"I just thought it was me": How Smartphones Fail Users with Mild-to-Moderate Dexterity Differences

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ABSTRACT

Accessibility solutions often focus on the experiences of people with more severe disabilities, such as those who are unable to perform certain tasks unassisted. However, disability exists on a spectrum, and people with moderate disabilities may be overlooked when studying or sampling for differences. As a result, these individuals and their needs are excluded from relevant research. In this study, we interviewed 12 adults with mild-to-moderate dexterity impairments about their experiences using smartphones and other mobile devices. While our participants frequently experienced accessibility challenges, they struggled to know where to find help, in part because of discomfort with traditional labels of disability and accessibility. We found four key themes: (1) There were large gaps in available and usable accessibility tools for this population, (2) Users were unlikely to seek out accessibility features due to complex disability identity, (3) Contextual concerns impacted mobile device use, and (4) Users relied on self-created adaptations and modifications to improve usability. We suggest that individuals with mild-to-moderate dexterity challenges are a unique cohort that would benefit from further consideration from the accessibility community and accessibility features that support their needs.

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1 INTRODUCTION

Across the mobile device accessibility landscape, mild-to-moderate dexterity challenges (hereafter referred to as MMD) are not a frequent focus. Research and design solving for motor needs tends to be dedicated to acute user needs that require complex multimodal solutions such as switch access. However, there is a broad group of technology users with less acute motor challenges where touch input is somewhat usable, but smartphone use still causes pain, frustration, embarrassment, and discrimination due to gaps in accessibility.

These gaps could be in part because MMD needs, especially related to touchscreen input, can be complex and difficult to address with a simple solution. Though there has been research on mouse usage for users with motor challenges, touchscreen input is a more complex action that occupies an area rather than a point, and can have several different movement characteristics when touch contact is made [10]. Further, in contrast to some other accessibility-related needs like vision or hearing, dexterity needs can often vary broadly within an individual, even moment to moment [8]. Where some types of accessibility needs can be met with assistive technology tools or features that a user can calibrate initially and use continuously without much adjustment, addressing MMD needs can require personalized and granularly adjustable solutions on a number of axes, such as touch input correction, user-interface simplification or magnification, and availability of multi-modal input like voice access [23]. Setting up a one-time feature or solution is very rarely a complete solution, and constantly adjusting settings to accommodate changing dexterity needs can be an untenable burden on the user. Detecting subtle changes in physical capabilities can be challenging even for the individual users themselves, so understanding the type of settings adjustment needed or how much to adjust at a given time can be near impossible to do manually. Further, in situations where dexterity abruptly worsens, there can be very little time or capacity to change settings, leaving a user scrambling and overwhelmed as they try to use their phone in a moment of need.

Each time a user with MMD needs interacts with their smartphone, they must juggle many variable factors that impact their user experience, including chronic and transient user characteristics, phone stability and hold position, software design and quality, and the impact of being public or mobile at the time. Because so many factors are at play, users encountering frustrating or painful touch interactions sometimes assume it must be their failure to use the technology correctly that is creating difficulties, rather than recognizing that their smartphone may truly lack the capacity to accommodate their dexterity needs. By design, touchscreen interaction demands certain ways of moving and using the hands and fingers which often do not match the physical capabilities of individuals with MMD challenges. This can lead users to simply avoid phone use altogether rather than trusting that the device might have supportive features to enable, much less find motivation to actively seek them out.

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Additionally, the range of experiences leading to MMD-related challenges is broad, and not limited to functional capabilities alone. As with more acute motor challenges, there are physical diagnoses and characteristics that can either cause or exacerbate dexterity challenges. MMD needs can stem from congenital diagnoses, such as cerebral palsy, or from developed challenges, such as multiple sclerosis, Parkinson's, or arthritis. Users can also experience intermittent challenges, such as a repetitive strain injury like carpal tunnel syndrome where stiffness or pain can come and go, and at times, completely resolve. And importantly, regardless of the genesis of MMD needs, the types and quality of challenge can vary widely due to both physical and environmental factors, from general pain, to pain with use, to physical restriction of any part of a finger or hand, to tremor and other uncontrollable movement. It is crucial to note that designing to accommodate functional characteristics alone without considering other factors–like the user's relationship with disability or accessibility and environmental impacts like experiences of discrimination or vulnerability–will not necessarily lead to an accessible device for this group of users. When we do not incorporate the interplay of internal and external factors that are impacting these users, we risk exacerbating the impact of their disability in an avoidable way.

In order to better understand those who experience MMD challenges and to create a potential roadmap for what a smartphone solution should include, we designed a foundational qualitative interview study focused on two primary questions: 1) How do those with MMD needs interact with mobile technology? and 2) How do those with MMD needs currently understand and address their own accessibility needs? These questions also allowed us to explore 3) Whether users with MMD needs have similar or different needs to those with more acute motor needs and 4) How users with MMD needs relate to concepts of accessibility and disability in general. This study design was intended to let users define their own context, needs, accessibility gaps, and pain points when using smartphones. We included prompts regarding both smartphone usability as well as the socio-emotional context impacting smartphone use for these users, with the understanding that smartphone use does not happen in a vacuum. Just like other smartphone users, users with MMD challenges are balancing their physical needs, psychological needs, and cultural context whenever they use their device [24]. Our approach allowed us to map out potential areas where assistive features and tools could be most helpful, and where even the most technologically advanced solution would fail if we did not adequately consider the user context.

Conducting in-depth interviews in a US sample, we engaged with users of a variety of smartphone models to understand their experience and watch as they showed us how they use their phone themselves. We worked to identify user considerations along the entire smartphone-related technology adoption process, from identifying a need, to seeking a solution, to testing that solution, to deciding whether or not to adopt longer term. From this line of inquiry, we found a gap in smartphone usability resulting in users struggling daily to use devices that facilitate critical components of their lives. This usability gap results in pain, frustration, loss of productivity, and feelings of inadequacy. We identified four key findings that collectively indicate that the smartphone experience of users with MMD needs is at best lacking, and at worst, wholly inaccessible.

First, *there is a large gap in available and usable accessibility tools that fully support users with MMD needs.* The smartphone itself is difficult to physically use due to the requirement to hold and manipulate a large object using stretching and precise movement. Users experience difficulty with accuracy and efficiency of touch interaction, spending a considerable amount of time and energy trying to input text and engage with the phone. Further, assistive features are difficult to find, understand, and implement (if they even feel relevant to a user at all).

Second, *many users were unlikely to seek accessibility support* or have awareness that it might exist at all. This seemed linked with an internal mindset of self-blame for the challenges they experienced, as well as a complex relationship with their own disability identity.

Third, the *context in which technology was used affected users' decisions about technology.* Users expressed worry about phone use exposing visible differences related to disability in public, leading to potential judgment and misinterpretation of their physical characteristics. At worst, users fear being more vulnerable to discrimination or crime as a result of visible differences exposed by needing to use their phones differently.

Finally, *users developed creative adaptations* to bridge gaps in usability, such as experiments with positioning and stabilizing devices, privacy trade-offs to reduce the touch-input burden, using additional connected devices, or simply avoiding use when the pain or strain was too great. Even with the additional effort, smartphones remained difficult to use and at times completely inaccessible to users.

Overall, users reported ongoing struggle and frustration with phone use due to different physical needs. Most grapple with their own identity as a person with MMD challenges, and inaccessible technology can magnify that ambivalence further. Additionally, users worry about public visibility of their differences and make intentional calculations about their use or non-use of certain technology as a result. These findings demonstrate that users with MMD needs experience a range of challenges that differs significantly from users with more acute motor needs, and it is imperative to continue exploring specific potential solutions for this group as a unique cohort.

2 RELATED WORK

2.1 Motor Disabilities and Mobile Device Use

There is much research about the accessibility challenges experienced by people with mobility impairments when using mobile devices. Though this research primarily focuses on more acute motor needs, it is still important background for this work. Research has focused on the accessibility challenges that people with mobility impairments encounter when using touch screens [1] and other pointing devices (e.g., [14, 21], as well as difficulties experienced when stowing, storing, or retrieving a mobile device (e.g., [8]). Researchers have explored alternative ways of using a mobile device to overcome accessibility issues (e.g., [5, 25, 30]), although these sometimes require changes to the underlying operating system or even the hardware itself; often this means that these improvements stay as research concepts and do not make the leap to actual devices [3].

Some motor accessibility advances, such as sticky keys for keyboard input [22] and swipe typing [29], have made it into mobile device operating systems, while others, such as cursor-based interactions (e.g., Android's Quick Cursor [1], Apps for Accessibility on the iOS App Store [2]), are enabled by third-party software.

It is important to note that "motor impairments" is a rough and somewhat arbitrary category, which may cover a wide range of disabilities, health conditions, and identities; for example, Anthony *et al.'s* study of people with motor impairments on YouTube [1] included individuals with cerebral palsy, spinal muscular atrophy, quadriplegia or hemiplegia, spinal cord injury, and others. This paper focuses on individuals who have milder impairments, and may or may not identify as being disabled. For people in the mild-to-moderate group, physical differences can be more invisible to others. These individuals may have more latitude to jump into and out of the static category of "motor impairments" at will than someone with more acute difficulties. Because these personal decisions about disability identity may impact the ways that these individuals engage with technology, we chose to focus on this group alone.

2.2 Discovery, Adoption, and Abandonment of Assistive Technologies

Beyond inventing new accessibility features, there remain the problems of letting users know that these features exist, and encouraging them to try (and keep) using accessibility features. Often users are unaware of potentially supportive accessibility features on their own devices [4, 27]. Wu *et al.* found that mobile device users had low awareness of available accessibility features and what they do, and benefited from systems that proactively recommended accessibility features [27]. In subsequent work, Wu *et al.* evaluated several algorithmic strategies for determining when to surface assistive features to users, noting that different interactions may require different detection approaches. Once users were alerted to a potential feature match, they identified it as helpful [28].

Once adopted, though, assistive technologies are frequently abandoned by their users [12, 15], even if they are useful. Assistive technologies can be abandoned if they are difficult to use [13], but may also be abandoned for social or personal reasons, such as when using the device clashes with the user's disability identity [11]. Trewin *et al.* noted that even existing mobile accessibility solutions require a high level of dexterity to configure and use, leading to abandonment after an initial period of enthusiasm [23].

People with MMD needs may have the same challenges around discovery, adoption, and abandonment as those who have more significant disabilities, but may encounter different trade-offs. Specifically, Sin *et al.* explained that siloing supportive features behind the term "Accessibility" could contribute to *digital design marginalization*, or an experience of feeling pushed away from mainstream users that can lead to lower perceived self-efficacy and more social stigma, ultimately reducing the likelihood of discovery of these features [17]. Since users with MMD challenges may be slightly more flexible in how they use a digital device than those with more acute needs, failing to proactively surface features and keeping them contained within an accessibility menu could further reduce discovery and adoption for this group.

[1]https://play.google.com/store/apps/details?id=com.quickcursor

[2]https://apps.apple.com/us/story/id1266441335

2.3 Disability Identity and Assistive Technology Use

Choices around the use of assistive technology may be significantly impacted by an individual's disability identity. Technology users with any type of disability may experience ableism, or the cultural, often subconscious belief that certain abilities are more valuable than others and those who are disabled are therefore less valuable [26]. These beliefs can also be turned inward in a form of internalized ableism or self-stigma, where a person believes that they are inherently less valuable than others. The experience of ableism and internalized ableism can impact disability identity and the choices a person makes about what assistive technology to use, if any [2].

Because using an accessibility feature may identify someone as having a disability, they may strategically choose when to use or not use a particular feature [15, 16]. People with disabilities often prefer using mainstream devices, even when specialized devices might be more effective [8, 19]. Due to their social acceptability and ubiquity, smartphones are often the best option for people to solve accessibility problems in their daily lives [19, 20]. These challenges may manifest differently for people with invisible disabilities, who may have different lived experiences than other people with disabilities [9]. Our present work considers people with more mild disabilities, which may be effectively invisible in many cases.

3 RESEARCH STUDY

3.1 Participants

We recruited 12 participants from a large city in the US Midwest using mailing lists of local research organizations. Rather than recruiting according to diagnoses related to dexterity, we conducted a brief screening interview to determine whether participants qualified for our MMD needs criteria, which we defined as identifying with the statement, "I have reduced dexterity in my finger(s)/hand(s), or I have difficult moving my finger(s)/hand(s)," as well as endorsing one or more dexterity-related phone difficulties, such as "Phone responds to unintended screen touches" or "Difficulty reaching some parts of the screen." This allowed us to capture potential participants who experienced MMD dexterity challenges but may not have a related medical diagnosis. Post-screening, we discovered that all participants who screened into our sample had received a related medical diagnosis where dexterity challenges were an expected symptom. We also biased screening toward Android phone users as our research group is experimenting with development for the Android platform. Participant ages ranged from 34 to 70 (mean=49.6, SD=11.3) and varied on gender (7 male and 5 female). Participant demographics are summarized in Table 1. Participants completed a consent process and received $300 USD for their participation.

3.2 Procedure

We employed a two-stage qualitative study design to cover our thorough interview script without overwhelming participants. Additionally, our two-stage design allowed participants to return a few weeks later after having been primed to consider their dexterity accessibility needs. Prior to the interview sessions, we asked participants to complete a pre-interview task of self-recording a 5-10 minute video discussing key dexterity challenges when using a smartphone. Participants completed this step at home, and it provided us with some insight into each participant's dexterity characteristics prior to meeting with them. The total time commitment for post-screening participation was 1h 45m.

Stage One included a one-hour semi-structured interview in the lab, where participants explained and demonstrated dexterity-related pain points of smartphone usage and any adaptations or workarounds they used to reduce discomfort, limitations, or frustration. Since we wanted to understand contextual user experience, we asked participants to demonstrate tasks that they frequently engaged with on their phone, and to pause and explain further if they found that part of the process was impacted by a dexterity challenge, such as difficulty with pressing hardware buttons, precision, reach, unintended taps, or stability. Because text entry is often particularly difficult due to requiring a combination of precision, reach, and social factors, we prompted participants to show us a text entry task if they had not already volunteered one themselves. Throughout the interview, the moderator noted and asked follow-up questions for any dexterity-related pain points, dexterity-specific adaptations, and any socio-emotional factors that the participant mentioned that impacted smartphone usage, such as avoiding voice input tasks in public. Finally, moderators asked participants to describe and show any accessibility-related features they currently use.

Stage Two was conducted approximately two weeks after the Stage One interview, and consisted of a 45-minute remote in-depth interview conducted via video chat, focused on technology discovery and learning, further engagement with accessibility language and settings, non-dexterity factors impacting smartphone use (disability identity, privacy and safety, interpersonal needs), and desired improvements. We also prompted participants at this follow-up interview to tell us more about any pain points or adaptations they may have been more aware of after our first meeting. Then, in order to better understand the extent of familiarity users had with accessibility settings, moderators prompted participants to try to find the accessibility menu on their phone and look for and/or test settings that might support dexterity needs. As participants searched, we continued to ask questions about barriers and pain points that arose, as well as the experience of searching for and testing accessibility settings.

3.3 Data Analysis

All moderated interviews were audio and video recorded for analysis. Videos were open-coded [18] by the interview moderator and collaborators for themes that arose across participants. Analysis focused on physical user characteristics, barriers to successful smartphone usability, and adaptations that improved smartphone accessibility. Themes and observations were compared, returning to raw interview footage when necessary to gather further detail about a given behavior. This report details pervasive qualitative themes that arose across participants throughout the interviews.

4 FINDINGS

4.1 User Physical Characteristics

Because our primary recruitment criteria was reduced dexterity as self-reported by each participant, our sample included participants with a range of motor experiences and diagnoses that impacted their smartphone use. Each participant had a unique set of complex dexterity needs that varied across several axes: developed/congenital, permanent/intermittent, and pain/restriction. Here are some examples of the complexity of participant MMD needs and challenges:

- Tim reported a loss of sensation and a limited range of motion in his hands and fingers. He described having less flexibility and reach in his right hand, and did not have subtle sensation at all in his right fingertips, making it difficult to sense when he was making contact with a smartphone screen. He described his dexterity characteristics this way: "Usually [touch input] is something I'll do with two fingers, and always my left hand. I usually do hold it in my right hand…You can see there is scar tissue here, so there is less range of motion. It is a little dull–there was some nerve damage. But otherwise it is functional…It doesn't hurt, but the touch is duller."
- Joe described struggling with physical restriction related to an injury that makes it difficult to type on the smartphone keyboard. This physical restriction is exacerbated by phone use and he experiences frustration and the need for breaks from his phone, despite needing to communicate with clients frequently for his work. He explained the process of trying to adapt when he lost capacity in one hand: "I couldn't use my right hand at all, so I had to start using my left for phone usage. It was a learning curve to get better at it, you know, we're adaptable creatures."
- For Jordan, the onset of MMD challenges was related to a diagnosis that impacts his whole body. He noted that he has been experiencing worsening tremor that makes it difficult to engage with his smartphone with precision. When describing his dexterity, he explained, "Sometimes [I have difficulty with] swipes, and all the time my finger jumps. I keep tapping the wrong thing." He reports challenges managing his healthcare via online portals due to difficulty with precision and fatigue.
- Dora described stiffness, pain, and fatigue in her hands and fingers that worsens with smartphone use. She regulates her pain by taking breaks from her phone. During our interview, she shared that it had been a painful day, "So today is a day I wouldn't use my phone as much…I'll need to catch up on everything tomorrow." She also reported that she no longer plays games on her phone because it is too painful, and refrains from using her phone in public because she is worried that others will notice her challenges with dexterity and see her as vulnerable.

Many of our users were restricted, uncomfortable, frustrated, and in many cases embarrassed, by the way they were engaging with

Table 1: Study participants.

Pseudonym	Age Range	Gender	MDD Challenge Onset	Employment	Technology Proficiency	Smartphone OS
Ali	31–40	F	1 to 3 years	Professor	Expert	Android
Cal	31–40	M	4 to 10 years	Electrician	Expert	Android
Corey	31–40	M	Since birth	Security guard	Proficient	Android
Dora	31–40	F	1 to 3 years	Service Manager	Proficient	iOS
Emma	51–60	F	1 to 3 years	Housekeeping	Competent	Android
Joe	51–60	M	4 to 10 years	Analyst	Expert	Android
Jordan	41–50	M	1 to 3 years	Executive Recruiter	Proficient	iOS
Lana	51–60	F	1 to 3 years	Homecare Aid	Expert	Android
Matt	61–70	M	4 to 10 years	Not Employed	Proficient	Android
Sarah	61–70	F	10+ years	Psychotherapist	Advanced Beginner	iOS
Tim	41–50	M	4 to 10 years	Investment Sales	Proficient	Android
Topher	41–50	M	Less than 1 year	Audio Visual Services	Expert	Android

their phones with their hands and fingers. They were also limited by pain and fatigue caused by using their phone, even for short periods. This led to a reduction in phone activities–especially when in public–and motivated them to switch to other devices–such as the laptop–when at home.

4.2 User Barriers to Accessibility for MMD Needs

We sought to focus our interviews not just on the physical restrictions related to MMD challenges, but also on the broader context around how this population of users engages with smartphones. Beyond physical barriers, we asked about characteristics of the phone, the user's mental model regarding assistive features, the experience of discovering and learning about new assistive features, the user's relationship with concepts of accessibility and privacy/security, and other environmental factors (such as public visibility) that might impact overall usability.

4.2.1 Barrier: Physical Positioning and Hardware Buttons Are Difficult. For most of our participants, smartphones were heavy and impractical to use. Current smartphone design is trending larger and heavier, making phones more difficult to hold securely and requiring more stretching to reach across the screen. These devices are very challenging, if not impossible, to use one-handed, where a user both stabilizes and interacts with the phone with one hand. Our participants often needed to use one hand or a flat surface to stabilize the phone, while using the other (often dominant) hand to engage with the screen. Some of our participants only had use of one hand, and in that case they required a stable surface or stand for their phone in order to use it at all. None of our participants were able to engage in one-handed use successfully. Additionally, due to difficulty keeping the phone stable, most participants reported having dropped or broken their phones at some point.

Many participants also talked about difficulty using physical buttons. By default, most phones require the user to interact with physical buttons for necessary features unless settings are adjusted, including waking the phone up or putting it to sleep, a function that is required for almost every use session. Hardware buttons are also used for critical tasks like restarting the phone, taking photos, taking screenshots, and adjusting volume. We found that placing pressure on fingers exacerbated existing nerve pain for some participants, since interacting with physical buttons usually requires a much harder press compared to on-screen tap targets. In one case, participant Cal had resorted to using a stylus to press the hardware button to wake up the phone, as it distributed the pressure and was not as painful as pressing directly. However, this tactic required precise placement and directed pressure on the stylus, which was particularly difficult for him. The process took about 10 seconds and several attempts each time the phone fell asleep throughout our interview.

4.2.2 Barrier: Default Software Settings Are Insufficient. Software usability barriers also led to a range of functional and emotional consequences for the user. Some settings that users leveraged to improve usability, such as magnification to increase the size of tap targets and reduce the need for precision, were applied differently across apps, and were in some cases not labeled or tagged for dexterity accessibility needs at all, making them difficult to search for. Participants also reported difficulty with certain software interactions that they were not able to adjust or change to meet their needs, such as answering calls on Android devices, which required a large swipe-down. Several users reported missing calls due to difficulty with this gesture, such as Lana, who explained that she largely relies on Bluetooth earbuds for answering calls to avoid the gesture completely. Users also reported difficulty entering security codes to unlock the phone because of the precision needed, often resulting in additional attempts (and therefore additional strain). Several participants complained about the inadequacy of voice input as an alternative to touch as well–especially when the phone required the use of touch input to correct mis-typed voice input. Multiple participants also described strain and frustration with laborious touch-input processes required to manage secure information–such as navigating a medical chart or appointment, or engaging with two-factor authentication. Such tasks can require many different steps and a high number of touch interactions across several apps. Users also reported inflexible icon size and placement in many apps, requiring strain to reach input targets and varying levels of precision needed for different tasks. And lastly, a common complaint from many participants was difficulty with the camera shutter button across devices, since it requires simultaneous reach and precision. Several participants reported relying on family members to take photographs for them instead, or not taking pictures at all.

4.2.3 Barrier: Users Blame Themselves When the Phone Is Difficult to Use. Perhaps because of the cumbersome nature of both the hardware and software on smartphones, we found a pervasive theme among most users: they believed it was their own failure to use the phone correctly that led to pain and frustration. Though participants also expressed frustration with the limitations of the phone's software as mentioned above, many alternated between blaming themselves and blaming the device. This self-blame mindset, exacerbated by the burden many smartphones place on the user to discover solutions hidden in nested sub-menus, seemed to lead to a lack of exploration or discovery of potential supports and solutions that might have existed on participant devices. Participant Sarah explained that she had internalized a belief that, "The phone was correct, and my problems were the burden." Participant Topher offered an example of trying to change his technique to improve voice input accuracy, saying, "If changing my accent is going to get the phone to [do what I need], I will do it…I have to change my way a little bit for the convenience." Another participant (Lana) stated similarly, "I just thought it was me…I didn't hit it right…I'm looking at it as human error, not phone error." She continued, "I'm not thinking, this phone needs to be designed to know what I'm trying to say!" Despite recent technological advances in effective touch or voice input for users, most of our participants did not expect the phone to adapt to their needs.

We also found that participants who described more self-blame did not seek supportive features in most cases, unless the need was pronounced, painful, or brought on quickly by phone use (i.e. unavoidable). They did not believe that the phone might have adaptive settings, and the few that had searched were unable to find much that made their phones feel truly accessible to them. A small handful of participants did make some physical changes–like using a grip case or a stylus–but reported little consideration of other accessibility-related tools or features. When presented with a hypothetical question, "Should you adapt to your phone, or should your phone adapt to you?", some participants expressed surprise and delight at the concept that a smartphone might be able to adapt at all. For instance, participant Cal responded, "I want the technology to adapt to me. I'm meeting the technology more than halfway today. I don't want that to be the case."

4.2.4 Barrier: Not All Users Identify as Having a Disability. Not all of our participants saw themselves as having a disability, restricting the likelihood that they would be aware of or seek assistive technology for their devices. When we asked participants to choose whether they believed having MMD needs and having a disability were essentially the same thing, we received mixed responses. Some of our users did feel that having MMD needs was in the same category as others with more acute or global accessibility needs, such as Corey who responded, "I have come to the realization that yes, I do have a disability, I do have a handicap…I didn't develop it overnight, it's not going to improve overnight." Other participants expressed that they did not belong in the category of people with disabilities at all. For instance, participant Joe explained, "I've lived with this for six years, and I'll live with it until I die…I just never categorized myself as having a disability…It's up to me to do what I need to do for myself to be able to overcome these things."

For some, despite large gaps in smartphone usability, there was a perception that their own challenges were not restrictive or permanent enough to qualify as a disability, or that others must experience greater struggle, so they should not identify as having a disability themselves. These users sought to minimize their needs and place others in front of them on the imagined hierarchy of needs. Participant Tim explained, "As far as I'm concerned, I could use some aids to make [using my phone] easier, but it's still manageable. But I know for a lot of people that's not the case–and that could be me at some point."

For others, there was also confusion about the source of the MMD challenges, which complicated the user's relationship with disability identity. Participant Dora, concerned about additional dexterity strain caused by phone use, told us, "I would love to be able to have games on my phone, but I would make my hands worse. I'm only 39, I still have to have some type of mobility when I'm older…Sometimes I think about how I won't even be able to have a phone when I'm 70…It is a little scary." In this case, she recognized that her MMD challenges were increasing over time, but saw them partially as a byproduct of smartphone use itself.

4.2.5 Barrier: Users Do Not Associate 'Accessibility' With Features That Would Help Them. Though there are some features that can support MMD needs scattered throughout the accessibility and settings menus on most smartphones, our participants generally responded with ambivalence when asked about their identification with the word "Accessibility" or disability. This response was understandable for this particular group of users, who experience mild-to-moderate barriers to accessibility but perhaps have not needed external accessibility support in the past or in other ways, and so are sometimes unfamiliar with accessibility and assistive technology in general. Participant Corey told us, "I thought about [exploring settings] many times–the assistant sometimes helps, but I really just want to blend in sometimes." Another participant, Dora, explained, "I like to use [accessibility features], but to me they are more of a handicapped or 'not able to function' feature. That's how I think of it and how I define it myself. That's why I don't like the term, 'Accessibility Features."' Participant Cal expressed a similar sentiment: "When you see that guy [accessibility icon] in the corner, you think, 'Oh, that's for people that have major medical issues."' And another participant, Tim, offered a similar sentiment when discussing Accessibility settings, indicating that he had not explored them at all: "I'm unaware of them, and even though this presents challenges, I'm able to manage it."

Beyond lack of identification with the term, some users did not understand that "Accessibility" might describe features that could support their needs. Participant Dora explains, "Prior to this, I related 'Accessibility'...to more in-depth settings. I would never have clicked on it. It didn't register in my brain as being a translation of someone who has some type of issues." This participant went on to clarify that she had assumed that "Accessibility" settings were complex settings unrelated to disability needs, only usable by those who were highly technologically proficient. This confusion arose across participants, and was repeatedly shown to be a major barrier to feature access and implementation for this group. Another participant, when prompted to look for the Accessibility Settings menu on her Samsung phone and share what she found, responded, "So Accessibility is the fifth menu from the last choice. . . Wow! Oh my goodness, I'm seeing a lot of options here [participant throws hands up in surprise]...Interaction and dexterity, I have not even noticed that!" Though this participant might benefit from dexterity support, she was not aware of what her phone was capable of or where to look to find assistive features, much less the opportunity to experiment with them to see which ones might help her.

4.2.6 Barrier: Finding Helpful Settings and Features Is Difficult.

Related to user mindset, we found that our participants were not prone to seek out, explore, or discover new features and settings. There are several steps that need to be achieved for users to adopt a new feature, tool, or device, and our participants described barriers at each step, often barring them from discovering or implementing even existing accessibility supports.

Awareness. Our participants were largely unaware of any potentially supportive features. They saw the phone as a fairly static object, and therefore were not very inspired to explore further. Participants also stated that they did not want to prioritize dedicating time (and precious dexterity resources) to exploring the phone without a guarantee that they might find something useful.

Discovery. Without the phone proactively surfacing potentially helpful features, our participants did not know where to look for dexterity-related tools.

Understanding. Even if a participant did stumble across something that could be useful, they did not find adequate learning support on the phone to help them understand complex tools, leading to further discouragement of exploration.

Testing. Testing new features felt risky to many participants, too, as they worried it might scramble other components of their phone or be irreversible once implemented.

User Joe, who was enthusiastic about personalizing his phone and experienced with searching for and implementing new features and settings, described how his phone makes accessibility settings difficult to discover for users with MMD challenges: "Not everybody uses the settings–not everybody is as into that as I am. . . and I want to be able to get the settings easier. With [my phone], I have to pull down, and then pull down again just to get the settings icon." Here, Joe was referring to difficulty executing the complex gesture needed to access the settings feature on his phone, which required multiple sequential finger/hand movements. User Cal, when shown where some settings were on his Android smartphone that might support MMD needs, expressed frustration that the phone had not actively surfaced these options to him: "It was very much hidden in the phone, and I've been in the settings menu quite a bit. . . the phone knew that I was adjusting those settings, but it never hinted or suggested that it had some advanced accessibility settings that I might be interested in." Participant Emma described frustration with testing magnification settings that she had hoped would help increase tap target size to make precision easier: "A couple of times by mistake, I made it little instead of bigger. Once I made it bigger, but I don't know what it was or how to get back to it." With the barriers to discovering the few settings that do exist to support MMD challenges, and the difficulty involved with trialing them to decide if they are effective, it is not surprising that so few of our participants had discovered helpful settings, much less tested them or implemented them.

4.2.7 Barrier: Feature Discovery Is Near Impossible for Users With Low Technology Proficiency.

Where users with high technology proficiency were sometimes able to navigate settings menus, online forums, and user manuals to better understand what assistive tools might be available, users with low technology proficiency were particularly impacted when their smartphone's default settings created an accessibility gap due to their dexterity needs. In addition to the phone limitations and mindset barriers listed above, users with low technology proficiency were unaware of feature or support search tactics–in some cases users were even unsure of what search terms to use to find accessible features that could address their MMD challenges, either in their settings menu or online. User Dora explained, "I'm scared of going to settings. . . it just becomes a chore, where it's like, 'Oh, this is so complicated."'

Users with low technology proficiency reported encountering more emotional barriers to discovering and implementing settings as well, such as fear, isolation/lack of support, and embarrassment around potentially scrambling their phone with the wrong settings and needing to ask for help. More than one user described an experience where they had accidentally turned on their device's native screen reader and were not able to turn it off, which caused their phone to loudly dictate each thing they did, both publicly telegraphing their need for accessibility support and their lack of technological know-how to configure their phone correctly. Experiences like this caused our participants to fear engaging with settings altogether.

4.2.8 Barrier: Situational Factors Increase Users' Sense of Vulnerability.

The environment our participants were in and how they were perceived by their community appeared to be another major barrier to accessible smartphone use. Participants with MMD challenges have accessibility needs and difficulties that can at times be invisible to others, and in many cases, participants expressed that they would prefer invisibility. Participants often downplayed or masked dexterity challenges in public to avoid misinterpretation, prejudice, or vulnerability. Some worried that use of the phone in public was a key way in which their physical difficulties could be observed and interpreted as vulnerabilities by others. Participant Tim described his worry that others might misinterpret the way he uses his hands as something problematic, which could compromise his business relationships. "I'm in investment sales, and first impressions do matter. . . When there is a little bit of a shake or whatever. . . do they think I'm on drugs?...When you are in the trust business, if you look nervous, shaky, off, whatever–that's not a good thing." Participant Lana offered a very similar statement, saying, "It's rare that people will see the tremors, but when they do, they're like, 'Okay what's wrong with you?"' Users felt others perceived them as inferior–less able to do their jobs, or simply less able overall.

These worries manifested in actual shifts in user behavior. Several participants reported reduced phone use in public due to fear that the difficulty they have interacting with the phone might be visible to others. Worries ranged from drawing attention and feeling embarrassed to worrying that visible differences might make them more vulnerable to exploitation. Most participants described reduced use of voice input in public to preserve privacy and not draw attention, opting instead to avoid tasks that they would usually initiate or complete via voice input. Participant Cal reported that he rarely answered phone calls in public because he was not able to retrieve the phone from his pocket and answer it quickly enough, and did not want to risk unwanted attention or dropping his phone in a rush. Another participant, Topher, expressed embarrassment about how others might perceive him using his phone, saying, "I feel like some old Grandpa…I feel like someone is looking at me like, 'What, you don't know how to type?"' Participant Ali described feeling unsafe in public due to limited use of her hands, so she chose not to use her phone in public at all since others might see her struggle and consider her "a target." For many users, having a smartphone available in public might feel protective, but for these participants, public phone use decreased their sense of safety overall.

Several participants also described a cyclical effect in public where the stress of perceived and real pressure from others, self-consciousness, or fear of vulnerability can exacerbate dexterity difficulties with accuracy or task completion. This can lead to further overwhelm, and the cycle continues. Some concrete factors that can exacerbate physical dexterity differences are heightened vulnerability from using the phone in a visibly different way, lack of stability without a place to brace the phone, lack of spontaneous capacity to engage with the phone when it rings or notifies unexpectedly, concern for personal safety, and lack of digital security due to conspicuous entry of personal identification numbers, etc. in public. Participant Tim explained that when he feels nervous in public, his tremors tend to be worse, which leads to less accuracy, and then more nervousness about the lack of accuracy. He added that often, the only way to exit the cycle is to abandon a task or ask for help, if it is even available.

These environmental pressures result in several major impacts to users in two categories. Functional impacts include increased time to complete tasks, inaccuracy of touch input and mistaken selections, limited use due to avoidance of particular tasks, and device breakage due to lack of stability in public. For instance, participant Jordan described accidentally canceling a long-awaited doctor's appointment on his phone because of an unexpected "finger jump"–a mistaken selection that would have required a phone call and time spent to reinstate the appointment, if it had not been rebooked already. Emotional impacts included reports of missed opportunities such as answering calls in time or participating in group chats that required text input, frustration around not being able to complete tasks as intended in a reasonable timeframe, embarrassment due to visible differences in phone usage, and in some cases, worry about discrimination and rejection by others.

4.3 Adaptations Bridge the Usability Gap Somewhat–But Not Completely

We found that all users had discovered and implemented at least some adaptations to improve their smartphone usability experience, though no participant was able to achieve full, unencumbered accessibility. These adaptive methods fell into five primary categories: (1) Accessibility features, (2) Positioning and stabilizing adaptations, (3) Privacy trade-offs, (4) Tech ecosystem adaptations, and (5) Substitution and non-use. Interestingly, accessibility features and settings were the least commonly found adaptations. Users were much more likely to rely on adaptations from the other four categories to engage with their phones when accommodating their MMD challenges.

4.3.1 Adaptation: Accessibility Features. Though some of our participants did engage with a few on-device features to try to improve their experience using the phone, use of assistive features was not widespread. Several participants had implemented a few easier-to-find features, such as magnification to increase tap targets, and keyboard size adjustments (which for many phones, only makes the keys taller rather than wider, and our participants reported that errors tend to happen due to narrow target width rather than height). Only one iOS user (of three) in our study had discovered Apple's "Assistive Touch" feature and had configured it to avoid using hardware keys. Some participants expressed disbelief that accessibility features could possibly accommodate their needs, and so had not searched for them at all. When asked why she had not explored accessibility options, participant Dora responded, "It's just me in my head coming up with my own solutions, maybe in part to minimize it, rather than going out and looking for things." Participant Topher also illustrated this by explaining, with a laugh, "I can't imagine that there would be some sort of assistive technology that would let me play Candy Crush without some type of painful gesture."

4.3.2 Adaptation: Positioning and Stabilizing. We found that participants were far more likely to adapt the way they use their phone physically than to try to adjust software to accommodate their dexterity needs. We recorded examples of participants repositioning their phones to switch hands and fingers, bracing on a stable surface or their own body, and using a phone stand, holder, grip, or case to improve the accuracy, precision, and speed of touch interaction. In all cases, these adaptations were readily available to all users and not labeled as "Assistive Technology" or exclusively available to users with accessibility needs. Even still, some participants expressed self-consciousness about the way they needed to hold their phones or use their fingers to interact with the screen, noting that they did not want to have to use their phone in visibly different ways. These interaction methods and adaptations tended to vary within-participant as well, depending on the type of activity, the environment, and the user's level of pain or fatigue.

4.3.3 Adaptation: Privacy Trade-offs. In light of the barriers our participants described in trying to use their smartphones, it may not be surprising that we found several cases where users were willing to exchange personal information or compromise phone security to improve phone usability. As mentioned above, the touch-input heavy phone wake-up and unlock processes were particularly difficult, especially because they must be conducted for each and every use session, and failing to hit the right targets or make an accurate sliding pattern could result in locking the user out of the phone. At least two participants had completely removed their lock screen passcode due to pain and strain with entry. Participant Cal explained his choice, "Turning the phone on and off involves a lot of pressure, so when I turn on my phone there's no password or anything. . . just to make it as simple as possible." When the moderator asked how he felt about not having a passcode, he responded, "Insecure, unsafe. Because of that, I don't have my banking app on my phone. It's a trade-off." Participant Dora, who had also removed her passcode completely, explained, "Everyone tells me [I need a passcode] for security. I don't care, I just want things to be easy." Participants who retained a lockscreen worked to reduce the amount of times they had to perform the unlock task, sometimes changing settings to leave the phone awake or unlocked for long periods of time. Many participants were unaware of biometric access options, even if their phone was capable. When prompted, almost all participants indicated that they would prefer not to use touch input to unlock their phones.

There were also circumstances where participants were willing to share potentially private data about how they use their phone if it meant an overall improvement in usability. Tim described his willingness to share sensitive information about his medical needs if it could lead to improved dexterity tools for himself or others, "I would definitely be willing to contribute to help create products that make it easier for people." Participants described a variety of types of information they felt comfortable sharing in the name of improved usability, such as self-identifying with specific dexterity challenges, completing a questionnaire or set-up wizard that factors in their needs, or opting into notifications about features or settings that might make their phone easier to use. Several participants expressed enthusiasm about the option of having their phone recognize their unique usage patterns and adapt settings automatically. Participants did note that there were limitations to this balance as well–most did not want to share specific medical record information, and did not endorse sharing any biometric or health information beyond the local device. These findings are in line with previous research in the accessibility community highlighting user ambivalence about how and when to make privacy trade-offs to improve usability of other technologies, such as adaptive assistive technologies on laptop or desktop computers [6, 7].

4.3.4 Adaptation: The Tech Ecosystem. In a few cases, participants were able to find external digital tools that allowed for improved smartphone usability. Several participants reported using earbuds connected to the phone to conduct calls or even send voice input prompts so that they would not have to hold the phone and interact via touch. This was especially helpful in public, so that participants would not have to worry about dropping their phones or visibly struggling while mobile. Participant Jordan described implementing a combination of earbuds, a smartwatch, and a tablet, all to reduce the need to engage with his phone due to small target size, worry about unintended taps, and physical strain. He explained, "I use my tablet constantly. Sometimes when people call me, I'll answer on my tablet."

4.3.5 Adaptation: Substitution and Non-Use. All of our participants reported ongoing challenges and barriers to usability that they had not been able to solve even with the software, hardware and positioning adaptations they had discovered. A primary way that they coped with gaps in usability (and the pain, strain, and frustration that tended to accompany it) was to simply put their phone down and/or seek to complete the tasks on a different device, if at all. Participant Emma explained, "I just deal with it. I look at it like, 'It could be worse.' It is what it is. If I have to wait, I wait." For longer written tasks, most participants indicated that they preferred to use a full-size keyboard and mouse. For tasks that involve continuous scrolling and selecting, such as online shopping or social media, many reported that they would rather use a desktop computer where the targets are further apart and the scrolling action can be accomplished with an arrow key tap rather than a complex swipe gesture. Several participants explained that they had given up playing games on their phones because the pain and strain of repetitive precise interaction was too costly. Participant Corey explained that phone use over time caused increased "shaking and twitching," and when asked what he did to address that, he said, "I just have to put it down." Though the phone was a major part of each participant's life, the scope of smartphone tasks accessible to them was greatly diminished.

5 DISCUSSION

5.1 Users With MMD Challenges Have Distinct Needs

Though significant effort has been dedicated to the development of multi-modal smartphone access tools for users with acute motor accessibility needs, such as switches and voice input, we found that users with milder motor needs are not well-accommodated by existing motor assistive technology. Moreover, because these users have dexterity needs that can at times be invisible to others, they often desire to move through their environments unencumbered by the attention or stigma that a more acute disability might invite, and are less likely to experiment with dedicated assistive technology at all. These users have and use smartphones frequently, despite experiencing significant barriers to efficient and precise input as well as pain and strain related to phone use itself. Users explained that many tasks they need to accomplish–especially around mobile communication–are not achievable without a smartphone. Despite the barriers to accessibility, they rely heavily on smartphones for important tasks and are able to accomplish just enough to make the frustrations of usage worth it.

These needs differ from users with more acute motor needs in part due to the lack of interaction this group has with medical or therapeutic education and support. Where many technology users with acute motor needs have received targeted occupational therapy and education around assistive technology, our participants with MMD needs had often only received general medical support–even to the point that many of our participants were unaware of what types of technology assistance might be available, and some did not even understand what the word "Accessibility" meant in the context of their smartphones. Because members of this user group are less likely to be introduced to possible supports through a medical or therapeutic setting, but still may be hindered by gaps in accessibility of technology they use daily, it is even more important to hone the discoverability and learnability pathways to features and tools that can improve their user experience.

Choosing to recruit via non-diagnostic selection criteria, including self-reported upper motor (hand and finger) barriers and pain points with smartphone use, allowed us to gather a group with a range of MMD challenges while preserving privacy around health information. In future research, this approach could be supplemented by transforming other common group experiences from our findings into screening criteria–such as difficulty answering calls or locking/unlocking the phone.

It is important to note that the distinction between users with MMD needs and users with acute motor needs parallels findings in other accessibility arenas, such as the necessary distinction between low vision and blind users [20]. Finding a similar variation in needs–especially around discoverability and learnability of accessibility tools, and the impact of environmental context–may indicate a need for more focus on the specific characteristics of mild disabilities across the accessibility spectrum. Because technology users with mild disabilities use technology differently than those with more acute challenges, it may be worth it to consider the lived experience and context of these users separately rather than assuming a smooth continuum of needs from mild to acute.

5.2 Disability Identity and Internalized Ableism

Throughout our interviews we focused primarily on participant device usage patterns, habits, adaptations, and barriers to successful task completion. As a secondary exploration, we also worked to better understand how participants related to ideas around disability and accessibility. This included whether or not participants identified with having a disability at all, and if they did, how that identification impacted beliefs about themselves and how they engaged with technology overall. Many participants seemed to wrestle with internalized ableism or self-stigma–a belief that disability makes one inherently less valuable [2, 26]. This concept could explain participants' self-blame regarding accessibility barriers, which inhibited trust that their devices could potentially accommodate their dexterity needs. Because ablelist cultural messaging is pervasive, users with MMD challenges may hold an assumption that smartphone users should have full dexterity capacity, and therefore they are not necessarily worthy of additional consideration or accommodation. Some participants expressed awareness of these cultural pressures when they worried about their dexterity differences being visible to others, for fear of judgment. Other participants, at times, extended that judgment to themselves even when removed from situations with external visibility, impacting their willingness to seek support or believe they were deserving of better, more usable technology.

5.3 Opportunities for Change

Based on the findings that accessibility settings for dexterity needs were not easily discoverable, testable, or widely adopted by those with MMD challenges, it is clear that smartphones are currently not providing an accessible experience for these users. Because so few users had discovered or implemented any accessibility tools on their phones, one thing we were not able explore very deeply was how effective existing accessibility tools might be at addressing MMD needs. The lack of surfaced features in our findings may be because users had not found them, but it could also be because there are not many very helpful tools to find that successfully address both the existing accessibility gaps and the complex relationship these users have with disability identity.

There is a distinct possibility that there may simply not be many smartphone tools that are effectively supportive for the physical needs of users with MMD challenges, and that our participants were not incorrect when approaching their phone with a weariness that it may not be able to meet their needs. This speaks to a much larger opportunity in the accessibility design space to innovate dexterity tools that can successfully accommodate varied and transient MMD challenges for users as they evolve over time, with the goal of increasing input accuracy and speed while reducing physical strain and visible difference. One major hindrance to solution development is navigating data collection around personal dexterity characteristics on smartphones and determining what users are willing to share, while being mindful of the sensitivity of usage data about MMD challenges. However, participants in this study were enthusiastic about the possibility of balancing these factors and more willing than expected to offer usage data if it could trade-off with improved usability.

Another possibility is that any solution hidden in layers of accessibility menu settings would likely be ignored by this group, regardless of effectiveness, due to the lack of consideration of non-physical factors (such as disability identity and fear of visibility) that these users are also juggling. To create a truly accessible solution, the industry may need to avoid focusing on distinct settings, tools, or experiences that are siloed exclusively for people with disabilities, and instead consider universal tools that these individuals would use without hesitation, fear, or worry–simply because so many other people use them. Though this has been a difficult design and engineering hurdle to date, advances in smartphone capacity and machine learning could offer new opportunities to bridge this gap in responsible, ethical, and effective ways for users in coming years.

6 LIMITATIONS

Because we were interested in ecological validity and contextual familiarity with accessibility settings, we relied on participants to bring and use their own devices for our interviews. This limited our dataset to devices that were participant-owned, which makes it difficult to draw conclusions about the state of smartphone accessibility for MMD needs as a whole. We were most interested in user experiences of Android devices, and so biased our sample toward Android device users. This limits our capacity to generalize about usability issues throughout the smartphone-using population. We also needed to conduct these interviews in a lab setting, which may have limited the range of adaptations that participants compared to the ones they may use regularly at home–such as additional positional adaptations when lying down, for instance. Also, we were not able to actively observe participants in a public environment where they may have been especially cautious about appearing to have a visible difference. As a result, we relied completely on self-report to understand those experiences.

To address potential sample limitations of conducting this study in the city where our operations are primarily based, which has a population that skews both wealthy and technologically literate, we purposefully chose a large city in the US Midwest because its population has a broader economic range. However, we were still limited to a sample drawn from one metropolitan area, which may have impacted findings around social models of disability if they differ in that location from other places in the US. Replication would be needed in additional US samples to address this issue.

7 CONCLUSION

Users with MMD challenges deserve parity in technology experiences, especially for smartphone use, which is indispensable for communication, connectedness, and professionalism in many places around the globe. These users are currently forced to grapple with smartphone functionality that does not meet their accessibility needs. Because this group of users may not endorse disability identity, traditional paths to assistive technology–such as device accessibility menus or guidance from occupational therapy or other medical resources–are not successfully providing needed support. Even with creative adaptations and workarounds (which the user must often discover or invent), users with MMD needs are not able to achieve the precision and accuracy of touch input they desire. They continue to experience pain and strain triggered by phone usage that pushes their motor abilities to their limits, environmental pressures to mask their differences and use only very discreet adaptations in public, and a conflicted internal narrative around whether their needs are acute enough to warrant seeking or receiving real support and relief.

Designing for this group will involve considering whether current mobile accessibility strategies, such as separating accessibility solutions from mainstream options, are actually effective for all groups. Additionally, innovators may need to reconsider the industry standard of prioritizing technology that addresses physical challenges at the exclusion of other factors, such as discoverability, learnability, and the complex nature of disability identity. Moving forward, it will be important recognize that users with MMD challenges require distinct considerations, and are worthy of supporting via solutions that are easy to discover and can truly accommodate their varied needs.

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