asking the same cohort of students the same questions again at the end of their degree. Since COVID-19 happened in the meantime, we also analyzed if the lockdowns had a significant effect on these perceptions.

The research questions (Q) guiding this study are:

1. How does the parameter stage in studies (beginning/end) effect perceptions with regard to computer use of younger and older people, women and men (i.e. perceived likelihood of regular use and expertise)?
2. How does the stage in studies effect the design aspects suggested for younger and older women and men?
3. How does the stage in studies effect the aspects of UX mentioned for younger and older people? Do students at the end of their studies have an increased awareness of the importance of usability for all age groups?
4. Do the accessibility aspects suggested for older people better reflect the recommendations of the WCAG at the end of their studies?

Background

Older people are diverse and have during the 60 or even 120 years of their life had different experiences. Hence, there can be large difference in their interests, knowledge, social situation, limitations and preferences, to name a few aspects. They are large part of the population, and many older people continue contribute to their communities, for example, through volunteer work or caring for grandchildren [5].

"Digital Ageism" refers to the assumption that based only on their age older adults are less capable of using technological devices [10]. However, it has been shown that many stereotypes of older people and technology are not accurate [1,5]. In fact, many can and do use technology [5], and technology usage among older people has increased rapidly the past ten years [6].

Due to the prevalence of computer-based systems, e.g. for banking, and the benefits systems can provide, it is important that older people can use systems if they wish to. In fact, the digital divide is often considered an inequality that should be remedied [10]. However, many older people report cognitive, physical and perceptual barriers of use [19], so that accessibility features are important.

The design of systems is essential, both for their usability and the resulting UX [4]. Increasing the UX of a system increases chances of success once it goes to market [15]. Thus, systems should be attractive to the future users. At the same time, there is an indication that older people may find devices aimed at older people stigmatizing [20] and be more willing to accept technology like that their grandchildren use [11]. So while designs must be accessible for older people, the design should not focus on their limitations [16], and also be acceptable to younger people.

At the same time, having systems that are easy to use and accessible is not sufficient to encourage use by older people, the technology must also provide benefits, i.e. be valuable to them [5].

Our Work

Each questionnaire included one picture of a person reading a book at the top, either a younger man, older man, younger woman or older woman (see examples in Figure 1). Participants were first asked to assess how likely this person was to use various devices regularly (desktop PC, laptop and smartphone) and how expert they would be with each of these devices (as in [12]), as well as whether an adapted technology would be needed. Following this, they were asked to list some design aspects that would be important for this person. Thus, we could explore the preconceptions or stereotypes participants had about each group and what impact these may have on the design of systems.

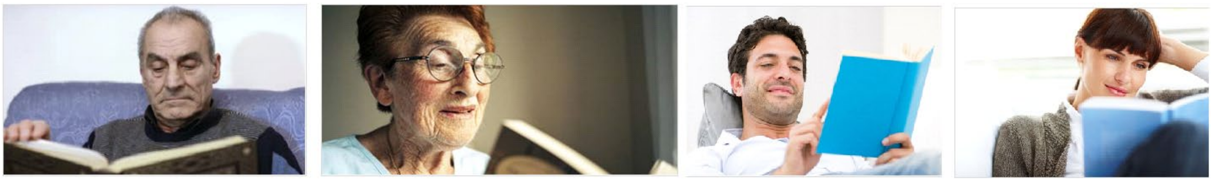

Figure 20-1: Examples of some of the people depicted (taken from [12] with permission): from left to right an older man, an older woman, a younger woman, a younger man.

Four runs were done using the same questionnaire (N is the number of valid questionnaires in the sample):

0. pilot study (autumn 2018)
1. class of 2022 computer sciences students at the beginning of their studies (autumn 2019, N=200, of which 64 identified themselves as female)
2. computer sciences students at the beginning of studies after COVID-19 lock-downs (autumn 2020, N=169)
3. class of 2022 bachelor students shortly before or after graduation (2022, N=99, of which 25 identified themselves as female)

Thus, the longitudinal study encompasses runs 1 and 3. The participants were chosen to be representative of computer science students in Austria, where the study was done.

A mixed method approach with both qualitative and quantitative methods was used, something that can improve the validity of the findings [14].

For 1, quantitative methods were used. ANOVA was used to determine which factors had a significant effect on the perceived likelihood of use, expertise and need to adapt the technology. The factors analyzed were:

- *age* of person depicted: younger, older
- *gender* of person depicted: women, men
- *device*: PC, laptop, smartphone
- *corona*: 0 (before 2020), 1 (2020 and later)
- *stage in studies*: beginning or end of studies

These analyses were done for the combined data from runs 1 through 3.

The remaining questions were analyzed using qualitative methods. Since the quantitative results did not find *corona* to be a significant factor, these analyzed only the longitudinal results, i.e. runs 1 and 3 from the beginning and end of the studies.

For 2, first an open coding was done for the longitudinal data to unify the terminology, as is common in qualitative methods such as thematic analysis [2]. Since the answers were short, the codes were taken from the data with little interpretation, what is called inductive coding [2]. To reduce potential bias, the questionnaires were mixed to include both age groups (younger, older) and all other responses were hidden. The most common codes mentioned for the different age groups at the beginning and end of studies were compared, i.e. those with the greatest extensiveness [9, p.147]. Only those terms mentioned by at least 5% of the participants answering for that age group were included.

For 3, the analyses regarding UX were based on Morvilles's honeycomb. For this the (uncoded) design aspects suggested by students were analyzed to see if these relate to one of the 7 factors: *useful, usable, desirable, valuable, findable, credible* and *accessible* [15]. This is similar to theoretical coding in thematic analysis [2].

The analysis for 4 was similar to that of 3, however based on how the Web Content Accessibility Guidelines (WCAG) apply for older people [17]. This includes a number of points, which are grouped into four main factors: *perceivable, operable, understandable* and *robust*. The main factors are the same as those in the current WCAG 2.1 version. This analysis was only done for older people.

Student Perceptions of Computer Usage

As with previous studies, older people and women are perceived to be less likely to use devices (desktop PC, laptop and smartphone combined) and also to be less expert with these (i.e. *p*-values < 0.001). Taking the devices separately, the factor *age* remains very significant in each analysis, but for the factor *gender* the significance varies by device. So that while for PCs the factor *gender* is very significant for the perceptions of both (i.e. *p*-values < 0.001 for likelihood of use and expertise), for the laptop it is significant for the likelihood of use (*p*-value 0.034) and very significant for expertise (*p*-value < 0.001). For the smartphone, the difference between women and men is only significant for perceived expertise *p*-value 0.045). Except for the laptop, there is not a double effect of being a woman and older, i.e. there is not a greater or lesser bias compared to younger women.

The effect of *corona* was not found to be significant except in a single factor: students starting after the COVID-19 lock-downs thought all people were more likely to use a smartphone regularly (*p*-value 0.014).

The *stage in studies* did have an effect on some results. As can be seen in Figure 2, taking all devices together, students at the end of their studies thought younger people are slightly less likely to use devices, but older people are more likely to use them. For the smartphone, the difference in the rating for smartphones for the factor *age* is significant (*p*-value 0.031 for likelihood of use). Furthermore, they judge both younger and older people to be more expert than they did at the beginning of their studies. With regard to *gender*, the perceived difference increased, with women being judged less likely to use devices and less expert. This effect was strongest with the PC (*p*-value 0.009).

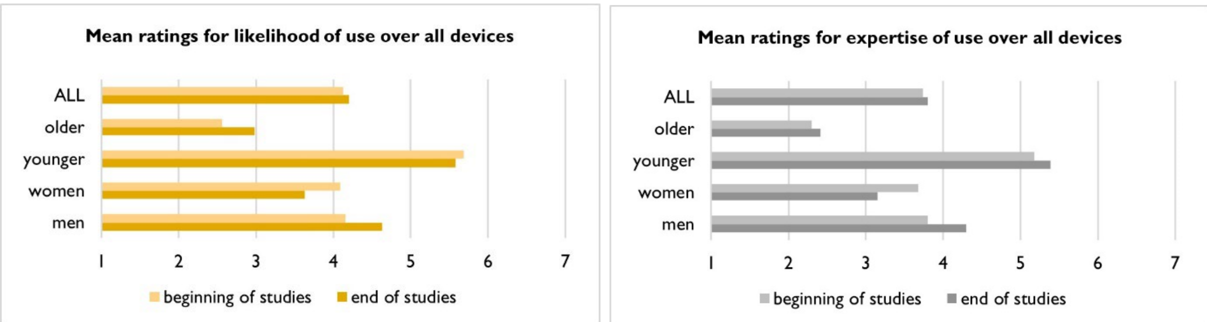

Figure 20-2: Comparison of mean ratings for likelihood of regular use (left) and expertise (right) for all devices combined both at the beginning of studies (first value, lighter) and at the end (lower value, darker)

Comparing the perceived need to adapt, more students suggest an adapted technology for older people at the end of their studies (*p*-value 0.037 if compare yes/no).

Based on this we conclude that the ageist bias is still present but reduced. However, the bias against women has increased.

Design Aspects Mentioned for Younger and Older People

As visible in the word clouds showing the frequency of the coded terms (Figure 3), the design aspects for younger and older people are quite different, and those recommended at the beginning to the end of their studies are quite different.

At beginning of their studies, the most extensive terms are (i.e. mentioned by at least 5%):

- for younger: aesthetic design, simple, easy to use, modern, small size, sleek design, colors, efficient to use
- for older: large fonts, simple, easy to use, large buttons, large symbols, easy to read, easy to get an overview, reduce functions, easy to understand, usability

At end of their studies, instead:

- for younger: easy to use, simple, modern, easy to understand, easy to get overview, usability, minimalistic, intuitive design
- for older: large fonts, easy to use, large buttons, reduce functions, simple interface, large symbols, large design elements, easy to understand, audio assistant, not too many settings, no changes / updates, large screen, large interface, few options, easy to read

There are some notable changes, especially for younger people. For younger people, *aesthetic design*, *colors* and *sleek design* are no longer mentioned as often, but instead *easy to understand*, *easy to get overview*, *usability* and *intuitive design* are some of the most common. For older people, more different things are now mentioned, including *audio assistant*, *not too many settings*, *no changes / updates* and *few options*.

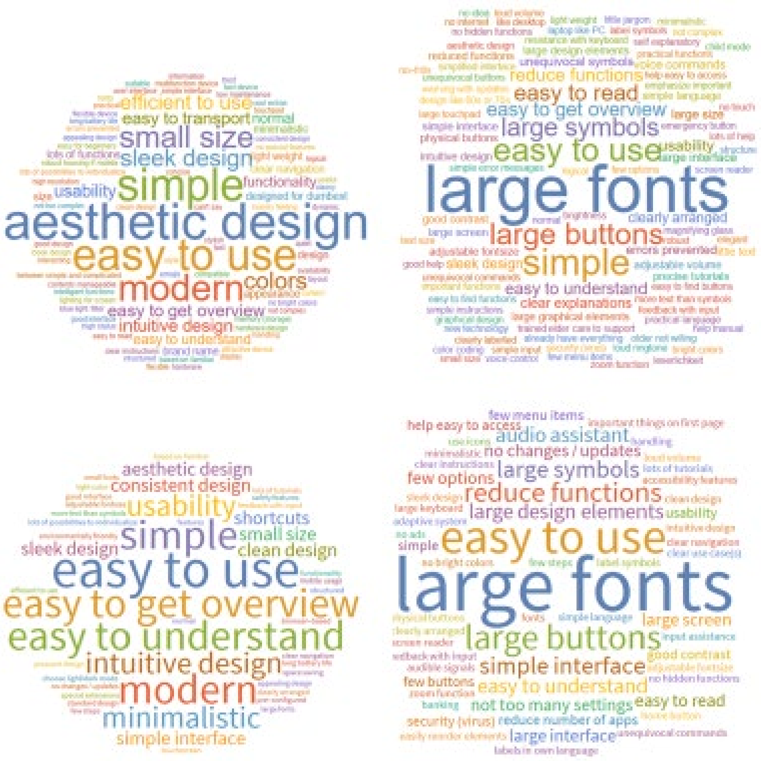

Figure 20-3: Weighted design aspects for the younger people (left) and older (right) at the beginning of the studies (above) and at the end (below)

Aspects of Usability and User Experience Included

Relating the aspects mentioned to the factors of UX, the two most common for each age group remain the same:

- for younger: usable, desirable
- for older: accessible, usable

At the end of their studies, students included more aspects relating to *usable* and *findable*. This indicates that usability is given more importance for all ages, as expected. For older users, aspects related to *accessibility* are mentioned much more often, which matches the increased need for adaption found with the quantitative results. Fewer *desirable* or *valuable* aspects are mentioned for both age groups. See also the bar graphs in Figure 4.

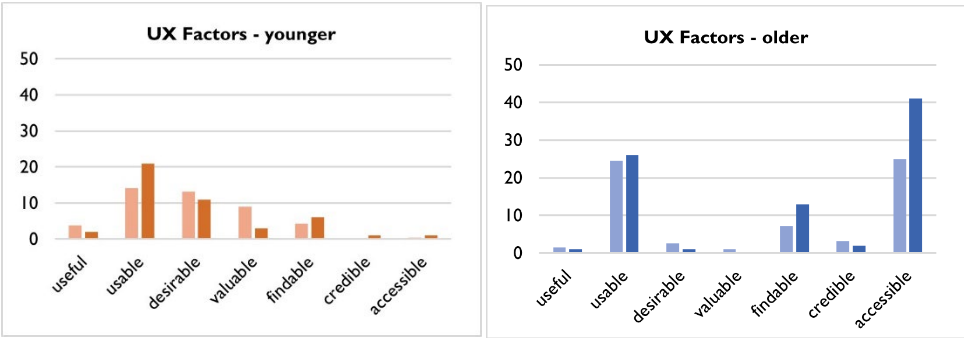

Figure 20-4: Relative frequencies the design aspects mentioned relate to the factors of UX for younger people (left) and older (right) both at the beginning of studies (left, lighter) and at the end (right, darker)

Aspects of Accessibility Identified for Older People

With regard to accessibility, the most aspects mentioned relate to *perceivable*, followed by *understandable* and *operable* (see Figure 5). As expected, at the end of their studies participants include more aspects related to those recommended to support older users for all four main factors of the WCAG, even though this is not a focus of the degree programs included in the study. A closer analysis shows that a lower proportion of these are *large font* (part of *perceivable*), and some of the other recommendations are mentioned more often than at the beginning of their studies, such as *instructions and input assistance* and *understandable language* (both part of *understandable*).

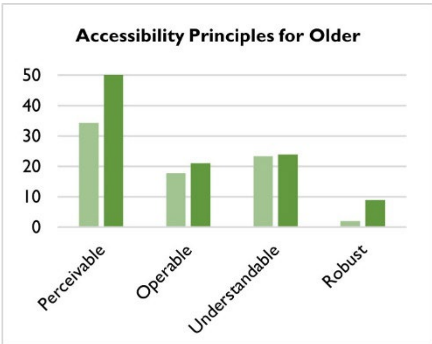

Figure 20-5: Relative frequencies the design aspects mentioned relate to the factors of WCAG for older people both at the beginning of studies (left, lighter) and at the end (right, darker)

Conclusions and the Way Forward

There are significant differences between the opinions of students with regard to computer literacy at the beginning of their studies and at the end. Students at the end of their bachelor studies still assume older people are less computer literate. However, there is less difference in the perceived likelihood of regular use by young and old. Unfortunately, there is more bias against women. However, there is no double effect of being a woman and older.

These biases extend to the design aspects suggested, and the aspects of older people focus on usability and accessibility. This may result in stigmatizing devices that are not used by older people.

It is encouraging that at the end of their bachelor's students are more prepared to design usable systems. For all age groups, more aspects related to usability are mentioned. With respect to older people, students at the end of their studies see an increased need for accessibility, mention more aspects from all four factors of the WCAG, and put less focus on *large fonts* alone. Still, the low number of desirable design aspects mentioned, particularly for older people, is concerning with regard to the acceptance of systems designed in the future by these graduates. In order to counter this, using personas that show how well-known older people may have encountered technologies in their lives might help when designing for older people [13], much as personas can be used to identify gender-inclusiveness problems in systems [3].

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21. The Economics of Investments in Accessibility for Persons with Disabilities

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Abstract

Emerging trends in technology are providing opportunities for a broader range of mobile and pervasive assistive technologies (MPAT) to positively impact persons with disabilities in terms of independent living and employment. However, such technologies typically require significant investments by entities that offer such options. It is not clear how such firms compete in a market with other firms that may not provide such options. Understanding such competition can help promote greater investments in accessibility infrastructure by entities and provide insights into how federal efforts can further boost such efforts. To that end, this paper presents a game-theoretic framework of market competition between two firms where one invests in accessibility (bearing additional upfront costs) and compares it with another one that does not. Numerical evaluations demonstrate the range of parametric values where accessibility investments pay off.

Introduction

Disability is part of the human condition. Almost everyone will be temporarily or permanently impaired at some point in life and those who survive to old age will experience increasing difficulties in functioning beyond the age of 40 [1]. Despite advances resulting from the Rehabilitation Act of 1973 and Americans with Disabilities Act (ADA) (and similar efforts around the world), people with disabilities remain part of the underserved population with regards to employment, income, and health care [3]. A big part of this challenge is lack of or limited options for access to information and or built environments.

Assistive technologies (ATs) can serve to ameliorate detrimental impacts of disability on body function or structure, environmental obstructions, and societal barriers. Well-known assistive technologies include wheelchairs, vision-correcting lenses, and hearing aids, all of which address a problem in body function or structure, help the user navigate environmental obstructions, and through increased inclusion, overcome societal barriers. Accessibility for digital media have seen a lot of positive developments over the last decade [14]. More recent developments in pervasive and mobile computing have led to a specific sub-category of ATs called Mobile and Pervasive Assistive Technologies (MPATs). MPATs have emerged because mobile and pervasive devices have become platforms of choice to enable assistive technologies that improve the quality of life of people with disabilities. Pervasive sensors and actuators can provide vital information about the environment to those who traverse it, while mobile devices allow for computing and communications. Coupled with the fact that mobile devices are also compact, widespread and socially acceptable, MPATs can be leveraged to achieve ubiquitous assistance for activities of daily living (such as mobility, information access, interaction with the environment, or with other people) [2, 9, 20, 25, 29, 32].

However, just like wheelchairs need to be supported by investments in infrastructure (ramps), many MPATs often need to be supported by back-end infrastructure to enable or enhance their functionality. For example, many of the recent advances in navigation and wayfinding in built environments with MPATs require infrastructure modifications or augmentations such as addition of radio-frequency identification (RFID) tags, Bluetooth Low Energy (BLE) beacons, or other location-tagging devices [25, 36]. Another example of such a scenario where MPATs are being used is that of national grocery chains setting up kiosks for customers to scan items themselves using a device (smartphone) that is already accessible for users.

While laws such as the Americans with Disabilities Act (ADA) and Section 508 [3, 10] and equivalents have led to investments to modify physical spaces for accessibility (ramps to access buildings or vehicles) or create accessible technology, they have not yet led to similar investments to support MPATs which often fall beyond current legal requirements as "convenience technologies". Currently, such investments are either federally supported for some public spaces or limited to a few private efforts. For the most part, technology exists to make many environments (such as smartphone-based wayfinding for built environments) sufficiently or conveniently accessible, limited only by the inability to prepare the environment to deploy such MPATs. The primary challenge is often to get private entities willing to invest in making spaces accessible using MPATs.

Given that market forces often determine the feasibility of adopting accessibility options beyond the requirements of the laws, this paper explores the theoretical underpinnings of what may motivate entities or firms to invest in support of MPATs and in general AT infrastructure. In this paper we propose a game theoretic model that will help analyse the importance of various parameters and the incentives firms may need to provide better accessibility.

State of the Art

Numerous ATs have been developed over the years to assist persons with disabilities with activities of daily living such as wheelchairs and screen readers. Many MPATs have recently been developed for navigating and operating within built environments [4, 5, 7, 11, 13, 15, 18, 19, 24, 25, 31, 32]. While the success of some of these MPATs requires effort or investments only from the end-user (for e.g., [4, 5, 7, 11, 15, 32]), the vast majority of these MPATs require adequate investments from the enablers or managing entities (for e.g., [13, 18, 19, 24, 25, 31]). For MPATs where any kind of investments are needed, the enablers and managing entities need to carefully consider the benefits and costs and determine the economic feasibility of offering such products or services. Beyond legal and ethical considerations, eventually firms need business success to be sustainable. This necessitates adequate tools be available for making such decisions, especially for cases where a firm is contemplating increasing accessibility beyond minimum legal requirements to something more meaningful or convenient.

Methodology

The proposed economic framework developed in this paper considers two scenarios; one firm that adopts (supports and invests in) MPAT specially geared towards improving the quality of life for people with disabilities (called Firm 1), and another firm (Firm 2) that does not make specific investments to cater to the subset of the population with disabilities. By comparing the demand for Firm 1 in a Cournot competition [35] with Firm 2, a better understanding of the feasibility and challenges in consumers adopting the accessible choice (offered by Firm 1) can be gained.

For simplicity and intuitive results, we assume a market characterized with two firms (a 2-player market). We model firms that can be considered to operate in an oligopoly market structure. For example, the grocery market is concentrated with few major players, so modelling two firms (duopoly) is expected to capture most of the market dynamic. Assume that Firm 1 has adopted an MPAT system which is enabled through investments. For Firm 1 to offer the accessibility option, it must make significant investments in accessibility infrastructure. Firm 2 does not make such investments and hence can be characterized as the "accessibility-unfriendly" option.

Using the Mussa and Rosen's model of vertical product differentiation [35] where differences in consumer attitudes for accessible services are accounted for, demand facing the two firms can be derived. Solving the profit maximization problem for the two firms competing on capacity/output (Cournot competition), quantity demanded and price for each firm's service at equilibrium is determined. The impact of the underlying costs to the two firms are of particular interest to determine the feasibility of Firm 1 offering accessibility options. Firm 2 is assumed to incur a "base" cost of C_{base} which is assumed to be the cost to offer a unit quantity of the product without any additional costs incurred to provide accessibility. Firm 1 incurs an additional percentage cost C_a per unit of product for providing accessibility. The intuition here is that accessibility costs are likely to scale with overall costs of a firm. A larger firm with larger operational costs will have to spend more on accessibility. Economies of scale in accessibility investments can of course reduce these costs, in which case our cost function for Firm 1 will over-estimate costs and likely under-estimate the competitiveness of Firm 1. The cost function can be expressed as:

$$C_{base} \leq min\left(\frac{2k_1 - k_2}{1 + 2C_a}, \frac{k_1 k_2}{2k_1 - k_2(1 + C_a)}\right)$$

Where k_1 and k_2 are positive real numbers from the Mussa and Rosen model that describe the average consumer or user experience of shopping at Firms 1 and 2, and $k_1 \geq k_2$ due to our assumption that Firm 1 offers a more accessible experience without compromising on any needs of those customers who do not care for accessibility.

Numerical Evaluations

We perform numerical evaluations to demonstrate the model and its use in interpreting the impact of important parameters based on conditions derived from the theoretic model. The metrics under consideration are the following:

Market Share

It is interesting to study the evolution of market share for both firms as the cost of accessibility investments increase. One would expect Firm 1 to lose market share as its underlying costs increase, while Firm 2 is likely to benefit from this. Figure 1 shows how market share of both firms (Q_1 and Q_2) varies as the ratio of user experience k_2/k_1 increases. As expected, the market share for Firm 2 increases and even crosses that of Firm 1 as the user experience ratio get close to 1 with the point of crossover depending on the accessibility costs C_a incurred by Firm 1. Higher accessibility costs without a significant advantage in user experience allows Firm 2 to gain market share over Firm 1. Thus, Firm 1's user experience advantage must overcome its investments in accessibility for it to gain a market share advantage over Firm 2.

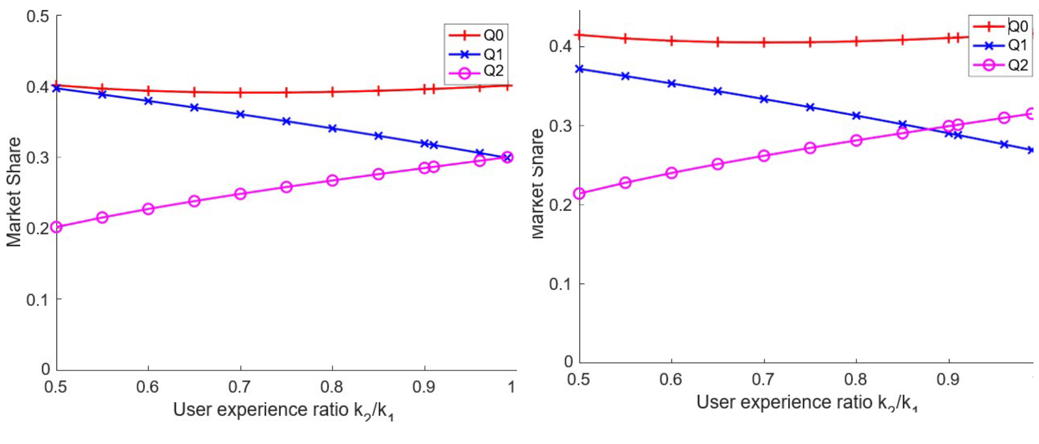

Figure 21-1: Market share for increasing k_2/k_1 ratios with C_{base} =10 and accessibility costs C_a=5% and 50%

Profit

The impact of both accessibility investments and unit costs of products on profits will help illustrate the scenarios where firms will be competitive. Profit for Firm 1 expectedly increases as the user experience advantage over Firm 2 increases. For larger unit cost products, (C_{base} = 50), profits are reduced due to loss of market share where the consumer decides not to choose either firm's services as seen in Figure 2. The major result here is that even with large accessibility costs, Firm 1 is still able to make a profit.

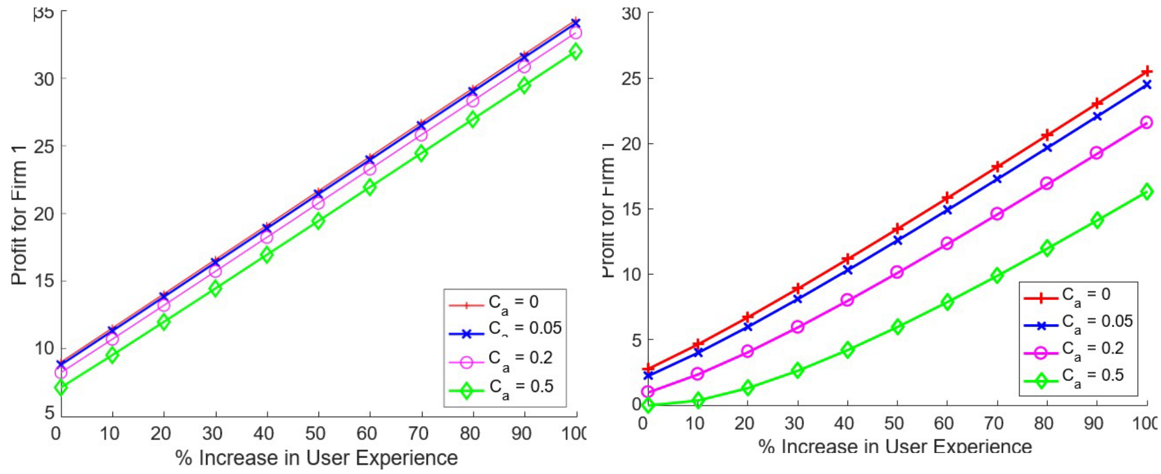

Figure 21-2: Profit vs user Experience advantage for Firm 1 for various accessibility costs when C_{base} = 10 and 50

Conclusion

This paper presents an economic framework to compare a firm that invests in providing accessibility possibly with another firm that does not. The model and its evaluation help understand what parameters are more significant to motivate accessibility infrastructure deployments. This framework can be used to answer questions such as given a firm's operating costs and revenue, how will an additional investment in accessible spaces or technology improve or hurt market share and profits based on a user's experience.

The results presented indicate that any firm considering making accessibility investments can expect to make profits and gain an advantage over its competitors if the expected increase in average user experience is significant (quantified as 20% or more for parameters considered in this work) across all potential users. This reinforces the fact that firms should focus more on quantifying and improving average user experience, and that accessibility investments need not be a barrier. Future work will look into quantifying using case studies how much of an increase in user experience can be expected with accessibility investments.

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22. Assistive Technologies in Austria: Exploring the Impact of Legal Frameworks and Subsidies

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Abstract

Assistive Technology (AT) can improve the quality of life of persons with disabilities by promoting increased independence, social inclusion, and facilitating the ongoing demand for deinstitutionalization. Legislation and funding systems have a significant impact on access to AT. Therefore, the submitted paper asks which legal frameworks and funding schemes in Austria influence the affordability, access to, and use of AT with a special focus on housing, and whether existing legal frameworks and funding schemes in Austria allow for individualization in the provision of AT. A combination of methods was used to gain a comprehensive understanding of how legal frameworks and subsidy schemes influence access to AT in Austria. The empirical findings show that there is no formulated legal right to AT in general, and certainly not in the area of housing. So-called benefit catalogues for AT refer primarily to medical rehabilitation measures, are not standardized and do not reflect the state of the art. The financing of AT in Austria is not transparent. Some users have to rely on additional donations from private organizations, and often lengthy procedures prevent persons with disabilities from immediately getting to use the AT they need.

Introduction

Persons with disabilities usually mitigate their functional limitations by relying on personal assistance provided by human caregivers and utilizing assistive technologies (AT) [1]. ATs are commonly defined as all technical 'aids' that help to maintain and/or improve a person's functional resources and compensate for functional limitations [2–4]. These technologies encompass a spectrum of basic tools like canes and ramps to advanced solutions such as (electric) wheelchairs and devices designed to remind and assist persons with disabilities in tasks like medication management and eating. Given the rising need for long-term care services and the anticipated shortage of human caregivers in the future, policymakers are exploring whether AT can serve as a viable alternative to paid long-term care services or if it should be viewed as a supplementary form of support [1]. AT devices and applications can address various challenges faced by persons with disabilities, enabling them to perform daily activities more easily and efficiently [5]. It is essential that AT is selected based on human needs, not vice versa [4]. This means that the development should and must also be guided and driven by the people who use AT and individualization plays an important role in the effectiveness of AT.

AT also increases the likelihood of working, accessing the community, participating in social life, and succeeding in different environments. Furthermore, AT enables users to perform activities with greater autonomy, empowering them to manage their time, select activities, and participate according to their preferences [6]. Additionally, advancements “in assistive products help persons who need them to come out of their isolation, reducing their dependence on others for their health and care, and building confidence in them” [7]. Thus, access to appropriate AT can mediate the ongoing demand for deinstitutionalization in the area of housing [8]. Deinstitutionalization refers to a change in the housing support system away from large and complex facilities towards community-based, individualized services in order to achieve full, effective and equal participation in society, self-determination and participation in everyday life [9]. This change also includes the access to AT. As a sub-sector of AT, ambient assisted living (AAL) aim to support the independence of users, particularly in their own homes through the use of information and communication technologies (ICT). It is essential for the development of AAL products to combine new technologies and social factors in order to place people at the center of the technology. Examples of AAL products and services include home emergency call systems, telehealth systems, navigation systems for pedestrians and wheelchairs with voice control [10].

Given the importance of AT the financial barrier posed by its cost cannot be ignored. Recognizing this, the provision of subsidies by the welfare state becomes central. In this context, two research questions are addressed in this paper: What are the legal frameworks and the funding systems for AT in Austria in general and with a special focus on housing? How do they affect the access to, affordability and use of AT?

State of the Art

Research highlights the importance of AT in providing appropriate housing solutions for persons with disabilities [11]. Ongoing studies focus on the development of AAL technologies tailored to young adults with disabilities, with the goal of increasing their inclusion and overall well-being in their living environments [12]. By addressing the specific needs of users, ATs in the home ensure greater independence and improved quality of life, in line with the goal of leaving no one behind, as outlined in the United Nations' Agenda 2030 [13].

Legal regulations have a significant impact on access to AT. The United Nations Convention on the Rights of Persons with Disabilities (CRPD) provides a framework for the inclusion of persons with disabilities through the use of AT [14]. However, there are still cases of non-compliance with the CRPD and discriminatory laws and regulations [6]. The optimization of AT resources and services is hindered by factors such as the scarcity of innovative technologies, which affects the formulation of effective policies and actions in this area [15]. Adequate provision of AT by states is crucial for the realization of the rights of persons with disabilities [16].

Government support and subsidies are critical for persons with disabilities to purchase AT. They help to remove barriers and increase access to AT devices and supports [17]. However, it is important to ensure that government intervention does not reduce diversity and innovation in AT products and services, as open markets and competition can deliver the best outcomes for consumers at the lowest cost [4]. Adequate provision of AT by States Parties is essential to the progressive realization of disability rights, and governments and other key stakeholders should increase access to AT through inclusive programs and services [15].

Methodology

A combination of methods was used to gain a comprehensive understanding of how legal frameworks and subsidy schemes influence access to AT and enable individualization in Austria. The contribution relies on qualitative content and data analysis [18].

A review of existing literature and official reports or documents on AT, disability policies, legal frameworks and subsidy schemes in Austria aimed to gain a thorough understanding of the current landscape surrounding these issues and to identify any gaps in knowledge. In addition, an analysis of relevant laws, regulations and policies on AT and disability support in Austria in general and with a particular focus on housing was undertaken. This analysis focused on the evaluation of AT provisions and implementation strategies. In addition, a comparison of legal frameworks and subsidy schemes for AT within the sub-national level of Austria was carried out. This comparative analysis aimed to identify common practices, highlight challenges and uncover opportunities for improvement in Austria's approach to supporting people with disabilities through AT.

The basis for the analysis was a set of relevant laws at the subnational level, official documents of social and health ministries, documents of Disabled People Organizations, an online portal for social benefits and health care and insurance documents.

Assistive Technologies in Austria

In Western welfare states, support systems aim to protect persons with disabilities through economic, legal, or educational aid, provided as transfers, goods, services, or rights [19]. Austrian disability policy is influenced by the conservative-corporatist welfare state model [19, 20], involving moderate decommodification and low de-stratification [21], relying on income-dependent transfer payments and limited social benefits, leading to significant stratification effects, particularly for persons with disabilities outside the regular labor market [22]. Consequently, disability policy profoundly affects the lives of persons with disabilities. The Austrian disability policy system is complex, involving multiple governmental departments and territorial levels. The central government regulates care benefits, while subnational governments handle housing-related matters, providing assistance through financial, material, or service-based aid, historically rooted in poor relief and operating on a needs-based, case-by-case, and subsidiary basis [23].

Legal Framework for Assistive Technologies

In Austria, each federal province (Bundesland) has its own set of disability legislation and policies, which may include cash or in-kind benefits, or services. Not every subnational government has implemented its own disability legislation. In Burgenland and Lower Austria, disability assistance is integrated into the Social Assistance Act [23].

It is noticeable that in the legal frameworks, »aids and appliances« are mentioned. For example, the Styrian Disability Act regulates in §6 the provision of prosthetic limbs, orthopedic aids, and other assistive devices, referring to a necessary application for a subsidy [24]. In the regulation, the Styrian government can set the amount of the subsidy. In addition, the regulation states that the subsidy will be granted on the basis of the cost of the least expensive and most appropriate assistive device available [25]. The Upper-Austrian Disability Act defines aids as devices that reduce or eliminate disabilities; these include in particular body replacement parts, orthopedic and electronic devices, medical aids, mobility and communication aids [26]. The Salzburg Disability Act also regulates in §7 the provision of body replacement parts, orthopedic aids and other aids and mentions that other aids are only those whose use, according to the available scientific knowledge or the practical experience gained, can achieve the sole purpose of helping people to participate [27]. The Tyrol Disability Act regulates Augmentative and Alternative Communication (AAC) in §7, as well as special aids for blind, visually impaired, deaf, hard of hearing and deaf-blind people and special aids for people with musculoskeletal impairments in §20 [28]. Upon deeper research and analysis, it becomes clear that »aids and appliances« encompass very specific forms of ATs focusing on rehabilitation, such as wheelchairs, prosthetics, hearing aids, and visual aids like glasses or contact lenses. This is also confirmed by references such as [29, 30]. Consequently, AAL systems for the housing area are not specifically included in the legal frameworks within the Austrian federal provinces (Bundesländer).

In summary, there is still no legal entitlement to financial support for AT, nor is there a uniform legal entitlement. This empirical finding is also supported by references such as [4, 10, 31, 32]. Around 63,000 people are directly affected by this situation and around 250,000 people indirectly - e.g. relatives, caregiver [10]. Moreover, the existing aid catalogs of the social insurance institutions relate primarily to medical rehabilitation measures (e.g. suction devices, bandages, prostheses, etc.) and are neither standardized throughout Austria nor do they reflect the current state of the art [4].

Funding Mechanism for Assistive Technology

In Austria, the responsibility for AT funding is divided between the regional authorities (national and subnational governments) [4] and the social insurance institutions (pension, health, accident insurance, regional social insurance institutions) [4, 32, 34, 35]. The funding process is subsidiary, meaning, if the necessary ATs are supported by one institution, no cost coverage can be provided by another institution [34]. Moreover, funding for AT consists of complex regulations and fragmented funding systems that make it difficult to provide adequate support to those in need [36]. For example, there are different health insurance providers – e.g. the Austrian Health Insurance Fund (Österreichische Gesundheitskasse - ÖGK), the Insurance Institute for Civil Servants, Railways and Mining (Versicherungsanstalt öffentlich Bediensteter, Eisenbahnen und Bergbau - bvaeb), and the Social Insurance Institution for Self-Employed Persons (Sozialversicherung der Selbstständigen - SVS). Depending on one's insurance provider, the application process and the amount granted can vary. Different procedures are followed for application and different required documents are asked. For the Austrian Health Insurance Fund (ÖGK), a non-formal application, a medical prescription, a cost estimate, and income statements of all persons living in the household are required. However, for the Insurance Institute for Civil Servants, Railways and Mining (bvaeb) and the Social Insurance Institution for Self-Employed Persons (SVS), the income statement is not required [32]. Moreover, there are different maximum funding levels for ATs, and there are also ATs that are not contractually regulated, such as AAC, alternative input devices, etc. However, as already stated in the previous chapter, the AT catalogs of social insurance providers primarily focus on health and rehabilitation [29, 30, 37], the area of housing is not covered by those institutions. Many persons with disabilities are also dependent on donations or funding from private donation organizations in order to be able to finance a device [4, 38]. The lengthy procurement process often means that devices cannot be used immediately [4].

The National Action Plan on Disability 2022-2030 (NAP 2022-2030) notes that not all assistive devices are currently covered by social insurance. Social insurance is bound by the legal framework in the allocation process. ATs that cannot be financed by the social insurance system can be financed by the disability assistance of the federal provinces. Due to the different responsibilities, a needs-based provision of AT is often not possible. Although cost sharing between social insurance institutions and the federal provinces (Bundesländer) is a long-standing practice, there is a lack of a single point of contact in the form of 'one-stop shops', which would greatly facilitate and ease accessibility. Several measures are formulated to remedy this situation, such as the establishment of contact points and the closing of funding gaps. With regard to the NAP, only three federal provinces (Vienna, Lower Austria and Upper Austria) are in charge of evaluating and adapt ATs to the state of the art and to focus on digitization [33]. Despite the formulation of measures, there is a lack of indicators to evaluate the achievement of goals in the field of AT. Thus, the actual and meaningful implementation of the measures remains unclear. Interestingly, the NAP includes one measure specifically for the area of housing: Competition for comprehensive barrier-free living with the use of ATs. Not all federal provinces (Bundesländer) are in charge of this measure, as Upper Austria and Lower Austria are not listed as responsible within the NAP. Furthermore, there is a lack of indicators in this area [33]. However, no measures for legal entitlement and funding of AT in the area of housing was set in the NAP.

Conclusion and Discussion

The empirical findings show that there is no formulated legal entitlement to the provision of AT in Austria. The existing benefit catalogues of the social insurance institutions refer primarily to medical rehabilitation measures and are neither standardized throughout Austria nor do they reflect the state of the art. The segmentation of the financing of AT between the regional authorities (national and subnational governments) and the social insurance institutions (pension, health, accident insurance, and regional social insurance institutions) leads to a significantly more difficult procurement process for AT in Austria. Many persons with disabilities are also dependent on donations or funding from private charities to finance their AT device. This lengthy process often means that the equipment cannot be used immediately [37]. In the area of housing, challenges related to mobility, financial security, inadequate funding for AT, and proposed reductions in accessibility requirements for housing costs significantly limit the rights of persons with disabilities to choose where to live [31].

AT plays a crucial role in supporting deinstitutionalization efforts and promoting the inclusion and well-being of persons with disabilities, but if persons with disabilities need AT in Austria, they are confronted with bureaucratic hurdles [17]. The empirical findings have shown that several barriers hinder access to appropriate AT. The absence of a formulated legal entitlement to AT in Austria highlights a significant gap in support for persons with disabilities. Current benefit catalogues primarily focus on medical rehabilitation measures and lack standardization across regions, hindering equitable access to AT. The segmentation of AT financing between regional authorities and social insurance institutions complicates the procurement process and exacerbates attainability issues. Reliance on donations or private funding further underscores the inadequacy of the current system in ensuring universal access to essential AT devices. Lengthy procurement processes often result in delays in accessing AT devices, impacting individuals' ability to lead independent and self-determined lives.

Policymakers must address these systemic deficiencies by reforming legal frameworks and enhancing funding mechanisms. However, the current National Action Plan Disability 2022-2030 does not adequately react to the barriers and hurdles that persons with disabilities face in accessing AT.

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23. Post-human, Disability and Inclusion

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Abstract

In recent years, the assistive technologies development has profoundly changed the idea of how to define human beings, in particular in the field of persons with disabilities. The first beneficiaries of aids (orthoses and prostheses), the perception of their condition has gradually transformed up to the CRPD which underlined that disability is a social construction. In this perspective, new concepts have been developed, such as empowerment, enabling, inclusion, habilitation, human rights that have changed the meaning of making tools available to encourage their full participation, today impeded by barriers, obstacles and discrimination. The assistive devices development has completely revolutionized the meaning of aids applied to these persons. The new products have reconfigured the human being limits for all persons and have made it clear that people with functional limitations can overcome the hereditary limits of the materiality of the body, activating enabling and resilient factors that configure a different normality of "doing". The post-human perspectives question the traditional forms of rehabilitation, which is no longer recovering a lost or limited function according to a predefined model of "normality" and health to achieve (abilism), but reformulating the idea of how a person can function keeping account of all its characteristics. It is precisely from the analysis of the human being functioning profile that new forms of protection of the human rights of people with disabilities can be explored, such as the customized participatory projects envisaged by the Italian welfare reform legislation. Assistive devices no longer become a tool linked to the health sector, but rather allow us to expand the ability to participate and broaden functional capabilities and therefore should be provided in a social context, as useful tools to achieve full citizenship.

Keywords: assistive devices, UNCRPD, post-human, habilitation, functional profile

Post-human, Disability and Inclusion

In recent years the development of analogue and digital technologies has profoundly changed the idea of how to define human beings. In fact, most of these technologies extend the natural capabilities of the human body, expanding their field of action and activities in various areas. This has in fact happened in the field of communication and information with the internet and mobile phones, the field of document production and their archiving with computers, the field of activities carried out remotely with communication platforms and activities of various kinds such as telemedicine, technical and professional consultancy, remote controls, the definition of assistive software, app development, etc. This revolution has been described on the one hand as neuronal extensions of the human body and the creation of new forms of intelligence (through computers [1]) and on the other as a vast field of analysis that is defined as post-human [2], which includes philosophical reflections and social and begins to prefigure profound changes in the way future societies develop. Literature itself, and not just science fiction, is questioning itself on these new perspectives of the future [3] and art has also begun to reflect on it. [4]

The Post-human and Persons with Disabilities

These new perspectives have important consequences for people with disabilities, both in the field of access to these aids and in the cultural and political interpretations of how to identify and assign them.

The current definition of aids is linked to the medical-rehabilitation field. They arise from evaluations based on interventions on the body: the current distinction identifies prostheses (an artificial device designed to replace a missing part of the body - a limb, an organ or a tissue -, or to integrate a damaged part) and orthoses (a medical device, a brace, orthopedic equipment or similar, used in orthopaedics, orthodontics or traumatology in the treatment of certain pathologies. It is an external tool used to help the patient in one of his functions). In practice, the two types of aid are centered on the functioning of the human body in order to recover its compromised functions. Over time, new materials and new designs have been used, improving performance, sometimes surprisingly.[5]

The approval of the United Nations Convention on the Rights of Persons with Disabilities (2006) then transformed the definition of disability as a social construction. In fact, article 1 paragraph two defines persons with disabilities as "those who have long-lasting physical, mental, intellectual or sensory impairments which in interaction with barriers of a different nature can hinder their full and effective participation in society on an equal basis with others"[6] . From this new definition, new concepts have been developed on how to guarantee the full participation of these persons in society, no longer centered on the individual, but rather on interaction with the environment and the living context. The ownership of all human rights in conditions of equality with other citizens (art. 1 and 5 of the CRPD), has highlighted how persons with disabilities are impoverished by negative social stigmas [7] and by barriers, obstacles and discrimination produced by society. New concepts have emerged such as that of empowerment [8] , and inclusion, which permeates the entire CRPD, which underlines that the rights of these people must be included in all general policies, which concern the entire population. Another important concept is that of habilitation. The Convention in fact separates the art. 26 on rehabilitation and habilitation from that on health (art. 25). It is a cultural and technical revolution, which on the one hand starts from the idea that rehabilitation and habilitation are not limited to the healthcare sector and on the other that disability is a social relationship, not a subjective condition of the person and therefore has needs to be addressed by skills that touch on all areas of rights. People can move around in wheelchairs, orient themselves with a guide dog, communicate with sign language and not have disabilities, if the world with which they interact takes these characteristics into account. Therefore the objective of the treatments to which they are subjected is to guarantee the highest possible level of health, but in a context in which health is not the absence of diseases or functional limitations, but the well-being of the person. Therefore, rather than dealing only with reconstructing a condition of presumed normality, which often leads to therapeutic obstinacy without results, on the basis of a ableistic approach [9] , people must be guaranteed the enjoyment of fundamental rights and freedoms: they are rehabilitated if functionality is recovered of the body compromised and/or lost, is enabled when new abilities are developed starting also from the condition of functional limitation and from the set of characteristics that allow a person to function in a certain way and on which adequate skills and appropriate supports can be developed.

It is clear that this approach transforms the idea of rehabilitative and social care: the Convention in fact recognizes "the equal right of all people with disabilities to live in the community, in equal conditions of choice compared to other members": a for this purpose the signatory states of the Convention (article 19) "shall take effective and appropriate measures in order to facilitate the full enjoyment (...) of this right and full inclusion and participation within the community, including by ensuring that:

(a) persons with disabilities have the possibility to choose their place of residence and where and with whom to live, on the basis of equality with others and are not obliged to live in a particular place;

(b) persons with disabilities have access to a range of home, residential or community support services, including personal assistance necessary to support life and inclusion within the community and to prevent isolation or segregation outside the community;

(c) community services and facilities for the whole population are available on an equal basis to persons with disabilities and are responsive to their needs."

These articles clearly show that the application of the CRPD entails a profound transformation of the current protection-based welfare to an inclusion-based welfare, widely highlighted during the pandemic crisis, where people with disabilities and their families have suffered a disproportionate burden of problems, as stated by the European Commissioner for Equity Helena Dalli [10] and have been essentially unprotected.[11]

Reinforcing this perspective and underlining the importance of self-determination of persons with disabilities, Article 26 states: States Parties shall organize, strengthen and develop comprehensive services and programs for habilitation and rehabilitation, in particular in the fields of health, employment, education and social services (...) promote the development of initial and ongoing training for professionals and staff working in habilitation and rehabilitation services (...) promote the offer, knowledge and the use of support technologies and tools, designed for persons with disabilities, which facilitate their habilitation and rehabilitation".

It is clear that once the limit of rehabilitation capabilities has been reached, the approach becomes an enabling approach to allow people to achieve levels of autonomy, self-determination, independence and inter-independence. Non-medical figures mainly contribute to this objective.

Also in this case, for all persons with disabilities, but in particular for people who have serious welfare dependencies and for those who cannot represent themselves, a radical transformation of care is taking place: from traditional institutionalization (the result of a approach based on the medical model of disability) we move on to social systems of support for maintenance in living and family places, to family-based forms of reception, to social inclusion policies and services, to personalized projects and supports.[12] In this framework, the direct participation of the person with disabilities or those who represent them is essential. It is a substantial change in the concept of taking charge: the person with disabilities chooses, like all citizens, the supports that favor their life plan. In the assessment of persons with disabilities it is necessary to use ICF [13] in connection with the CRPD: in fact ICF is a nosographic instrument to evaluate the presence of persons with disabilities in a population, but not consider barriers and discrimination as a violation of human rights as CRPD stress. [14]

At the same time, Article 20 of the CRPD recognized personal mobility as a human right of persons with disabilities, highlighting the limits of the current system for assigning aids linked to mobility and overcoming physical and technological barriers, which put in relation to articles 9 (accessibility) and 5 (equality and non-discrimination) of the CRPD require profound changes in the administrative recognition procedures of these aids.[15] Naturally, given the rapid evolution of technologies and the need to be promptly updated on new opportunities, it is necessary for beneficiaries to be informed free of charge about the evolution of the market, with free information services on all new solutions, in order to choose the most appropriate products for the single person.[16]

At the same time, the development of new technologies has highlighted the need to guarantee technical regulation that does not produce other barriers.[17] These new technologies have crossed the entire world society, developing the enhancement of human capabilities regardless of the capabilities of the body. Computers and the use of the internet, the spread of feature-rich cell phones, global access to information and communication have started the process of a post-human world that involves the entire human race.

Put in Value the Human Diversity

The WHO's recent position is particularly important. The WHO and Unicef definition of assistive devices is very broad. "Assistive technology is an umbrella term for assistive products and their related systems and services. Assistive technology is of fundamental importance for persons with permanent or temporary functional difficulties as it improves their functional ability, and enables and enhances their participation and inclusion in all domains of life. Assistive products may be physical products such as wheelchairs, spectacles, hearing aids, prostheses, walking devices or continence pads; or they may be digital, occurring in the form of software and apps that support interpersonal communication, access to information, daily time management, rehabilitation, education and training etc. They may also be adaptations to the physical environment, for example portable ramps or grab-rails. Definitions of assistive technology and assistive products differ depending on their purpose and scope".[18] This definition includes both devices currently considered healthcare and new information and digital technologies.

The development of the concept of assistive devices has completely revolutionized the meaning of aids applied to people with disabilities. This is because this new cultural and technical approach has reconfigured the limits of human beings for all and has made it clear that person with functional limitations can overcome the hereditary limits of the materiality of the body, activating enabling and resilient factors that configure a different normality of "doing" and of being.

The post-human perspectives question the traditional forms of rehabilitation, which can no longer limit itself to recovering a lost or limited function according to a predefined model of "normality" and health, but reformulate the very idea of how a person can function, even with functional limitations of the body, taking into account all its characteristics and appropriate supports.

The concept of enablement introduced by Article 26 of the CRPD makes the meaning of Article 3 point d) of the CRPD clearer: "respect for difference and acceptance of persons with disabilities as part of human diversity and humanity itself ". We can no longer be treated as people in whom only the psychophysical condition is highlighted, impoverishing the person who is reduced to that sole characteristic of the body or mind. Examples in human history allow us to understand this revolution, John Nash junior won a Nobel Prize in economics with his game theory despite living with schizophrenia (1994)[19]; Henri de Toulouse Lautrec was a great painter even he had a congenital malformation[20]; Ludwig van Beethoven was a great musician who became deaf, but continued to compose.[21]

The change must therefore first of all be understood as not reducing the person to a medical diagnosis. Medicine has also started to reflect on diagnoses, particularly in the United States where precision medicine and precision psychiatry were born.[22] Observing that people who had the same diagnoses had different functioning, this approach shifted attention to describing how people function to understand how that person has specificities that require personalized treatment.

It is precisely from the analysis of the functioning profile of a human being that new forms of protection of the human rights of all people with disabilities can be explored. To understand what we are talking about, let's take the great cosmologist Stephan Hawkins as an example. Affected since 1963 by ALS, amyotrophic lateral sclerosis, he had lost his autonomy, was unable to articulate words and would have been destined, if evaluated by an Italian regional commission, to a residential facility. Instead, evaluating his functioning profile and the person's abilities, he had personal assistance 24 hours a day, he moved with an electric chair that he controlled with the joystick and communicated through a computer that read the movement of the eyelids and eyes. communicating with speech synthesis software. Evaluating the elements of his way of functioning, he continued to do his job with the appropriate supports.

This profound revolution in the field of aids makes us understand how this new approach also changes the meaning of the provision of these products to persons with disabilities. In fact, most of them no longer have to do with the area of health, but with the areas of participation, independent living and full citizenship. The 2022 WHO report, quantifying the current need for assistive devices at 2.5 billion people and predicting that it will reach 3.5 billion people in the next few years in 2050, says it explicitly: "access to appropriate, quality assistive technology can mean the difference between enabling or denying education for a child, participation in the workforce for an adult, or the opportunity to maintain independence and age with dignity for an older person".[23]

Therefore we should start discussing whether the supply of assistive devices is entrusted to the field of rehabilitative health, starting from the idea of intervening in the field of functional recovery of the body, or instead it should be included in the field of support for full participation and full citizenship, transferring resources from a health competence to a social competence.

Here is another field of cultural and technical revolution produced by the CRPD!

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3. See as an example the web site https://www.grafiati.com/en/literature-selections/posthuman-literature/ .
4. See the following site which provides a review starting from the work of Jeffrey Deitch, https://inanimanti.com/2020/07/13/cera-una-volta-il-post-human-jeffrey-deitch-mostra-1992/
5. Suffice it to say that Oscar Pistorius ran in the London Olympics in 2012 with two prosthetics ("cheetahs", a name inspired by cheetahs) on both legs, amputated through the use of very expensive materials used in aerospace engineering. These prostheses have raised controversy as to whether the South African runner was improperly advantaged by the use of these prostheses.
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9. Ableism is a cultural paradigm similar to racism and sexism and discriminates against people with disabilities. This concept assumes that all people have an able-bodied or "normal" body, that is, one that fits within the social and cultural conventions accepted by the community. The word "ableism" indicates a world designed and built without taking into consideration people who may have physical, mental or other impediments. From this it follows that people who do not fit into the concept of "normality" are excluded from society, ghettoized and discriminated against because they do not respond to the ordinary vision of things, because they are "unskilled". See Bellacicco E., Dell'Anna S., Micalizzi E. and Parisi T. Nothing about us without us. Una ricerca empirica sull'abilismo in Italia. Milan, Franco Angeli, 2022. See too Exploring internalized ableism using critical race theory , FAK Campbell - Disability & society, 2008 - Taylor & Francis and Scuro J. Addressing Ableism: Philosophical Questions via Disability Studies. Lexington book.
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24. From the Support to Specific Limitations of Ability to the Facilitation of an Autonomous Life in the Smart World

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Abstract

Traditionally, the problem of the relationship between humans and ICT technology has been approached with the assistive technology approach. That is, a person cannot access a system (a computer) and it is necessary to develop an adaptation for the person's problems (e.g., how to get a blind person to access the screen). In this example, the problem led to the development of voice synthesizers and screen readers, able to give access to the screen if the person is not able to see it. Now the situation has unquestionably changed toward greater complexity due to the development of the technology leading to the smart environment concept and the change of the general approach to the integration of people in the society. The work analyzes the problems related to this evolution, with reference to the possibility of developing an environment suitable and/or adaptable to most inhabitants. The conclusion is that due to the complexity of the problem, it is necessary to facilitate its solution by the use of Artificial Intelligence in collecting, organizing and using all information needed for supporting all people.

Keywords: Assistive technology, Ambient intelligence, Artificial Intelligence

Introduction

Since the start of the development of information and communication technologies, there have been concerns that the equipment and services made available could create access problems for some groups of users, e.g., access to telephones for deaf people and to screens for blind people. Research and development activities solved specific problems of these user groups with the use of special additional hardware and software (Assistive Technology) [1]. Now, most of these solutions are part of the operating system of e.g., mobile phones. Therefore, in most cases, accessibility to the system and applications running on it are directly possible.

However, in the meantime, ICT technology has developed towards the possibility of implementation of smart environments (house, school, work, city) populated by computer-based interconnected objects and the society's attitude towards the problems of integration in the society has changed. Recently, there has been an increasing interest about people well-being, which, in accordance with the principles in WHO-ICF [2], is defined as the possibility of conducting an independent, active, and fulfilling life, being able to conduct the activities necessary for living.

Being people well-being the main concern in future developments of the society, the present paper is not interested in accessibility with the help of assistive technology, but in the possibility of structuring the living environments to facilitate the independent life of all people.

A Possible Innovative Approach

An approach to increase the well-being of people is the development of “ambient active living environments [3].” It aims to the cooperation of technology in the environments (smart environments) to help all people in their living activities and to compensate for their lacking or reduced abilities.

A person who, for example, needs to feed herself is supposed to live in a smart kitchen like the one schematized in Fig. 1.

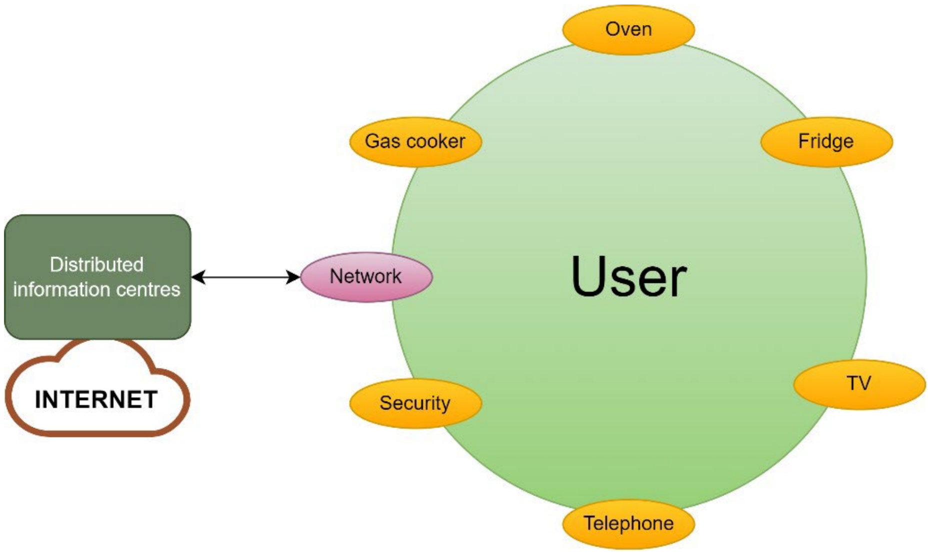

Figure 24-1: Organization of a smart kitchen

The user is interfaced with all the equipment in the kitchen, which are interconnected among themselves and with the network. This also makes possible the creation of communities of users and the connection with public services (for example the hospital).

The main point in organizing a support environment is the definition and collection of the information about the activities to be conducted and about the conditions of the people living in it.

Fortunately, the activities necessary for living and the abilities necessary for carrying out each activity are reported in the details in the document WHO-ICF. The study of the connections between the activities and the abilities necessary to carry out them is supposed to be useful for all people. Several documents of WHO and UN [4,5] support the idea this may be particularly useful for the independent life of people with limitations of activities, including older people who may see some of their abilities decreasing in time [6]. In this context, accessibility, and usability, although necessary, are not sufficient. It is necessary that the design of the smart environments is centered around the well-being of people. Therefore, the environment must be orchestrated around activities for living (see ICF) considering the abilities necessary to per-form them. How people can be helped, when some abilities are limited, must make use of capabilities for monitoring, also in real time, possible difficulties, and reasoning to adapt, fine-tune and evolve over time the type and level of support provided. This development must include the possibility of contact with other people, not only professionals (e.g., doctors and psychologists) when necessary, but also members of the community in which people live. Finally, the efforts must consider ethical values.

In the new technology-augmented environments, whatever the reasons for which individuals may be at risk of exclusion, the challenge is that the support of universal usability and usefulness become a matter of paramount importance in the forthcoming future, when available technology will not only mean access to information and communication but ability to carry out all the activities contributing to a complete integration in the society. The requirement for more holistic approaches is now more prominent than ever.

Usability versus Usefulness

Traditionally, the problem of supporting people in their activities has been approached by starting with their access problem (the person is deaf and cannot use the telephone) and looking for a way to allow the solution of the problem with the sup-port of a specific assistive technology. Now, an approach must be used that starts with the conditions of people, in relation to their activities. The goal is to design systems that can support (most of) people to carry out (most of) the activities fundamental for an independent living.

Obviously, this approach is part of Design for All, but with an extended definition, addressing not only a single problem, as in the case of architectural design, but, in principle, any problem in any environment. Moreover, the fundamental point is not the accessibility and usability of technologies, but their usefulness, with reference to the entire population.

This shift has two main consequences. First, a richer architectural approach to the use of technology is necessary, where a control component that integrates the available smart objects and controls their cooperative use in supporting people is introduced. This control must not be seen only from the perspective of the communication and interoperability of the technologies but has the specific objective of embed-ding in the system the knowledge about technology and users [7]. The envisaged usability built in the environment does not only imply ease of use, ease of learning and effectiveness in use by the average user, but also personal adaptations of the services, because different people may need or prefer to carry out the same activity in different ways or need to receive different types of information to carry it out.

Interaction and Cooperation

Of course, for the interaction with the environment and the services made available by it, there is an emphasis on "natural" user interfaces [8], meaning interactions based on modalities and media typical of human-human interaction (e.g., using speech, the body language, gestures, facial ex-pressions and so on). However, it is also assumed that social interactions need to be fruitfully embedded in the very fabric of a smart environment, which is supposed to be always plugged into the internet network. The information coming from social networks, if conveniently processed and organized, may contribute to the available knowledge of the group, and limit possible social segregation.

New technological environments also have the potential of effectively improving old and new accessibility issues and requirements. In particular, the abundance of interactive and distributed devices can result in a relaxed and enjoyable interaction, employing multimodal interfaces, thus providing for each user those interaction modes that are more natural and suitable [9]. Other benefits ensured by these new environments include the possibility of task delegation to the environment and its agents, which can reduce physical and cognitive strain. Henceforth, an additional and fundamental benefit of these environments is that they will be able to provide higher quality healthcare [10].

From the Solution of Specific Problems to the Access to Well-being - A Case Study

To understand the usefulness and the complexity of the proposed approach to the development of applications aimed at improving the autonomy of all people in smart environments, it is useful to start with practical examples. They are based on applications already implemented in our laboratory (help with food preparation [11], support in situations of loneliness [12]) or in progress (pedestrian accessibility to the external environment). These applications refer to problems of increasing complexity and have led to the awareness of the need to introduce components of artificial intelligence in their production.

An essential activity for living is to feed oneself. What is the information that must be available for planning and implementing the functionalities needed in an application expected to help people in this activity? First (see Fig. 2), the application must know the structure of the kitchen: available appliances, their intelligence (possible automatic functionalities), and the connection between them. Then it must know the person using the kitchen (part of the knowledge database): for example, gender, age, medical situation, food she likes, ability to cook (elderly housewife or elderly widower completely ignorant of any aspect of cooking), physical and mental abilities, and so on.

Initially, the person must decide what to eat. If she is a person who knows how to cook, reference can be made to her database of recipes. If no available recipe satisfies her, the applications must make other recipes available. How? It depends on the person ability to interact with the environment. If her skills are sufficient, it can pro-vide access to one of the recipe sites on the network. Otherwise, it can propose dishes by reasoning on what is already in her recipe database. Obviously, it must consider incompatibilities with the health situation of the user to suggest a convenient diet. Otherwise, it can contact persons in her community or, if she has serious health problems, the doctor (even if, in many Europeans countries this service is not available). If the user does not know how to cook, it should offer her a series of simple dishes and follow her throughout the preparation of the food. Of course, the proposals must be based on the knowledge of what the person has in the pantry or refrigerator, or to know if the person has the possibility and ability to procure the missing ingredients.

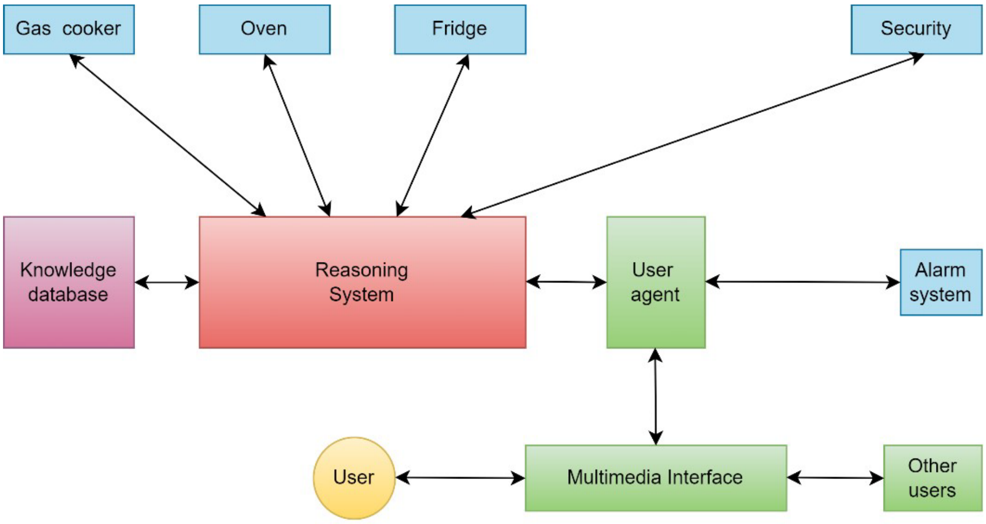

Figure 24-2: Intelligent kitchen

Once everything is available, the application must guide the person to manage the necessary operations to cook the dish. If she has experience, for example, it can first tell her to make a sauté. Otherwise, it must explain what a sauté is and guide her in preparing it. Specific preparations depend on the user's knowledge and/or skills. If she is at least relatively experienced, she can only be said by the system, for example, to grind an onion. If she has no experience in the kitchen or has problems in handling home tools, it is necessary to guide her in choosing the right tool and explaining how to use it.

If the person is at home and feels lonely, can anything be done for her? Now the problem becomes more complex from two perspectives. First, a way must be found to identify the person's solitude state and then how to help her. The first problem can be solved by monitoring her behavior or measuring some physical parameters. Then if it is a matter of recommending something that the person can do on her own (e.g., watch television or go for a walk) the situation is simple. If, on the other hand, other people need to be involved (in an implemented experimental application a condominium has been considered), the situation becomes more complex. First, it is necessary to take into account the relationship that the person has with each member of the condominium, the availability that each member has offered and the availability at the time of manifestation of the need. This means thinking about the situation, people's availability, and their ability to help.

The problem becomes even more complex if the person must move, for example, inside the city to buy what she needs. She needs to know if a service (e.g., a pharmacy) is nearby, its opening hours, and the route to reach it. She must also be informed about the accessibility of the route. Even if she does not move in a wheelchair, a bumpy sidewalk, a risky crossing could put her in difficulty. The main problems are the availability of real-time information on environmental conditions and the knowledge of the changing abilities and interests of people.

Role of Artificial Intelligence

It is fundamental to consider that for living comfortably it is necessary to carry out complex activities, such as feeding, and it is necessary to study how smart environments, which it is now possible to create due to the technological developments, can allow everyone to carry them out even if she has some lack of ability.

The additional functionalities can be obtained by introducing Artificial Intelligence in the system, with the evolution of a control component made of two main blocks: a knowledge base and a reasoning system [13], as shown in Fig. 1. The content of the database and need of reasoning are briefly described with reference to the kitchen application, which has been instrumental in fine-tuning the problems of the approach.

The database is a fundamental building block of the system. It must contain in-formation about many distinct aspects of the situation. First it must have a detailed description of the user profile. For each individual user it must know the medical situation, her abilities and lack of abilities (the user knows how to cook but has short-range memory problems), her requirements, habits, and preferences. One of the main tasks of the reasoning system is therefore to build and enrich the knowledge about the user, acquiring, integrating information provided by the user herself or members of her community. It must also be able to extract knowledge about the user (machine learning) from available informal information and to learn from usage to refine the knowledge base in real time. This is particularly important, because the person's situation can change over time, for example because she gets tired.

In addition to the user, the system must know in detail the task to be carried out, to be able to identify the functionalities necessary to conduct the necessary activities (control of the chicken environment and detailed information about the dishes to be cooked and how to cook them, access to the pantry, etc.). So, it needs to identify the technologies available in the environment (gas cooker, oven, fridge) and their interoperability issues, i.e., interfaces and communication protocols.

Finally, to allow the user to work in the environment, interaction issues must be de-fined and solved, considering the user interaction problems, if present, and available interaction devices and modalities. For example, the user is blind, and it is necessary to guarantee her the access to all technology that uses a screen to communicate.

The conclusion is that the implementation, maintenance, and run-time use of the system must be conducted under the control of a reasoning system (intelligence in the environment), capable of carrying out the adaptations to match its behavior to the characteristics of the user. Finally, the knowledge in the database must be used not only to adapt the functioning of the system to the present situation (for example, the user is tired and the support that is given to her needs to be reinforced), but also to reason about if and what functionalities should be made available according to the varying capabilities and preferences of the user and to the evolution of technology.

Conclusions

As mentioned above, the social attitude towards the problems of people who are unable to carry out certain activities has varied from the study of specific solutions to allow them to carry out them to the effort to promote their well-being in general. As a starting point for this task, it seems interesting to see how an independent life can be ensured. Fortunately, the present technological developments in ICT with the creation of the possibility of implementing objects based on computers (smart objects) that can be connected to each other and the developments of artificial intelligence allow, at least at a conceptual level, to create environments capable of observing people and helping them when they need it. This is also demonstrated by the applications carried out in our laboratory. The key question, at the moment, is when these developments will become market products that can be distributed in a way that really can have an impact on a large scale. This requires two components. The first is that the applications of artificial intelligence and smart technology become invisible enough in the environments and they do not alarm the people who live there. The second is that it will be understood that the development is interesting for all people and, as has been the case with some of the assistive technologies, these possibilities are incorporated into standard industrial products.

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25. Bridging the Gap: A Comprehensive European Strategy for Digital Skills Development in Work Integration Social Enterprises

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Abstract

Work Integration Social Enterprises (WISEs) play a crucial role in improving the employability of workers with support needs and promoting inclusive employment. Due to the changing labor market and industrial digitalization, they face challenges in adapting to evolving technologies while maintaining their mission-driven goals. This paper examines WISEs across Austria as part of a Europe-wide evaluation and a European strategy, exploring their varied types and digital skills gaps. Using qualitative research methods such as focus group discussion, case studies and expert interviews, the study explores the level of digital literacy within WISEs and suggests strategies for improvement. Different types of WISEs - productive, social, and training - face different digital challenges that require tailored solutions. Empirical findings indicate that productive WISEs face competition-driven pressure to adopt advanced technologies while remaining inclusive and an inclusive employer. Social WISEs prioritize social development alongside digital upskilling, using technology for training and communication. Training WISEs focus on preparing workers for mainstream employment, recognizing digital proficiency as essential. In addition, the results show that despite varying levels of digital progress, WISEs agree on the need to embrace digitalization for competitiveness and inclusiveness. Challenges include resource constraints and inequalities in digital access. The study advocates for structured digital training, user-friendly eLearning platforms and management support within WISEs and emphasizes the societal importance of digitalization and the role of WISEs in bridging social divides.

Introduction

The project "Blueprint for Sectoral Cooperation on Skills in Work Integration Social Enterprises" (in short: B-WISE) addresses the challenges faced by Work Integration Social Enterprises (WISEs), which aim to integrate disadvantaged individuals into the labor market. An early project outcome highlights the pressing issue of skills shortages and mismatches, particularly in digital skills and soft skills, affecting WISEs. To address these challenges, the project proposes the development and implementation of a strategic approach, known as the blueprint, which promotes sectoral cooperation to address skills gaps in the WISEs sector. Key objectives include identifying sectoral labor market needs, analyzing the responsiveness of existing vocational education and training (VET) systems, developing transnational curricula to assess current and future needs, and promoting good practice at national and regional levels. In addition, the project aims to develop a sustainable plan to match demand and supply of identified skills, build a supportive community for skills growth, innovation and competitiveness in the sector, and design a long-term action plan for the progressive implementation of the strategy. Led by two European networks and involving 28 partners from 13 EU countries, the B-WISE project focuses on creating flexible and adaptable outputs, ensuring local implementation with a clear European perspective.

WISEs improve the employability of workers with support needs (WSNs) and are recognized as important and inclusive employers themselves [1]. The European Commission's 2021 Action Plan [2] to strengthen the European social economy recognizes both the importance of WISEs in promoting an equitable and inclusive economic recovery and their importance in supporting the green and digital transition. In addition to the labor market integration, WISEs have to balance between their own vision, mission, and technology. Additionally, as enterprises, they are embedded in the process of economic, social, and digital transformation, and today they are challenged by digital services and trends, such as internal and external interaction with the administration, human resource management, allocation of services and tasks to departments, internal and external public relations, knowledge management, applications to the public employment services, e-government, and the design and implementation of digital services for those served by WISEs. WISEs face multiple challenges [3].

WISEs also need to remain competitive with other profit enterprises in the future, including a further development and adaptation of their business models [1, 4]. Technological developments, their internal application and their use in the labor market integration create new (digital) qualification requirements for WISEs and their employees [1].

These pressing issues are focused within this paper. Starting from a general outline of the typology of WISEs, categorizing them as productive, social, and training WISEs, each with different objectives and operational dynamics; the paper then examines the different staff categories working in WISEs, then details the methodological approach used in the study, and then presents the findings. The results highlight the specific digital challenges faced by each typology in Austria, as well as the critical role that key workers (supporters) and managers (enablers) working in WISEs play in fostering digital empowerment. Finally, the paper discusses the implications of these findings and offers recommendations for improving digital literacy within WISEs, emphasizing the importance of collaborative efforts to address digital skills gaps and promote inclusive employment practices.

Categories and the Associated Diversity of WISEs

WISEs run their business (e.g. restaurants, handicraft workshops, digitization or maintenance services) while at the same time qualifying, empowering, stabilizing, and providing a temporary employment or job perspective for workers with support needs (WSNs). For their work in the WISE, WSNs typically earn a significant amount of money for their living [5]. WISEs are characterized by diversity in terms of their employees, their business area and their size. Additionally, there is an "extreme variety of legal forms, public policy approaches and cultural traditions in Europe" [5].

Three ideal types of WISEs can be distinguished: Productive WISEs, Social WISEs and Training WISEs. Productive WISEs are "strongly production-oriented; their sustainability depends exclusively or almost exclusively on the sale of goods and services on the market, where they compete with other enterprises, both WISEs and, above all, non-WISEs. In some cases, they reach significant economic size (some millions of euros)", and partially employ WSNs long-term, at least longer than in training WISEs [5]. Training WISEs are often situated within or closely connected to productive WISEs. WSNs "should be realistically prepared" for the regular labor market. As modern labor is driven by digital tools, they are considered as crucial. Thus, training WISEs use numerous digital technologies to train and prepare WSNs realistically [5]. Social WISEs are more intervention-driven and tend to strengthen WSNs via social inclusion, provision of care services, and also productive actions. WSNs stay longer than in training WISEs. Their income is mainly based on subsidies and public funding, partially on self-earned income which is usually lower than in productive WISEs [5].

Three different staff categories work in a WISE: Workers with support needs (WSNs) are trained in WISEs and include a wide range of people: long-term unemployed, older people, persons with disabilities, people with a history of migration, NEETS (Not in Education, Employment or Training) and other groups who are at risk of exclusion from the labor market. They need productivity, operational, communication and digital skills to carry out productive and service tasks, to use applications and technologies within WISEs and for applications. Key employees (Supporters) address and work with WSNs and support the management (enablers). They act at the core of a WISE and qualify, stabilize and place WSNs at the labor market. At the same time, they do administrative work, apply for funding and train individuals. They need pedagogical, caring, motivational, problem-solving, monitoring and digital skills. Enablers are at the management level of a WISE. They guide, organize and monitor WISEs in the areas of finance, personnel, administration, policy, networks and more [5].

Methodological Approach

Based on these three types of WISEs and staff categories and a qualitative research approach the following questions were addressed:

1. How can work integration social enterprises in Austria be classified in the typology?
2. Which people work in WISES?
3. What digital skills gaps and needs exist in Austrian work integration social enterprises and how do they respond to them?

The results are based on 1) a focus group discussion with eight participants from the field and 2) ten case studies with participant observation. Additionally, for the case studies qualitative expert interviews with 20 enablers, 32 supporters and 40 WSNs were conducted. The focus was primarily on the use of technology and the digital skills of employees.

The case study as a research approach enables an intensive and in-depth examination of the social enterprises. Case studies are particularly suitable for capturing complex issues in reality. Conducting a case study requires looking at the phenomenon from different perspectives, i.e. the data is brought together in a triangulating manner in the course of the analysis [8]. The focus of a case study is strongly on an inductive, explorative approach. The cases are collected on site in as natural an environment as possible. A selection of different methods provides multiple data sources, which increases the quality and reliability of the analysis [10]. The individual cases were collected and presented separately and then categorized and analyzed using the established typology of social enterprises [8].

A SWOT analysis with a focus on digitalization was then carried out. The case selection represents a mixture of production-, social- and training-oriented Austrian social enterprises [6, pp. 32-33;171-172]. The subsequent SWOT analysis was carried out on the types of social enterprises, which also incorporated the results of the digitalization analysis. The four sections are presented and categorized according to their importance: The strengths (Strengths), the weaknesses (Weaknesses), the conducive framework conditions (Opportunities) and the inhibiting framework conditions (Threats) [9].

Digitalization of WISES in Austria and the Related Challenges

The following chapter is dedicated to the analysis and consideration of Austrian social enterprises divided into the typology of production, social and training. The use of technology and digitalization in these individual types is highlighted.

Production WISEs

Social enterprises with a focus on production are either socio-economic enterprises or sheltered workshops. The former employ people on a temporary basis, the latter usually on a permanent basis. This leads to differences in the target groups and their placement options. The services and goods are sold to private or public customers. Some of the social enterprises operate a shop. Productive WISEs in Austria prepare workers with support needs for employment in the regular labor market, in some cases through further social support and training (on the job or structured training). Productive WISEs, both sheltered workshops and socio-economic enterprises, have a regular clientele. They endeavor to increase the number of their customers. Large work orders enable recurring work and lead to good performance and quality. The social enterprises can thus present themselves as potential business partners.

Digitalization is an essential topic in almost all of the Austrian productive WISEs surveyed or is seen as an asset for the target group and key workers, even if time and people in the target group want to avoid digitalization skills. Some social enterprises have started projects to promote digitalization in their company or developed training programs for their social workers/key workers (e.g. F1, F2, CS2). Some productive social enterprises use advanced technological equipment, e.g. special tools for assistive technologies (F1, F5), specific computer programs, e.g. for sales and inventory management (CS1), and technologically advanced machines.

Some productive WISEs, on the other hand, still use technology that can be seen as out-of-date for profit-oriented enterprises. The investment costs, the low failure rate, the age of the employees and their previous skills may be the reasons, as the interviews showed. Old machines are being replaced or are due to be replaced, in order to fulfil orders from companies on the regular labor market.

Social WISEs

Austrian social WISEs concentrate on the social development and stabilization of their target group. They generally offer a wider range of social work than producing social enterprises. The target group is employed on a temporary basis. With a few exceptions, the employment contracts last several years. Young adults receive ongoing training in manners, social and digital skills and cultural techniques (reading, writing, arithmetic), as do adult employees, but usually with a stronger focus on social and digital skills.

Social enterprises with a focus on social development and stabilization emphasize the importance of technical equipment. As many also offer training courses, they highlight the importance of technology and digitalization for the training processes. It is important that the target group is trained realistically. For communication with WSNs, social WISEs rely on private messenger services such as Signal. This allowed a continuous communication even during the coronavirus pandemic (e.g. CS6, CS7) and was also used on a peer-to-peer level of self-advocates in social enterprises. At the same time, digitalization was experienced as complicating communication, e.g. by some people in management (F5).

In order to create more motivation for digitalization within social WISEs, the topic should be approached in a more structured way and workers with support needs should be asked what they really need. In the rigid work context, people are too tired or not interested in learning something new at the weekend or in their free time. If digital training were integrated into the programs as standard with a compulsory character, it should be practice-orientated, combining different digital devices and should also solve everyday questions.

Training WISEs

Austrian social enterprises with a focus on training aim to prepare employees specifically for employment on the regular labor market through training. The employees are hired on a temporary basis. Their training lasts several months or - in rarer cases - years. Since the training in the social enterprises is to a certain extent closely interwoven with producing social enterprises as some employees are subsequently placed there (second labor market). The social enterprises that provide training are subsidized by the state, but must meet high profit quotas. This is seen as problematic, for these quotas were particularly difficult to achieve during the pandemic.

Digitalization plays a significant role in the social enterprises surveyed, as it is part of training (F1, F3, CS2, CS10) or is being planned as part of training (CS4). Disadvantaged people should be realistically prepared for the regular labor market. As digitalization is part of modern employment, this is seen as crucial. Technical equipment must be up-to-date. This is difficult to fulfil. Social enterprises often use word processing and other software that is usually older than the current state of the art (S2/CS2). Nevertheless, training social enterprises endeavor to use advanced technological equipment (e.g. computer programs, technologically advanced machines, accessible technology). As the qualitative results demonstrate, some of the social enterprises analyzed also benefit from their size (e.g. when a production and training WISE were interwoven) and can invest higher amounts or receive better pricing conditions. High investments have to be made in digital technologies, costs for staff training were extra.

Digitalization can be a challenge for target groups. Older people, but also young adults, find it difficult to use digital devices or programs and to transfer this knowledge into everyday life. Also, emotional barriers to use it are high (F4, CS1, CS2, CS7). Age as the only limiting factor was not detected. One digitalization expert notes: "There is the wording that digitalization has something to do with age or educational background. But the opposite has happened to me. I met older people who were very interested. On the contrary, young doctors who didn't want to deal with it at all" (E3/CS2).

Training WISEs are still investing in distance and blended learning systems. The learning platform Moodle is popular because it is open source, but eLearning offers often degenerates into a non-engaging document management system. One reason for this is the allocation of time resources to developing staff. Many trainers prepare content for face-to-face teaching and digital training. Documents and links to websites are provided for self-study. A second reason requires a well-planned and well-prepared introduction to setting up eLearning seminars, including customizations of the technical modules. Social enterprises, however, are rarely motivated to pay for these customizations. The social enterprises lack of support in setting up useful eLearning resources. A third reason is support from the management framework. Objectives and guidelines need to be named and publicized. A team or at least a single point of contact should decentralize knowledge and technical support. Another finding is that eLearning systems must be easy to use, easy to understand and motivating. People must take center stage in training; eLearning should be a supplement and not a substitute. All in all, social enterprises with digitalization experts paid a larger attention to this.

The social enterprises surveyed highlight the need for greater digitalization. Blended learning and online training not only better prepare people who are moving directly into the regular labor market, but also facilitate the productive area of social enterprises with upstream training measures. The reality is however that only a few training WISEs offer eLearning. They did this during the coronavirus pandemic, but do not have a structured remote learning platform. Secondly, some are preparing their eLearning platforms for employee training only and do not focus eLearning for the (digital) upskilling of WSNs.

Conclusions

Many WISEs face a digital skills gaps among their employees, including the need to remain competitive with other players. Productive WISEs benefit from public funding and purchase digital technologies for production and sales services. However, employees need to be familiar with these technologies. In some cases, respondents perceive (digital) technology as a threat. Digitalization is happening rapidly, and WISEs are struggling to keep up with the state of the art [6].

Cost-Benefit Ratio

The scope of future developments depends on the subsidies allocated by the local authorities. In general, the social enterprises are planning to further develop and better distribute their resources at the various locations. They plan to optimize and automate work processes and to enhance and professionalize training.

A well-prepared and implemented introduction of digitalization is cost-intensive. Enablers require tangible results and a well-balanced cost-benefit ratio. In the meantime, the social enterprises analyzed are investing in (digital) machines, equipment and the necessary software for training and production. The associated investments amount to half a million in some cases. In future, social enterprises also expect costs for ecological challenges (digitalization-related area). At the same time, WISEs recognize these sectors are likely to open up new areas of activity for disadvantaged workers within social enterprises and perhaps prepare some of them for permanent employment in the labor market. Following this, managers (in the study entitled as enablers) see the potential of digitalization and value the cost-benefit ratio highly, but also recognize the risk of exclusion if technologies are not accessible.

Digitalization as an Ongoing Agenda

All WISEs surveyed use digital devices and software. Digitalization is an ongoing agenda and all examined social enterprises agree on this. The specifications and progress vary greatly. The fact is that the training WISEs are the most advanced, followed by the productive WISEs. They use components such as computers, office software, assistive technologies, video conferencing tools and to some extent eLearning platforms. Their hardware is usually state of the art, although often one to two years behind the private sector. "The significant integration of technology and digitalization in the production cycle raises the issue of the lack of digital skills of workers and the use of technology, which is a problem when facing competition" [6].

The pandemic necessitated changes. The WISEs reacted and created tools and framework conditions at short notice. The coronavirus crisis was a technology booster. Laptops were purchased in big scale. Employees (enablers, supporters, workers with support needs) worked remote and video conferencing, including team meetings and supervision, increased. Since then, working from home has been permitted, sometimes only for specific tasks such as preparing reports. Shared calendars and resource calendars for room allocation are used. An intranet has been set up for the internal exchange of information. Certain groups use additional release points. Data is stored either in the cloud or on database servers and made accessible from anywhere. Database systems for participant administration are currently being implemented. Despite the digitalization push, many WISEs are noticing personal backlogs. Many of them are now reducing these or preparing for future developments.

Digital Offers

All social enterprises surveyed use standard office software, video conferencing tools, administration tools, and documentation tools. Some use apps for electronic time management. Some offer intranet and approval points, usually only for enablers, supporters and overheads. Individual social enterprises started attempts to provide workers with support needs with electronic time recording or an intranet. As a rule, intranet systems provided information that could also be found in a public search. The survey shows that the intranet is hardly used by those affected. The question could be asked whether a presentation of publicly accessible information on the intranet makes sense and whether they would benefit from information about their individual situation (e.g. documentation, data protection rights, contract).

Digital Gap

Some social enterprises describe their target groups as having little digital knowledge. There are workers who are interested in digitalization, but many try to avoid acquiring digital skills, as described above. In relation to this, there is a digital gap between professional and private use of digital tools. Disadvantaged employees often have little technical equipment at home (e.g. smartphone, limited internet access, rarely laptops), with restrictions due to socio-economic reasons.

The digital gap between well-equipped social enterprises and hardly any equipment at home was obvious and could reinforce digital illiteracy as well as (digital) exclusion of related persons [5]. Thus, digitalization also reveals a social divide. The WISEs recognize a responsibility towards the target group.

Motivation to Learn

Managers see the potential of digitalization and are motivated to use digital tools. At the same time, they recognize the to some extent overwhelming load of administration by means of digital tools. Depending on their professional background, supporters are generally willing to acquire and improve digital skills. However, they rarely find the time to take advantage of further training programs in their day-to-day work due to the output that needs to be achieved in terms of products, selling goods, placement of WSNs on the labor market, and administration. Thus, some lack of motivation. The empirical findings also reveal differences in digital literacy among WSNs: some, also younger workers with support needs, are accustomed to using digital devices, but occasionally have problems in generalizing their knowledge, while other WSNs tend to reject technology, hypothetically due to mental overload, and uncertainty how to cope with digitalization.

The attitude of training participants towards the technology varies greatly. Those in favor (e.g. S1/CS2) assume that many of those who are interested now will also be interested in the future. Many of those who reject the technology will continue to do so in the future. Little will change in their attitude. In contrast, digitalization experts dream of supporters and employees who take digital systems for granted and use them (e.g. E3/CS2, S1/CS7).

Many supporters agree that the devices must be easy to understand and use. They must be available to supporters and disadvantaged workers (e.g. barcode systems for warehousing, digital devices for shops to count incoming goods and sales).

eLearning

Many WISEs agree about Moodle. It is popular because it is open source, but it needs to be updated regularly and requires prior knowledge to set up and maintain. Additionally, trainers are required to be trained in web editing, ideally in an accessible form, as many social enterprises also cater for people with disabilities and people who need text-to-speech due to low literacy skills. Last but not least, it requires time resources for planning, preparing, uploading and maintaining training materials. These are some of the fundamental risks that WISEs face.

The results demonstrate a gap between the availability of a well-prepared and well-maintained eLearning system and the support of WSNs. A person in charge would be needful, also for another risk: the degeneration of eLearning systems into a document management system. eLearning is often very text-intensive, based on slides, text passages and questionnaires. A system would benefit from a motivating and inviting layout, well-coordinated text-image-video-audio presentations and as many live sessions as possible. Again, it would need a person in charge.

Finally, the audience addressed is limited. Social enterprises often offer eLearning platforms for the training of supporters. Little social enterprises also offer online training for disadvantaged workers.

A final Conclusion and Future Implications

Many WISEs intensively discuss digitalization, some discuss how to provide a well-developed offer and accept the relevant workload to be well-prepared for future. This also leads to intensive networking and community of practices related to digitalization as well as digital upskilling of staff. National communities of practice in Austria exist, but they need to focus more on digitalization which is integrated by B-WISE consortium. By means of B-WISE consortium, WISEs are currently entering and establishing a sustainable transnational community of practice with regard to digitalization, also including upskilling digital skills within WISEs. For this, the transnational curricula will be certified at national levels.

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