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Supporting Partnerships in Participatory, User-centered Co-Design of Artificial Intelligence Mediated Devices for People with Disabilities: Identifying Needs and Opportunities

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ABSTRACT

One billion people, fifteen percent of the world's population, have experienced a disabling condition that impacts their physical or cognitive function according to the World Bank Group. Such disabilities can result in challenges that present major barriers to entering and persisting in the labor force. In the United States, at least 80% of people with disabilities were not part of the 2024 labor force according to the US Bureau of Labor Statistics. This disparity has been particularly pronounced in technology-related employment. Only 3% of the science, technology, engineering, and math (STEM) workforce are people with disabilities and representation in STEM workforces remains relatively unchanged from a decade ago, despite an increase in the number of people with disabilities across professions since 2011. Americans with disabilities earn only 66 cents for every dollar earned by their counterparts without disabilities. While employment opportunities world-wide in technology industries continue to grow, they are largely inaccessible to people with disabilities. This inaccessibility is primarily because standard computing interfaces are nearly impossible to operate for many people with disabilities, especially those with physical challenges.

The research presented in this paper explores the challenges that people with physical disabilities have in accessing and using technologies and provides merit for the role that artificial intelligence (AI) and machine learning may play in changing the outcomes for people with disabilities. Such adaptations may provide people with disabilities with full accessibility to technology when it is facilitated by AI powered, machine learning mediated accessibility devices. This research presents a structure and process for obtaining information about the individual and collective needs of people with physical disabilities in designing accessible hardware and associated software wrappers to meet their needs. Furthermore, it highlights promise for working with people with disabilities in co-design of technology that will meet such identified needs. Results of this research indicates that people with disabilities can play a significant role in designing, testing and developing accessibility tools for themselves and others associated with technology use in education as well as in employment.

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Introduction

One billion people, roughly 15% of the world's population, have experienced a disabling condition that impacts their function [1]. The Centers for Disease Control and Prevention estimates that one in four adults (24.8%) has a disability [2]. These statistics underscore the national and global impact of this challenge. Despite how common disabilities are, society and institutions often fail to provide adequate accommodations or truly inclusive spaces for all to participate equitably [3-5].

Employment Needs and Disparities

Disabilities result in challenges that present major barriers in life and especially to entering into and persisting in the workforce. At least 80% of people with disabilities were not part of the 2021 labor force [6]. Moreover, the unemployment rate for people with disabilities is double that for people without disabilities in the US, (7.6% vs. 3.5%) [7]. People with disabilities who are employed are more likely to be self-employed than those without disabilities (9.5% vs. 6.1%), and are also almost twice as likely to work part-time, reports the Bureau of Labor Statistics (30% vs. 16%) [6,8]. Employment disparities have been particularly pronounced in technology-related jobs. Only 3% of the science, technology, engineering, and mathematics (STEM) workforce are individuals with disabilities and representation in STEM workforces has remained relatively unchanged from a decade ago, despite an increase in the number of people with disabilities employed across professions [9]. The median annual wage in computing and information technology was $97,430 in May 2021 in the US [8]. However, Americans with disabilities earn only 66 cents for every dollar earned by their counterparts without disabilities [10]. As recently as April 2023, the average annual pay for people with disabilities was $36,630 in the US. The knowledge economy is growing at a rate of 1.9 million jobs per year and demands for computing jobs are projected to increase by 22% over the next 10

years [2]. Accordingly, overall employment in computing related occupations is projected to grow by 15.4% by 2031.

While employment opportunities in technology industries continue to grow, they are largely inaccessible to people with disabilities. This inaccessibility is in large part due to the fact that standard computing interfaces are nearly impossible to operate for many people with disabilities, especially those with physical challenges. Moreover, students with disabilities have sparse access and support to persist in colleges and universities as preparation for their future employment [5].

Quality of Life and Independence

Although the majority of people with disabilities desire independence, employment disparities have led to profound decreases in quality of life. Without employment, it is significantly more difficult for people with disabilities to live and thrive independently. Participation in communities and in society has been a longstanding goal of many interventions and support services for individuals with disabilities. Most recently, research on the quality of life for people with disabilities has focused on independent functioning, satisfaction, decision making, and self-determination [11]. Information and communication technology plays a significant role in the immediate and long-term quality of life of people with disabilities [12]. Without access and successful navigation of information and communication technology, people with disabilities face significant barriers to their personal independence, their ability to make decisions about their current life experiences, and their desire to engage in self-determination of their near- and long-term futures [13]. People's independence and employment are deeply interrelated; without employment, one's independence is often stifled [14].

Health and Function

Not only does the level of independence of people with disabilities matter, their health and everyday function can be significantly hampered by their dependence on others [15]. As people with disabilities age, health and everyday function can decrease if they are not included in communities and exercising independence [16]. It is well understood that information and communication technology can improve health and function for people with disabilities as access and successful use of technology enables people with disabilities to receive information that is critical to their everyday function and to their health care needs, including on web platforms, electronically mediated applications on portable devices, and via telehealth [17,18].

It is for these important reasons that access to and success with using technologies are critical for people with disabilities. As such, the research presented in this paper has been intended to determine the needs of people with disabilities with a future goal of alleviating barriers to using technology through research and development of personalized multi-modal, fully accessible and interactive technologies to enable participation in society and the economy for individuals with disabilities.

Profound Needs, Personalized Opportunities

People with disabilities stand to benefit most from personalized technologies that attend to their goals and needs and assist them in overcoming challenges to improve their life and to achieve equitable employment [19]. These potential benefits are especially important given that their unemployment or underemployment levels are significantly higher than many other groups, and their ability to earn a living wage is often hampered by technology-related barriers [17].

These limitations in the availability, quality, and nature of accessible technology arise from the longstanding attitude of industries that such `small niche markets are not profitable, and therefore remain use-cases with sparse attention. It is important to revolutionize the information and communication technology space by turning the tables: creating avenues by which people with disabilities can effectively access the inexpensive and ubiquitous technology marketed to large consumer demographics, rather than continuing to hope that industries will create technologies tailored to the `niche' market demographic of people with disabilities as they are presently perceived to be. Artificial intelligence (AI) may just provide a viable and supportive avenue to tailor technologies for users with varying disabilities. This may be accomplished by developing and using software wrappers and other AI mediated software applications to provide the communicative "glue" between hardware and software, while also facilitating adaptations and connections across hardware that enable personalization people with disabilities with diverse, needs, challenges, and goals.

Research Context

The research was driven by a profound, real-world need by disability communities that requires a convergent research and development approach. This need is akin to the "digital divide," where the infrastructure exists, but is not equally accessible. Consumer products and technology for information and communication technologies exist and are rapidly expanding, but people with disabilities represent a market that is often underserved. Consequently, the employment disparities in the cyber economy for people with disabilities are well known, as is the lack of accessible and personalized interface technologies for people with disabilities, for the workforce, for technology-mediated information and communication, and for the quality of life and health needs of such individuals [18,20].

Given the researcher's longstanding history of working with people with disabilities, and her deep engagement in use-inspired work over the past 10+ years, she fully engaged with communities of people with disabilities and service-oriented stakeholders in direct use-inspired research to establish an extensive understanding of the diverse strengths, skills, goals, needs, and barriers of people with disabilities as they use assistive technologies to participate in technology-mediated information sharing, communication, and computing [21,22]. This process required her to synthesize the users' and stakeholders' needs as precursors to the development of creative, action-oriented, convergent solutions, while emphasizing the use of available consumer products to the challenging technological barriers that individuals with disabilities face [14,23,24].

Methods

For this study, the researcher engaged use-inspired, evidence-based exploratory research with a goal of describing the technological challenges and the needs of people with physical disabilities [25]. This methodological approach can inform diverse fields of disabilities, therapeutic interventions, education, engineering, computer science, medicine, social services and general accessibility.

Study Population and Participant Recruitment

The population of participants or the research in this paper includes diverse groups of people within the workforce age-band of 18-70 years who have physical disabilities involving sensorimotor conditions including cerebral palsy, multiple sclerosis, spinal cord injury, stroke, and traumatic brain injury as well as other permanent motor function injuries that prohibit

them from effectively and sustainably accessing information and communication technologies focused on workforce-readiness, and, by extension, health, function, community participation, and quality of life.

Recruitment of participants for the research was facilitated in partnership with community-based organizations and agencies in the fields of developmental disabilities and hospital-based therapeutic intervention programs. These organizations were made aware of the project's recruitment criteria and advertised the research opportunities in their clinics, support sessions, health visits and in other applicable opportunities via provided flyers. The individuals with whom the research was conducted were people with disabilities who are young adults through employment ages (18-70) because the goal was to focus simultaneously on quality of life, community participation, health and function, and employment outcomes of such individuals, identifying their technological challenges needs and desires. The researcher interviewed thirty-one persons with disabilities and twenty-two stakeholders, both groups for multiple interviews with the specific types of data inquiry described as follows.

Community-based, Use-inspired Research Approach

As noted, this research followed a use-inspired collaborative approach with people with disabilities with a goal of exploration, discovery and determination of the needs of people with diverse challenges. Accordingly, the researcher worked in partnership with the target population of people with disabilities and community practitioner partners (stakeholders) to ensure that the research approaches reflected the strengths, goals, and needs of people with physical disabilities and associated conditions.

Methodologically, the research involved the use focus groups, one-on-one think-alouds and iterative technology trials to establish useful data that addresses the project's research questions and inquiries [26,27]. Figure 1 represents such use inspired research.

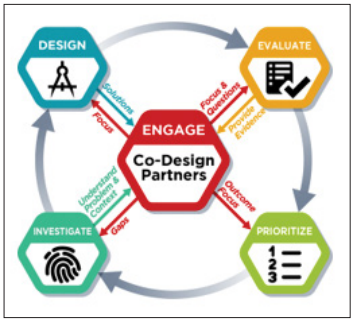

Figure 1: Use-inspired Research Model

As previously noted, this research had as its primary aim to engage in a formal needs assessment to determine the primary and secondary needs of people with disabilities. This needs-based research was also intended to achieve a general understanding of the strengths, needs, goals and expectations of individuals with disabilities [14,21]. Through this research, the researcher interviewed thirty-one people with physical disabilities for a total of 227 hours and twenty-two stakeholders (therapists and care providers) for a total of 52 hours, with a grand total of 279 hours of use-inspired qualitatively focused data collection.

Several research questions were posed for this research:

1. What are the needs and barriers that people with disabilities have in accessing and using information and communication and other assistive focused technology?
2. What workarounds have people with disabilities used to access such technology, and where are their "pain points" associated with these processes? and
3. What are the goals and desires of people with disabilities for using technology as they relate to the outcomes of community participation, quality of life, employment, health and function?

As an exploratory research project, the aim was to identify and describe the barriers to and facilitators of improved outcomes of individuals with disabilities related to technology, as well as existing practices that are associated with increased technology access for people with disabilities.

Technology User and Stakeholder Focus Groups

This research involved in-depth inquiry in which user focus groups, one-on-one think-aloud interviews, and interview-based technology trials were paired together to establish a user needs assessment from the study population. The focus group interviews took place on Zoom to facilitate maximal user comfort during data collect from their homes. In engaging in stakeholder focus groups, the intent was to determine the major resources and hurdles for people with disabilities that stakeholders were aware of to fully access, learn, and perform with diverse technologies in workforces, with health care and function, and with chosen communities.

User focus groups with 4-6 (per group) people with disabilities and other stakeholders were convened so that depth of need and use were collected accurately and in detail [28,29]. The focus group meetings established user resources, needs and preferences for information and communication technology tasks, including determining the off-the-shelf technology that participants have used and adapted, and the hurdles that they have faced in accessing and being successful in engaging with technology.

One-on-One Technology Think-Aloud Interviews and Trials

One-on-one think-aloud interviews as well as iteratively focused technology trials (Figure 2) with users were employed to capture feedback on potential technology adaptations for users of assistive technology. These were conducted in the researcher's accessibility lab at her university [30,32]. In future research associated with that which is presented in this paper, user data gathered from the interviews will be used [33,34] for successive personalization improvements of accessible technology.

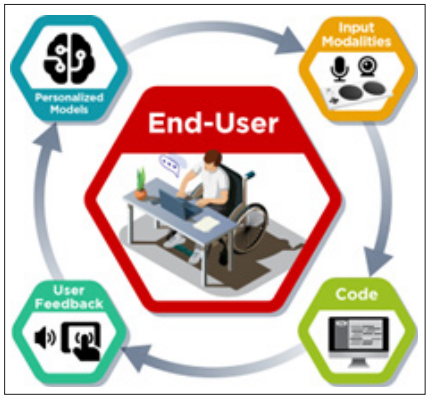

Figure 2: Tech-trial Configuration

Data Analyses

Data from the described focus group interviews, think alouds and technology trials were video recorded and transcribed in preparation for comprehensive qualitative analyses. Once

transcribed, the data was coded and thematically categorized using a constant, comparative method. Special attention was paid to disconfirming evidence and outliers in data coding, as well as elements of frequency, extensiveness, and intensity within the data. Ideas or phenomena were first identified and flagged to generate a listing of internally consistent, discrete categories of user needs, barriers and preferences (open coding), followed by fractured and reassembled (axial coding) categories by making connections between categories and subcategories to reflect emerging themes and patterns in use needs, barriers and preferences and descriptions of indicators of user challenges and successes. Categories were integrated to form grounded theory (selective coding), to clarify concepts and to allow for focus group and interview interpretations, conclusions and to inform the user needs, preferences and barriers, as well as to determine how users define successes in their lives, their community participation, their employment and their health and function [35]. Frequency distribution of the categorized data were obtained using a computerized qualitative analytical tool, NVivo [32]. The intent of this qualitative analysis was to identify patterns, make comparisons, and contrast one transcript of data with another during analyses to determine metrics of success for the research [36,37].

Results

Results and findings from this use inspired research were interesting and diverse. Descriptively, the data collected and analyzed through the three types of interviews indicates that individuals with disabilities who engage with technology often use both portable and computer devices with predictive text to communicate and gather information. They have difficulty both with speed and accuracy in these technology mediated tasks. Furthermore, the data identified extensive variety in the type and frequency of use of technology focused assistive devices that individual participants use and that to which they have access.

Table 1 (below) illustrates the depth and breadth of their needs, challenges and desires for technology use via thematic analyses and frequency distributions of such qualitative data.

Table 1: Frequency Distribution of Strengths, Challenges, Needs, Desires of Technology Use

Category	End User-Freq (%)	Provider- Freq (%)	Example(s) – From end Users
Purposes			
Communication-email, text	39 (10.8)	20 (10.1)	"I email at work, text with my friends, my family."
Production- social media, YouTube,	29 (8.03)	14 (7.07)	"I use Facebook, try to do YouTube videos. It's pretty hard though."
Homework- reports, papers	24 (6.64)	16 (8.08)	"In school I have to write papers, some reports."
Work projects – reports	20 (5.54)	9 (4.55)	"I work full time so I gotta write reports. They can be kinda long.. It's tough without help. I wanna use Chat GPT , but then.. is it really my work?"
Creating- graphic design, art	18(4.99)	4 (2.02)	"I do a lot of graphics. I can send you some."
Life, transportation, wheelchair, access (windows, doors)	15 (4.16)	12 (6.06)	"I use my chin to move my chair. It works."
Games	8 (2.22)	1 (.505)	"I'm a gamer, so I use electronic games a lot."
Type			
Text-to-speech	24 (6.64)	19 (9.60)	"I gotta use text-to-speech. It makes mistakes. And doesn't sound like me."
Speech-to-text	20 (5.54)	9 (4.55)	"I talk to write. Can't use my fingers. Sometimes it's a mess."
On-screen keyboard	20 (5.54)	6 (3.03)	"I have an on-screen keyboard. It does the job. But not everything is on it."
Motoring activation (wheelchair movement, driving)	14 (3.88)	8 (4.04)	"My chair has a stick. I can use it now, but that might change."
Predictive text	9 (2.49)	7 (3.54)	"Autocorrect helps me. It gets used to my words I use a lot. And they come up for me."
Media completers	8 (2.22)	5 (2.53)	" I video edit for my Instagram stuff. It's not that great though."
Mix media manipulation	8 (2.22)	4 (2.02)	"I use the erase and cropping. That's hard though cuz I cant use my hand too much."
Adaptive keyboard	5 (1.39)	2(1.01)	"I tried a special keyboard. What bothers me about that is that it has more than one letter on one key so that's confusing. And slow."
Switches, buttons	4 (1.11)	1 (.505)	"I have a couple switches. I couldn't use tech without them. They work well."
Headsets	4 (1.11)	3 (1.52)	"I have a headset with a button and I use eye gaze. It took some getting used to. But I can do it now."
Joysticks	4 (1.11)	2 (1.01)	"I have a gaming stick. I can use it with my good hand."

Controllers	4 (1.11)	2 (1.01)	"I use a game controller – you use them for games but I use mine for everything on my computer. I wish it connected to my tablet."
Mounted adaptive devices	3 (.831)	5 (2.53)	"We mount things on my tray, and on a shelf at my desk so they're in the right position for me. Kinda like a riser."
Difficulties			
Making things work	13 (3.60)	5 (2.53)	"Oh…so many problems- stuff doesn't work. Or it starts out okay and then it just stops. Failed technology… Can AI help with this?"
Having tech. communicate/ connect	12 (3.32)	7 (3.54)	"The gadgets are great but many times they won't connect together or work together. They aren't compatible."
Adapting to motor needs	15 (4.16)	6 (3.03)	"I have a lot of fine motor needs. I can only type with one finger. So it is slow and tedious. I don't know, maybe AI can help me some"
Accuracy	11 (3.05)	9 (4.55)	"The predictive text makes so many mistakes. And autocorrects to something I didn't say. My speech is difficult for it to understand, so that makes it worse."
Fluency	11 (3.05)	10 (5.05)	"It's just not smooth. It misses some of what I say. It can be very rough."
Working with other tech.	8 (2.22)	7 (3.54)	"The tech. cannot work together. Like a switch or button and keyboard. Not so great."
Work Arounds			
Taping together	6 (1.66)	3(1.52)	"My assistant tapes things together with duct tape but it falls apart when I use it a lot. Or… we can't get it apart when we want to."
Using Velcro	4 (1.11)	2 (1.01)	"Velcro is the best. Double-sided. We can put stuff on my tray on my wheelchair."
Stacking	1 (.277)	0 (0)	"We sometimes stack things but they slip and then they're completely useless."
Total	**361(100)**	**198 (100)**	

The results displayed in Table 1 (above) indicate great diversity in terms of needs, desires and challenges that technology users with disabilities reported in the interviews. Participating users reported experiencing pronounced barriers, frustrations and difficulty with technology use, however the interview data note their persistence and strong desire to use technology for school, in their careers, and in their everyday lives. More specifically, the majority of users in this exploratory study reported that they find assistive devices difficult to navigate. They informed the researcher that "they (devices) don't communicate well with one another" or with their computers, nor with their portable devices.

In terms of their desires for technology use, the users overwhelmingly expressed a keen desire for personal and professional independence. They expressed the importance of knowing what works-what doesn't from others who are technology users themselves with shared characteristics and lived experiences. They also reported wanting to get technologically relevant jobs and in fact they named particular employment opportunities of which they held interest. They shared experiencing enjoyment using technology when they could use effectively and communicate with it.

Paired with user comments about user friendliness, were specific uses that they identified. For example, user participants were interested in engaging in graphic design and data analytics with regard to career aspirations, preparedness and goals. Furthermore, both participants and their therapists and caregivers (stakeholders) agreed technology use often becomes so cumbersome for users that they give or become discouraged to use the technology. As such, that which is intended to assist users with disabilities become a hindrance, often because the software and hardware required for assistive technology do not interact or communicate well.

In addition to providing information about the particular technology needs that users had, both that which they identified, and that which their therapists and care providers reported, the participants also identified quality of life and associated career goals. Virtually 100% of the interviewed participants with disabilities had specific career goals and aspirations. Many of them (67%) desired to give back and help others with disabilities as part of a current or future profession. Some participants had jobs and wanted to rise in their current professions (21%), while others were attending college (38%) with career aspirations associated with their college majors. Of those in college, roughly half of the participants were majoring in STEM related majors. Two individuals with disabilities who were in the study have since graduated from college and one such recent graduate is now employed in a STEM field. Importantly, of the participants who are presently employed, 28% are in STEM fields [38,39].

Discussion

The participants in the present research recognize the value of operational and integrated technology for their personal, educational and workplace needs. Moreover, their combined input across the study's interviews demonstrated how profound the technological barriers are for people are with disabilities. The results from this research further provide strong indication that

people with disabilities are limited not only by their conditions, but also by the limits of the technology that is currently available to them. The frustration that many technology users experience in general is not trivial, however such frustrations are certainly magnified for technology users with disabilities as exemplified by this study's participants. The research demonstrates that in spite of the challenges that they face in using technologies, the participants in this study have persisted in their use efforts and have desires and aspirations to continue with technology use in spite of their identified barriers. Furthermore, the participants provided suggestions and work arounds for using technologies so they can be more user friendly and dynamic. They also offer hope for the future of using technology as demonstrated by their participation in this research.

Conclusion and Future Directions

This exploratory study involving people with physical disabilities and their technology use highlights the pronounced barriers that people with disabilities encounter when attempting to use technology in school, in workplaces, in social situations, and in navigating their lives. The findings from this exploratory research underscored results of studies conducted by Anderson and Perrin, in which their research indicated that technology users with disabilities desire to have technology to support their independence and not to hinder their independent living. The present research demonstrates the role that technology can play in transforming the lives of people with disabilities particularly if it is functional, integrated, fully accessible, and dynamic in terms of meeting the diverse needs of technology users with disabilities. Furthermore, the research speaks to the role that artificial intelligence and machine learning may play in meeting the needs of individuals with disabilities in their technology use in making it more accessible, integrated and user friendly. This is especially pertinent as it relates to the dynamic needs of individuals as their needs change, and the potential that AI and machine learning that is integrated with accessibility hardware may have in personalizing people with disabilities' development, growth, education, and workforce practices.

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