Research Article

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The Next Decade in Accessibility Research

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Abstract: Accessibility research has matured over the last three decades and developed a better understanding of accessibility technologies, design and evaluation methods, systems and tools as well as empirical studies in accessibility. We envision how progress in new contexts over the next decade can be made to develop stronger links to other areas in Human-Centered Computing and address the research communities. A human-centered perspective on disability needs to develop from a medical model to a social model. New methods will utilize generative AI in design and development processes that address accessibility from the start of system design. We build on AI embedded into future design processes to address participation of small numbers of users better, and new technologies to allow for personalization of multi-modal interaction to improve verbal and non-verbal communication, making body-centric computing and natural interaction truly accessible.

Keywords: accessibility research, disability, ability, user needs, user characteristics

1 Introduction

The goal of an information society is making progress and the availability of an abundance of digital products, systems, and services has changed our way of living. However, not everyone has equal access to the development of such services, products, environments, systems and facilities from the beginning on and often, the extent of use is rather limited if not at all existing. Early accessibility work such as that of Stephanidis et al. has sketched an R&D agenda [33] by identifying technological and user-oriented issues, application domains, and support measures needed to address users with a disability in a universal way. Accessibility research now comprises accessibility technologies, design and evaluation methods, systems and tools, as well as empirical studies in accessibility according to ACM's Computing Classification. It is placed in the domain of Human-Centered Computing along with Human-Computer-Interaction (HCI), Interaction Design as well as Collaborative and Social Computing [26].

More recently, Mack et al. have summarized accessibility research published at CHI (Conference on Human Factors in Computing Systems) and ASSETS (SIGACCESS Conference on Computers and Accessibility) for the period from 1994 to 2019, analyzing a total of 826 papers. They coded 506 papers published between 2010 and 2019 regarding communities of focus and methodological decisions [17]. Their code for communities of focus lists people who are blind or have low-vision, who are deaf or are hard of hearing, people diagnosed with autism, people with an intellectual or developmental disability, motor or physical impairment, cognitive impairment, as well as older adults, studies aiming at general disability or accessibility, and others. Looking forward, Mack et al. refer to accessibility as becoming a key area of CHI.

The premier conference on accessibility in the German speaking countries is ICCHP (International Conference on Computers Helping People with Special Needs) whose inception in 1989 predates ASSETS,

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and typically attracts more than 300 researchers primarily from Austria, Germany, Switzerland, wider Europe, and Asia. Additionally, the section Computer Science and Inclusion of *Gesellschaft für Informatik* organizes workshops in national computer science conferences. We expect that the *Mensch und Computer* conference can gradually attract the accessiblity research community as CHI already does on an international level.

With respect to the focus of research in the area of technology and disability over the last few decades, the context of accessibility studies has widened more and more from employment and work-related barriers to barriers in learning, education and research as well as lack of access to entertainment and leisure time activities [42].

In the following, we envision how this research might continue in the next 10 years.

We identify several challenges for our research community and unfulfilled user needs. We conclude that there remain numerous issues and a range of existing barriers faced by people with a sensory or physical disability, such as their lack of access to body-centric computing (e.g., Virtual Reality systems supporting non-visual feedback for locomotion only, avatars unable to synthesize sign language despite 30 years of research [12] or unavailability of tactile hand to hand communication for deaf-blind people despite numerous exoskeletons). Here, we focus on changes needed regarding the perspectives on disability and research methods to address not the medical but the social model of disability in the hope that this will contribute to the development of technology that meets the needs of disabled people, and serves the interest of disabled communities. Learning from the past, any progress in research can lead to new products and services for accessibility support and effectively improve justice in access that our societies have long committed to (*e.g.,* UN BRK [35]), more sustainable and equitable economic opportunities and higher quality of life for all of us, as well as a better legal framework allowing establishment and possibly enforcement of all measures needed to close the digital divide in the information society.

We chose to envision how accessibility research will evolve over the next 10 years and added the concept of accessibility support briefly. The gap between support systems in place and research is often considerable, and some results will never make it into commercial products (as part of mainstream or assistive technology). Audio description, for example, was developed in the early 1990s, it took at least a decade before broadcasters have accepted additional costs and started to provide audiodescription for the movies and TV. Research is now coming up with approaches to synthesize such scene descriptions using AI. We feel the scope of this special issue is not support provided to people with a disability but on the research needed.

2 Perspectives on Disability

Historically, computer science has viewed assistive technology as a way of addressing impairment. Thus, our field has implicitly or explicitly subscribed to the medical model of disability, which understands disability as an individual deficit that is in need of cure [30]. Increasingly, social and post-modern models of disability are leveraged to expand on this narrow perspective. Following Mankoff et al.'s call to build on disability studies as a lens to critically reflect upon the design and development of assistive technology [18], views have expanded, and assistive technology is increasingly understood in its sociotechnical context (*e.g.,* see [29] on social accessibility, assistive technology, and stigma), recognizing human interdependence [2]. Such approaches more closely align with social models of disability, which view disability as a result of environmental and societal barriers rather than a characteristic of an individual [22].

However, there remains a challenge with respect to the strong focus on the design and development of technology that is *useful*, *i.e.,* assistive technology that increases access in the context of education or work, or that directly contributes to health through therapy and rehabilitation (*e.g.,* web accessibility [42], early screening of dyslexia [25], or chatbots for adult attention-deficit hyperactivity disorder (ADHD) [28]). While this is of course valuable, it also reveals a reductionist view on disabled users of technology. For example, a recent review of games for neurodivergent people [32] found that even in the context of play, the overwhelming majority of research efforts addresses therapy rather than free play. This is a missed opportunity, and in direct conflict with legal frameworks such as the UN Convention on the Rights of Disabled People [36], which highlights the right of disabled people to access culture and leisure. While ratified by the German parliament, a recent review revealed significant shortcomings in implementation, including the area of culture [7]. Here, we see an opportunity for HCI research to expand its application areas, contributing to self-determined access to culture and leisure.

Directly connected with this shift in perspectives on disability, there has also been extensive advocacy work for disabled self-determination, not just with a focus on daily life, but also in the context of research participation of disabled people. Within the German-speaking community, disability activists such as [13] have extensively highlighted the need to involve disabled persons in research in meaningful rather than tokenistic or exploitative ways. This involves participation of disabled people when shaping research questions and projects, fair remuneration for time contributed to research, and generally accessible research design. For the Human-Computer Interaction research community, this is associated with pressing questions around accessible research methods (*e.g.,* when exploring often inaccessible emerging technologies).

Finally, we also want to raise a question for the future: How can our research community contribute to access and inclusion being understood as a two-way street, *i.e.,* requiring continuous labour and commitment from disabled and non-disabled persons alike? While there have been many calls to action from the perspective of disability justice also within our research community (*e.g.,* [34]), disabled perspectives in academia remain underrepresented. This is a future challenge for our field that expands beyond setting research agendas that center disabled people [19]: To truly shift power in accessibility research, we also need more accessible academic systems, environments, and approaches to graduate education that structurally empower disabled people to take up research careers themselves.

3 Accessibility methods

HCI has developed many methods suitable for analysing user needs, for designing user interfaces, and for evaluation. When working for disabled users these methods face some obstacles. First hand experience of sensory, physical, or cognitive limitations is often missing by researchers and insight into user needs is hard to establish. Designing user interfaces to be supported by assistive technologies requires to acquire competences such as keyboard control when touch or a mouse is the standard mode of input. During an evaluation, successful communication with users can be a challenge. For example, discussing with users who are blind about accessible graphics (for VR or AR glasses) embeds visual concepts, or communication with people who are deaf is guided by words and sentences when sign language is needed.

Personas help to define user requirements and their development is part of accessibility research today as small user groups of persons with a similar accessibility are not asked the same questions all over again. At the same time, personas promote stereotypes and are not helping to understand individual needs that should be addressed by customization, *i.e.,* personalizing software for the individual needs of a person, *e.g.,* beginners *vs.* experts or visual *vs.* visually impaired.

We need to accept that concepts like *one-fits-all* or ability-based designs[40] have flaws we need to address in the future to improve the quality of systems for an even wider group of people and include the neurodiversity paradigm. For instance, it is neither ethical nor constructive to focus solely on an individual's weaknesses, as a person's identity extends beyond mere strengths and weaknesses, highlighting the importance of understanding how others induce being different from normal.

Acknowledging that each person has unique needs and that not everything can be universally applied renders system design more complex, regardless of whether we also incorporate accessibility requirements. This complexity persists despite arguments that catering to a small group is too cumbersome: still, our design methods need to reflect, support and enhance the inclusion of accessibility.

Some HCI methods employ unique barriers in itself and are not supporting a disability-centered research [19]. To avoid the "*disability dongle*" [9] (*i.e.,* designing irrelevant technical artifacts) we need to make sure evaluation methods are advisable: For example, asking visual impaired people to use the "*think-a-loud*" method for evaluation of Voice-User-Interfaces (VUI) will not produce good insight as the commands for a VUI are also verbally and interfere with the method. A post thinking aloud method has been found to be more suitable [20], in particular when screenreaders provide also spoken feedback. Another example is the analysis of mental maps. Mental maps help to analyse the navigation of users. Blind users cannot draw such a map easily and hence more tangible approaches have been found to be useful [21].

Future directions in HCI should prioritize participatory design approaches, not only by addressing their needs but also by actively involving a person with special needs in the research process and provide an enhancing working environment. Also, we need to accept intersectionality and address the challenge of different characteristics and avoid stereotypes. Key questions for the next decade are: How can HCI design practices incorporate intersectionality to better address the complex needs of users with disabilities? What kind of research design guidelines are needed?

4 Designing more accessible systems

The design of novel interactive systems has not always taken accessibility into account. Although off-the-shelve mobile phones nowadays include screen readers, magnify the screen, simplify some of the layout, and allow for video conferencing in sign language, sound recognition and captioning as well as control by head gestures, some even out of the box, the same does not hold for all fields of current HCI research.

An essential attribute is to target a new challenge such as autonomous cars (in particular taxis) and researchers should take that opportunity to include all different kind of characteristics of a person when designing such a new technology to consider new self-driving wheelchairs and robotic guide dogs likewise in the next decade.

We are not referring to the concept of one-fits-all instead we mean finding the impact characteristics of a user important for the context and holding on to quality criteria such as privacy concerns. For example, VUI [3] (*e.g.,* Amazon's Alexa, Apple's Siri, and Google Assistant) are a perfect example used by all kinds of people with different characteristics in various contexts [11]. VUI enable individuals with disabilities (*e.g.,*visual [23] or motor[4] impairments) to access technology with, *e.g.,* graphical interfaces by facilitating work task such as writing emails or everyday tasks like listening to music, web searches, checking weather, playing audiobooks, and home automation [15, 42]. But not always are the traditional characteristics such as age as important when designing systems, *e.g.,* no major age effects in VUI users [5]. And at the same time a vulnerable person (having characteristics such as elderly individual with sensory impairments and a *tech-novice*) might not be aware of the privacy issues VUI still have nor the technical ability to change settings, *e.g.,* elderly interacting with VUIs for TV control, yet facing challenges in adjusting settings to limit data collection. Hence, combination factors are changing the way a system should work. Over the past decade, 43% of papers have focused on accessibility for individuals with blindness or low vision [17], highlighting the importance of recognizing and addressing the diverse needs of all users such as named in the ICD[41] or in the context of web technology[42]. This implies that we must be aware of the users' abilities, attentive to ethical considerations, and responsive to the context in which the system operates to integrate this into the designing and evaluation process.

Especially, with the progress we made in the last years on artificial intelligence (or better call it artificial computation), it should be easily possible to address all kinds of individual user needs in, *e.g.,* education with new technology such as VR or Generative AI offers the opportunity for personalizing systems (*i.e.,* customization). For example, to generate different levels of task for a person with dyslexia or with language barriers. It appears to be the opportune moment, equipped with all the necessary tools, personnel resources, and prioritization, to embark on designing new systems with a primary focus on individuals.

Designing for users needs in HCI implies to include participants directly or indirectly into the design process. Due to the HCI methods (*e.g.,* interviews or user studies) and participants characteristics (*e.g,* visual impairments or neuodivergent people) data sizes are small or even tiny. In certain situations, utilizing small data sets is favored over big data as it can streamline the analysis process [6]. In other scenarios, only small data sets are available. Accessibility researchers need to make the best out of small data sizes having in mind the limits of the data set such as the ethical aspects or focusing on the wrong measurements factors. For example, we need to make sure machine learning results are trustworthy, so they do not harm a person by being wrong. We can do that by taking care of algorithms we use and following recommendations from others[24]. The spectrum nature of, e.g., dyslexia introduces variances in our data set for participants diagnosed with the condition. Until now, interpolations (estimating a value) are not useful in small data sets with high variances because it adds noise to the data sets. But AI-based systems can generate text or artificial data sets to produce high quality and bigger data set out of tiny data sets without adding a bias.

Having in mind the 17 goals of the United Nations[35], future directions of system design and evaluation needs to address even more the different skill levels, abilities, contexts, and ethical implications of the systems for personalised design/customizing. Excuses such as "*this is only for a small group*" or "*we do not have the tools and resources for it*" can no longer be ethically justified. We can think about: (1) new methods to make *artificial* small data sets robust and with high quality to reflect reality. (2) Or about method such as online experiments to collect and contact smaller populations easily. Another question is: "*What kind of regulation do we need to avoid overfitting in small data sets?*"

5 New and emerging technologies

When Mark Weiser described the computer of the 21st century and coined the term "*ubiquitous computing*", he considered digital systems with many sensors and how users interact with a disappearing computer through these sensors[39]. Following up on Weiser's vision, Bell and Dourish [1] highlight how the continued visibility of infrastructures and *messiness* of ubiquitous computing differentiate its present shape from the original vision. Here, research in the area of accessibility shows that this *messiness* is even more pronounced from the perspective of disabled people, with supposedly *natural* multimodal user interfaces remaining largely inaccessible [10]. Likewise, body-centric computing has predominantly focused non-disabled user groups [31], with related technologies such as Virtual Reality (VR) remaining inaccessible at large [8]. Moving into the next decade of accessibility research, we see potential moving away from universal design to hyperpersonalisation. For example, personalisation based on user models capturing needs and preferences at the one hand, and allowing adaption of assistive technologies through a public infrastructure on the other hand [37] can reduce burden on accessibility experts and apply AI-based methods instead to make commodity hardware and software accessible to even contradicting requirements [16]. Designing multimodal interaction is still far from being an industry standard due to the performance requirements for fusion of sensor data at the data level, lack of interoperability, and limited semantic disambiguation at the feature level.

Current progress in multimodal interaction involving verbal utterances through large language models (LLMs) for generating verbal image descriptions have potential to increase accessibility for blind users, and authoring images from verbal expression by blind users can help to link several modalities for communication systems in use by people with a disability with visual encodings of information: A recent Dagstuhl seminar identified as an emerging topic for the next decade the need for multimodal access to information visualisation [14] to reduce the barriers encountered with complex visualisations by people with blindness or low vision, but also people with physical or learning disabilities. Future research in multimodal information visualisation should address utilization and authoring of visualisation to come to a broader understanding of visualisations and non-visualisations through multimodal interaction with sonificiation and haptification of data.

Data glasses augment already now people with blindness or low vision to read text in front of their head, identify colors, or recognize other people. Such augmentation is accepted by other people depending on the disability[38]. Future work will have to develop more augmentation-based interaction aiming at sensory, motor and learning disabilities as well as development of an understanding of the situations and context when augmentation is acceptable.

Ubiquitous computing and augmentation can add the computational aspects of context beyond location [27] to accessible interaction regarding both the user with the widest extent of requirements and other users interacting through ubiquitous computing with such users.

6 Conclusion

In conclusion, there remains a key question: "*What needs to be done to make significant progress in the area of accessibility?*". Various aspects must be taken into account for this, which ideally interlock and reinforce each other.

The actual process of designing technologies for all is often hard to realise because access needs can be in conflict [16], and creating an accessible system for some users may imply reduced accessibility or exclusion for others. Here, we need to re-think and move toward more personalized approaches, which may be a better solution to fulfil diverse requirements and give more people the opportunity to participate within their scope of possibilities.

Additionally, some application areas already take into account accessibility requirements more so than others. Especially within the field of education (public sector organized), there are attempts to implement inclusion to make learning possible for all pupils (with varying degrees of success), and accessible educational technologies can support this. In the working world, however, things look different. Here, approaches are more fragmented, and it depends on the decision-makers (*i.e.,* management and human resources departments) how accessible the working environment or the developed tools are. In the area of leisure, there are few to none accessible systems that are not just made for a group of disabled people, which may further contribute to segregation, but rather for all characteristics of different people. Here, a sensitisation and rethink is needed to make accessibility a fundamental seal of quality, facilitating accessible leisure for all of us.

Beyond research efforts and in order to lead by example, the academic sector should offer an accessible framework for young researchers with or without a disability. Furthermore, professional skills in the field of accessibility should be taught to equip the future generation with the basic tools to take this with them into the academic or working world. Therefore, existing lectures should be extended and new lectures on accessibility must be developed. Also, in the field of research, different communities need to be made more aware of accessibility issues, and have to realise that accessibility is not just good for people with disabilities but also for a lot of other people like, *e.g.,* elderly people or people less experienced with technology. This would lead to greater accessibility both in the society and in the work approaches.

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