Workshop on Designing Accessible Extended Reality: An Opportunity for People with Disabilities and Disorders

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Extended Reality (XR) technologies offer a wide range of innovative use cases and interaction concepts. On the one hand, they provide several possibilities to reduce barriers for people with specific physical or mental needs, e.g., through simulations, gamification, or training scenarios. Individuals with anxiety disorders, dementia or autism-spectrum disorder, for example, may also benefit. On the other hand, it is challenging to design accessible XR technologies for heterogeneous user groups. Therefore, the area of accessible XR as well as adaptation based on users' needs and contexts, is of high interest and barely researched yet. Participants of the workshop are encouraged to discuss both – the major challenges and opportunities in designing XR-based assistive technology for different target groups and scenarios, as well as the accessibility of XR technologies.

CCS Concepts: • **Human-centered computing → Mixed / augmented reality**; *Accessibility technologies*; • **Applied computing** → Psychology.

Additional Key Words and Phrases: accessibility, extended reality (XR), virtual and mixed reality, assistive technology

ACM Reference Format:
Christin Engel, Jan Schmalfuß-Schwarz, David Gollasch, Meinhardt Branig, Gerhard Weber, and Susanne Dirks. 2023. Workshop on Designing Accessible Extended Reality: An Opportunity for People with Disabilities and Disorders. 1, 1 (May 2023), 5 pages. https://doi.org/10.18420/muc2023-mci-ws15-118

1 MOTIVATION AND TOPIC OF THE WORKSHOP

Extended reality (XR) covers diverse applications on the virtual-reality-continuum, ranging from completely real environments to completely virtual ones [17]. Recently, research has shown the high potential of virtual, augmented, and mixed reality (VR, AR, MR) applications for different purposes and user groups. XR technologies offer many benefits in different areas, such as remote meetings, enterprise training, project management, entertainment such as tourism, well-being programs that stimulate mental and physical exercises, and designing and testing products [7]. Particularly, XR has moved from a niche product to an important technology, and is successfully applied in various fields, such as education, communication, exergame, and training simulation [18]. On the one hand, XR technologies offer many advantages for diverse user groups, but on the other hand, they are not accessible to everyone, and most applications are not designed with accessibility in mind from the start [22, 18, 7]. For example, XR applications often require the user to walk, or physical input is needed [18], which causes barriers for people with mobility or motor impairments. Furthermore, there are still few guidelines on how to design accessible XR environments [18]. However, XR has already been widely applied to support people with impairments or to reduce symptoms of mental or cognitive disorders [26], e.g., to increase motivation in physical therapy, to perform exposure in anxiety disorders, to simulate social situations in interventions, to learn social or communicative skills [12], or for exploring educational content or environments that are inaccessible, e.g., for wheelchair users. Therefore, XR technologies can be beneficially applied to different user groups, e.g., for people with ADHD, autism-spectrum-disorder, sensory or cognitive differences, dyslexia, anxiety disorders, or several physical impairments.

2 XR APPLICATIONS FOR PHYSICAL AND MENTAL HEALTH

Recently, research has shown a variety of use cases and applications to support people with physical or mental challenges with XR technologies in many ways. In particular, XR is often applied to support navigation and orientation training for different user groups. Orientation and navigation skills require the creation of a mental map for outdoor or indoor environments, as well as dealing with unknown routes. Both physical impairments and mental disorders can be a limiting factor. AR and VR offer a variety of possibilities to better plan journeys or to guide people in real-time. For instance, Rocha and Lopes [20] present a smartphone-based AR system that instruct and navigate users with blindness while avoiding obstacles. While visual feedback provides the path from the start to a destination node with AR, users with blindness have access to an auditory interface with voice recognition. Hervás et al. [11] present an assistive navigation system that navigates people with mild cognitive impairments between Points-of-Interest based or well-known places. For this purpose, the authors designed an AR-based smartphone application that augments the real environment with contextual information. Moreover, user-friendly routes to a destination were generated based on the user context rather than the conventional street names and quantitative distances. Furthermore, Marasco et al. [15] discuss ways to provide virtual twins for inaccessible cultural heritage for people with mobility impairments. The authors present a design process based on personas and scenarios to involve the

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XXXX-XXXX/2023/5-ART
https://doi.org/10.18420/muc2023-mci-ws15-118

users in the development of the VR environment. Another important application is the use of VR and AR for people with visual impairments. For this purpose, information is often presented via audio output or is integrated into assistive technologies, such as the long cane [19, 23]. At the same time, VR environments are also used for mobility training [14, 25]. In addition, Albouys-Perrios et al. [2] present a system for people with visual impairments that uses printed tactile maps augmented with information via a projector and audio output.

XR technologies are also being profitably applied in rehabilitation, both for the support of people with long-term impairments, and as a rehabilitation aid for recovery after acute injuries [8]. Flint et al. [8] discussed possibilities for rehabilitation and retraining for people with traumatic head trauma. These people often have challenges in navigation, specifically in landmark recognition, allocentric location, and path route knowledge. The authors extracted 17 guidelines for the design of AR technologies for the described user group from previous research. XR technologies are appropriate to archive many rehabilitation goals. These include the support of experiential, active learning, the provision of a challenging but safe and ecologically meaningful environment, the flexibility of individualized treatment protocols, the ability to motivate patients, and the ability to collect objective performance data [21]. The latter is part of the applied psychophysiology field, where VR is used, for example, for human physiological monitoring and brain imaging for advanced research and clinical applications [28]. In this context, VR enables the recording of bodily events with low invasion to capture and understand correlations between mental and physical activities.

A large body of current research focuses on the use of XR technologies to reduce symptoms of mental disorders or cognitive impairments. Furthermore, it plays an increasingly important role in the diagnostics and treatment of mental disorders [27]. Wiebe et al.'s [27] research review identified the highest research activity and the most compelling evidence for VR-based exposure therapy in anxiety disorders, PTSD, and addictive disorders, as well as for cognitive training in dementia and social skills training in autism spectrum disorders. According to the authors, XR technologies can be used effectively to reduce anxiety symptoms of anxiety disorders, providing an alternative to conventional exposure therapies. Moreover, evidence suggests that exposure to VR cues can reliably induce craving of a drug or rewarding behavior [27]. In particular, XR can be used effectively for divergent people to acquire social skills, or to improve communication [3, 24]. Bozgeyikli et al. [4] conducted an extensive survey on VR applications as a training tool for people with ASD and developed guidelines for the design of such applications based on existing literature. The authors present a taxonomy of VR applications depending on the type of VR system (immersive vs. regular computer-based) and the skills addressed (social, life, and safety skills). Further controlled studies in this field are needed to better reflect the heterogeneity of the target group. Moreover, XR applications are becoming increasingly important in the field of assessment. In particular, Matsangidou et al. [16] developed a low-cost, home-based VR application for cancer patients to collect assessment data on symptoms to overcome the recall bias of symptoms. VR is used here for the treatment of pain based on traditional distraction methods.

The wide range of applications and past work clearly demonstrates the potential of XR applications to improve quality of life or reduce symptoms of disease, as evidenced by the increasing number of papers and applications published recently. Various challenges and specific requirements arise depending on the area of application and target group, which must be considered during development and evaluation. This requires interdisciplinary collaboration and the involvement of different disciplines in the development of XR applications, as compliance with all currently set standards for a clinical VR trial is challenging, costly, and hardly feasible without an interdisciplinary research team [27].

3 CHALLENGES AND REQUIREMENTS IN DESIGNING EXTENDED REALITY TECHNOLOGIES

Requirements strongly depend on the current context, task, and emotions, which must be considered in the development of XR applications. Requirements arise both in terms of hardware components (e.g., input and output modalities) and software components (e.g., user interface, interaction, feedback mechanisms). Nevertheless, general requirements can be derived that have to be met by all XR applications, which we discuss in the following.

Ability-based, User-Centered Design. XR applications should always be developed and evaluated in collaboration with heterogeneous users. Thereby, the focus should remain on the abilities of users instead of their disabilities according to ability-based design [29]. The goal here is not to adapt "non-standard users" to standard technologies through an assistive component, but rather consider how systems can be made to fit the abilities of whoever uses them. This requires both an in-depth analysis of the users' abilities and opportunities to involve as many users as possible in the development and evaluation process. Principles of ability-based design include for example adaptation, transparency, performance, context, or commodity. Mott et al. [18] discussed these five principles, and how they can be applied to VR devices to improve accessibility for people with mobility impairments.

Mobility. Evaluation of XR applications mostly requires special labs that represent a barrier for certain people (e.g., due to the need to travel, inaccessible hardware). In contrast, mobile living labs could be accessible for a wider and more heterogeneous user group [22]. For example, Schmelter et al. [22] present VITALAB.mobile that allows users to easily evaluate and experience virtual applications with a truck, regardless of location, time, and hardware constraints. The mobile lab is accessible for wheelchair users, the conditioning, heading, as well as light can be controlled, and it's equipped with innovative, novel technologies.

Another mobility requirement relates to the mobility of XR devices. The degree of mobility of XR devices is highly dependent on the use case and the integrated hardware. XR technologies designed for mobile use must take particular attention to the contextual requirements (e.g., space constraints, safety in public spaces, noise levels, data protection laws, light conditions). Additionally, ergonomic requirements and the needs of people with mobility or motor impairments must be considered.

Accessibility. There are no guidelines or standards for the accessibility of XR applications for people with different abilities [18]. First, accessibility of XR applications needs to be addressed at the hardware level [7]. So far, little work addresses the requirements for using XR hardware [7]. In particular, Mott et al. [18] identified the following seven types of barriers relating to the hardware accessibility of VR applications for people with mobility impairments: (1) Setting up a VR system; (2) Putting on and taking off VR HMDs; (3) Adjusting the HMD head strap; (4) Cord management; (5) Manipulating dual motion controllers; (6) Inaccessible controller buttons; (7) Maintaining a view of the controllers. Furthermore, Heilemann et al. [10] developed a set of guidelines for accessible VR games. The following eight guideline categories were included: (1) Input and Controls (e.g., compatibility with assistive technologies, adaptability of sensitivity of controls, more than one input device simultaneously); (2) Audio and Speech (e.g., no essential information covered by sound, avoiding of background noise, separate volume control for different audio types); (3) Look and Design: (e.g., edit display settings, use of enough contrast, no color for information coding alone); (4) Subtitles/Captions (e.g., captions for background sounds/texts, synchronous caption and audio description); (5) Simplicity (e.g., clear language, tutorials, reminder of controls, guidance within the game); (6) VR (e.g., option for dominant hand, multiple locomotion styles, no essential information outside the eye line of the user, no motion tracking, no head rotation or specific body types, option to disable VR simulation sickness triggers); (7) Multiplayer (e.g., voice and text chat, symbol-based chat, real time speech transcription); (8) Others (e.g., avoid flickering images, provide option to disable emotional content or surprises, accessible customer support). The author argued that all people can profit from better accessibility of VR games, as situational disabilities such as a damaged speaker, a noisy environment, or a broken arm can affect any user. Elor and Ward [7] also highlight directions for future research regarding the accessibility of XR applications at the hardware level. According to the authors, understanding accessibility requirements at the hardware level is an important consideration to perhaps influence the default capabilities of XR software applications. In addition, it may be possible to apply established accessibility guidelines for XR technologies, such as usability guidelines, or WCAG. Further research is needed for a better understanding of accessibility in XR applications.

Social Acceptance. The social acceptance of XR technologies, such as personalized assistive technologies, or smart glasses, is crucial to create a feasible and satisfying solution to support independent living. Therefore, the perceived usability and usefulness need to be considered when designing specific XR systems [6]. The acceptance of such systems depends significantly on the users but also on the surrounding stakeholders, i.e., coworkers and caretakers, due to privacy, ethical and moral aspects and can be increased through the usage of participatory design processes [9]. Additionally, future XR applications should support social acceptance, which is especially important for divergent people. Reducing stigma and barriers to XR applications are important factors for social acceptance. For example, XR systems for neurodivergent people should help others to understand them instead of promoting an alignment with the neurotypical world to be accepted by the users [3]. Reducing stigma is also an important aspect of hardware design and usage for different contexts. In addition, it must be ensured that the XR system can be used safely in public environments by users with different abilities to be accepted.

Data Protection. Privacy aspects can strongly influence social acceptance. Accordingly, the data protection concept of XR applications should not only comply with legal requirements, but also be designed to increase social acceptance. Data protection is an important factor as XR systems become more and more mobile and ubiquitous, integrated into everyday life sustainably. De Guzman et al. [5] examined current research focusing on mixed reality applications in terms of security and privacy approaches. The authors identified five protection aspects, divided into *input*, *data access*, *output*, *interactivity*, and *device integrity*. According to the authors, the following four high-level challenges of current and future mixed reality applications need to be considered: (1) Security and privacy of existing devices and platforms; (2) Native support with fine-grained access permissions; (3) Society, Policy, and Ethics, and (4) Best Practices for mixed reality security and privacy. Furthermore, Ahmed et al. [1] describe the privacy issues of assistive AR technologies for people with visual impairments from the perspective of bystanders. There is a risk that the personal data of people in public environments will be recorded, stored, and processed without their consent and further information about these people will be displayed, e.g., by means of AR. They conclude that individuals are willing to share more information with users of XR applications if they are able to control the data access and if the data are needed to support the user. The context and familiarity among the people play an important role. Kirkham and Greenhalgh [13] describe a concept for a real-time system using Google Glass in everyday situations for people with high-functioning autism. They discuss challenges that arise when collected data are made accessible to persons who are responsible for the user (e.g., medical doctors, legal caregivers). However, special approaches to address this, such as virtual walls, are not suitable for all everyday situations. There is no universal solution for these issues, according to the authors. Instead, such aspects must first be discussed in society and guidelines need to be developed.

. When designing XR for impaired or disordered people, accessibility needs to be considered to be useful for a wide target group. This is challenging because of the heterogeneity of user groups and resulting demands and needs. For instance, the use of XR can be particularly challenging for people with visual impairments or mobility limitations and, thus, cause barriers. Moreover, accessible interaction techniques, e.g., for wheelchair or visually impaired users, need to be considered. Future research should address accessibility from the start of development. In addition, legal and social requirements must be considered during development. This depends heavily on the context in which the applications will be used. Guidelines and standards can support needs-based development, but cannot replace close collaboration with the target group.

4 OPPORTUNITIES OF XR APPLICATIONS

XR technologies offer many opportunities for applications that improve the quality of life for a wide range of user groups. XR technologies allow people to work, socialize and play while being physically apart, which is beneficial for many people, e.g., those with limited mobility, social anxiety, poor immune system [18]. This can also be observed in the increasing demand for VR applications during Corona [18]. Furthermore, many areas of healthcare in particular can benefit from XR applications. For example, virtual reality allows the assessment of cognitions, emotions, and behavior in an ecologically valid environment [26]. They can provide objective data on physical or psychological health conditions in everyday life over a longer period of time. They have the potential to create systematic human testing, training, and treatment environments that enable precise control of complex and immersive environments within which advanced interaction, behavioral tracking, and performance recording are possible with low invasion [28].

Furthermore, XR applications are increasingly important for the diagnostics and treatment of mental disorders. Most evidence was found for VR exposure therapy in anxiety disorders, PTSD, and addiction disorders, as well as for cognitive training in dementia and social skill training in autism spectrum disorder. Moreover, VR-based assessment for dementia also appears to provide higher accuracy than traditional test environments. [27] Simulations can be immersive as desired, run in a safe environment, can be freely manipulated as well as adapted, and can be repeated multiple times.

XR applications are often used to train social, life, and safety skills for people on the autism spectrum [4]. In communication scenarios, XR applications also have the advantage of being neutral, in contrast to humans. Safety skills play a major role in orientation and navigation, for instance. In particular, they were used for mobility training, e.g., for people with mobility, or visual impairments as well as for some neurodivergent people. Training can take place in a safe environment, for example without other road users, or external conditions such as weather [25]. At the same time, VR environments enable the training of orientation and navigation in different locations without being directly on site. They can provide access to otherwise inaccessible places. [15]

5 OBJECTIVES

In this workshop, we will discuss and demonstrate applications and design spaces as well as challenges and opportunities of XR applications for people with different impairments and disorders, relating to the following research questions. Which use cases are suitable for the practical use of XR technologies? How can digital technologies meet the heterogeneity of different target groups? How can various challenges, such as social acceptance and stigmatization, of XR be adequately addressed for various target groups? Which interaction techniques can be used effectively for applications in this field? What is needed to make XR applications accessible?

6 PLANNED ACTIVITIES

We invite researchers and experts to submit papers related to the described topic. The submissions will be juried by experts. Selected contributions will be presented and discussed during the workshop. Following, the contributions and the associated findings will be summarized and published. The publication takes place as workshop papers with the aim of presenting current research activities in the field of XR systems regarding their accessibility and application to reduce barriers for impaired or disordered people. We would like to invite the workshop participants to discuss together how we can design XR technologies in the future in a sensitive, and inclusive way to improve the quality of life of as many people as possible.

7 TARGET AUDIENCE

This workshop addresses researchers and designers working in the field of neurodivergence, accessibility, or UX design for impaired or disordered people, either from the perspective of developing applications for these target groups or from the perspective of the target groups and their experiences with XR technologies. In addition, we will encourage the target audience (e.g., neurodivergent people, people with cognitive disorders, and physically impaired people) to contribute by submitting an informal experience report of up to 2 pages from a personal perspective.

8 ORGANIZING TEAM

All organizers are experienced researchers in the field of accessibility of HCI for people with disabilities who have developed and evaluated research prototypes with disabled users in the past and in ongoing research projects.

Christin Engel is a PhD student at the TU Dresden, Germany with research interests in usable and accessible, interactive graphics and visualizations, tactile graphics, GUIs, and interaction techniques as well as diversity-sensitive design and research.

Jan Schmalfuß-Schwarz is a PhD student at the TU Dresden, Germany. His work focuses on the research of contextual information and interaction adaptation, primarily based on spatial data, accessible maps, and its enrichment with accessibility information.

David Gollasch is a PhD student at the TU Dresden, Germany with research interests in diversity-sensitive interaction design as well as structured methods and processes around software variability and AI to build adaptive user interfaces.

Meinhardt Branig is a PhD student at the TU Dresden, Germany. His research focus is the design of accessible tangible user interfaces and data visualization.

Gerhard Weber is Professor of Human-Computer Interaction at TU Dresden, Germany. His interests are in multimodal interaction, non-visual interaction, tactile graphics, and teaching on accessibility. He is also the commissioner for students with disabilities at TU Dresden and leads a service center to support for students with a disability.

Susanne Dirks is a senior researcher at TU Dortmund, Germany. Her main research interests are digital accessibility, participatory research and development, and technology acceptance. She is a member of the research cluster "Technology for Inclusion and Participation" at TU Dortmund.

Timo Götzelmann is a Professor of Human-Computer Interaction as well as Ambient Intelligence at TH Nuremberg, Germany. Besides these fields, his research interests are focused on physical computing, VR, and accessible smart cities.

ACKNOWLEDGMENTS

The project at TU Dresden is funded by the Federal Ministry of Labour and Social Affairs (BMAS) under the grant number FT 1 – 58330.

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