Wireless Inclusive RERC

2020ONE

PROCEEDINGS

STATE OF TECHNOLOGY FORUM

MARCH 23 & 24, 2021

INCLUDE. INNOVATE. TRANSFORM.

NIDILRR
National Institute on Disability, Independent Living, and Rehabilitation Research

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2021 State of Technology Forum Proceedings

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INTRODUCTION

The Rehabilitation Engineering Research Center (RERC) for Wireless *Inclusive* Technologies (Wireless RERC), funded from 2001 to – 2021, is currently in year five of its fourth consecutive five-year grant cycle. Headquartered at the Georgia Institute of Technology, it partners with Georgia State University, the University of Texas, Arlington, and other stakeholders.

The mission of the Wireless RERC is to integrate established wireless technologies with emerging wirelessly connected devices and services to address access equity now and to perpetuate an inclusive future where individuals with disabilities achieve independence, improved quality of life, and enhanced community participation. Through an agenda of research, development, training, and outreach activities, successful innovations aim to engage, connect, and accelerate access to a dynamic, inclusive wireless ecosystem. The Wireless RERC brings together a highly skilled and committed team of more than 30 researchers, designers, technologists, engineers, and practitioners to address complex challenges and discern new opportunities. They collectively provide expertise and knowledge to sharpen the focus of proposed innovations in research, development, training, and dissemination needed to achieve the mission of the Wireless RERC.

Within each five-year grant cycle, a state of technology conference is held to discuss how changes in wireless technologies have impacted people with disabilities' lives. The Wireless RERC 2021 Virtual State of Technology (SoT) Forum originally scheduled for 2020, was rescheduled because of a series of events that stopped all business as usual – the COVID-19 global pandemic, which, at the time of the Forum, led to more than 500 thousand dead in the U.S. alone. Concurrently, devastating natural disasters, painfully evident social injustices, and attacks on democracy revealed disconcerting social fault lines. On the plus side, 2020 did not slow down progress; the Wireless RERC adapted to the new normal, modifying research protocols, pivoting to accommodate new barriers, and determined to continue advancing technology toward a more inclusive society.

Our goals in this 5-year grant cycle were successfully accomplished because of the stellar teams at Georgia Tech and our partners at Georgia State University and the University of Texas, Arlington. The diverse Advisory Board contributed insights on technological and access issues and provided support and encouragement for our efforts and activities. As such, the bar was raised for better user experiences, next-generation technologies, auditory devices, wearable displays, inclusive emergency lifelines, robotics, and augmented reality, among other projects.

Over the 20 years of the Wireless RERC, new generations of users with disabilities have embraced ever-changing wireless technologies, leading designers and manufacturers to incorporate universal design elements. Notably, one of the key achievements was to document the changing wireless industry mindset from a reluctance to develop accessible features to one where they are on the forefront of accessible and usable design and development -- envisioning an inclusive, engaged future for all. In parallel, Wireless RERC capacity-building efforts have introduced students to the importance of accessibility and usability. As a result, more graduates are taking their training into the government, industry, NGO, and academic workforce. Most excitingly, they have started training the next generation of inclusive technology advocates.

Forum Overview

The Wireless RERC convened the *Virtual State of Technology (SoT) Forum 2020One* on March 23-24, 2021. The by-invitation event brought together more than 75 disability experts from government, industry, academia, and the non-profit sectors. The 2021 virtual SoT was a focused, robust event, with a lively, informed, and diverse group of attendees representing the research community, people with disabilities, industry, technologists, advocates, policymakers, and disability service providers who explored the state of, and emerging trends in, inclusive wireless technologies and applications. It was fitting that the SOT relied heavily on wireless and connected technologies to virtually convene the Forum during the ongoing challenges of the COVID-19 pandemic.

The key themes: *Include, Innovate, and Transform,* were chosen to capture the character of the rapidly advancing, technology-driven field over the 20 years of the Wireless RERC. The SoT served as a mechanism for outlining critical research, development, outreach, and stakeholder engagement accomplishments to propel positive change in the field of wireless technology access, usability, economic inclusion, and products that can be characterized as transformational. The Forum examined wireless technologies' evolving nature and capacities and identified opportunities to meet a range of community needs for access, equity, and inclusion.

Participants discussed implementing research findings and evidence-based policy to invent a powerful future where no one was excluded based on disability. Discussion-based sessions explored the capacity of evolving wireless and associated digital technologies to facilitate independent living and community inclusion of people with disabilities. The exchange among stakeholders also led to identifying opportunities that could further contribute to change-making practices in end-user research, design of inclusive technology, regulations, policy advancements, and creating a next generation of leaders via capacity-building instruction.

The discussions were punctuated by videos and presentations, including Rapid Fire Research Papers that highlighted augmented reality and robotics; Lightning Development Demos that highlighted wearables, tactile graphics, and emergency life lines; and Selected Papers on social connectedness, personas, and socially assistive robots. These unique projects gave attendees a glimpse into the future of wireless advancements. The SoT outputs will help chart the next generation of wireless/connected technology opportunities and advance the full inclusion of people with disabilities.

The SoT Forum Proceedings cover in detail the input from all stakeholders over the two days and identify new research agendas in the field of wireless access and inclusion. The Forum Proceedings further includes themed videos and papers that highlight the projects of the Wireless RERC, demonstrating our contributions to wireless research, development, and stakeholder evolution over the past 20 years.

The SoT Conceptual Framework. Twenty-one years into the 21st Century, mobile telephones, once a luxury item, have become nearly ubiquitous computing devices. The rapid adoption of "smart" wireless technologies created disruptive change, supported by the undercurrent of foundational and institutional changes in our society. The Forum's key objective was to explore the capacity of these evolving transformational wireless and associated digital technologies to facilitate independent living and community inclusion of people with disabilities. We were successful.

SoT Program. The two-day program included a series of discussion-based sessions focused on the role of research, development, and stakeholder engagement in the design of inclusive technology, policy, regulations, and universal access for all stakeholders' inclusion. The discussions were punctuated by Rapid Fire Research presentations, Lightning Development Demos, and selected paper presentations. Links to these are embedded within the online Proceedings. The speaker/session PowerPoints can be found in the Appendices of the Proceedings. An overview of the sessions follows.

Day One

The first day of the SoT Forum consisted of three panels of experts who covered research, technology, and stakeholder engagement.

Session 1. A discussion of **The State of Research** was facilitated by Dr. Paul M.A. Baker with Dr. Nathan Moon. The session addressed how survey tool development and innovation can lead to more effective research outcomes. Dr. Moon noted "foundational" surveys have always served a critical role for Wireless RERC research and have been updated and administered continuously since 2002. Part of the discussion explored IoT, techno-ecosystems, real-time text, smart devices, basic phones vs. smartphones, and 3G vs. 5G technology. Dr. Moon, while presenting Next Generation Wireless Device Adoption and Use among Individuals with Disabilities: Findings from a National Survey of User Needs, 2019-2020, observed that some users with disabilities continue to use basic cell phones and elect not to transition to smartphones, in part, as the tactile sensation of physical buttons is comforting. However, many users will be forced to move to newer smart devices as the 3G networks are phased out.

The subsequent Q&A session raised some interesting points. An attendee asked whether devices created for senior citizens, such as the Jitterbug, were included in testing and research assessments about phone usage. Dr. Moon replied that although he hadn't interacted with many Jitterbug users, awareness of its use and presence is important to their information dissemination efforts. Another participant proposed adding a tactile component to smartphones instead of making users choose between basic feature phones' form factor and smartphones with the touch screen form factor. Dr. Moon noted that such modifications are currently up to developers to supply these features and peripheral devices.

Dr. Baker defined research and its importance in the field of accessibility and disabilities. He noted that there had been a shift from a focus on the wireless technology itself to the *use context* of wireless technologies, as well as increasing research adaptability and sustainability, borne in the face of the COVID-19 pandemic. He concluded that there are numerous opportunities for "bottom-up" observations of wireless technologies in changing environments, where the priority is placed on user needs and grounded in a participatory design process.

According to Dr. Moon, the current research cycle was the first to take an in-depth look at smartphones, the Internet of Things ecosystem, and how to integrate these smart devices into homes and daily lives. Dr. Baker provided a supplementary response by explaining that the synergy of devices and sensors and "semi-smart" systems between chat boxes and AI is necessary to aid accessibility. Additionally, issues and concerns of cybersecurity were discussed. Other key themes covered during the session included: (1) the continued importance of assistive technologies: screen reader and screen magnifier technologies; (2) growing use of real-time text (RTT) and intelligent assistants such as Siri, Alexa, and Google Assistant, and the importance of voice control; (3) society moving toward a holistic view: from the smartphone to a "personal ecosystem" of devices such as wearables, "smart home" technologies, Internet of Things (IoT), and other sensors. Dr. Moon noted, "We're moving away from a reliance on a single device such as a Smartphone to an ecosystem of devices." He concluded his remarks by sharing that people with disabilities are not different from people without disabilities when it comes to concerns about technology dependence and privacy when relying so comprehensively on technology to aid in so many facets of daily life. The field has much work to do to address these concerns.

Session 2. A discussion of **The State of Technology Development** explored moving the needle forward on transformational technologies for access and inclusion. Dr. Bruce Walker and Dr. Maribeth Coleman led the conversation. Despite the 30-year history of assistive wearable computing research and development (R&D), many individuals are surprised that there are fewer consumer products than one would expect given all of the R&D that has occurred. This reality is, to an extent, a function of the many barriers that exist, even while advancements are made. Dr. Coleman as the session facilitator, observed that there had been substantial developments in base technologies in the last five years, including hardware processors, memory, and sensors that have seen huge price reductions; in some cases, sensors that formerly cost thousands of dollars – now those sensors are smaller with a 10-cent price point. Dr. Coleman also noted other advancements in the field, such as more software authoring tools that are more usable and the rise of 3-D printing that allows individuals to create their own adaptations and devices.

Despite advancements, persistent barriers include a lack of sufficient, easy-to-use authoring and prototyping tools. There are not any established education, tools, or workflow to support product designs for things such as augmented reality. The rapid technological development cycles have led to developers overlooking the diversity of user needs, in contrast to traditional years-long development, with extensive bench and user testing. Dr. Walker echoed this theme noting technological advancements that helped to overcome some of the previously mentioned barriers. He introduced the SWAN 2.0 (System for Wearable Audio Navigation), created to help individuals with blindness navigate indoor environments and provide information on their surroundings, such as the presence of carpet, tile, walls, and door locations. SWAN 2.0 is the second iteration of the SWAN 1.0 prototype. SWAN 1.0 encountered significant hurdles, such as the size of the available technology at the time. An additional barrier was the lack of reliable localization technology such as position and facing direction, referred to as "Pose," which refers to a person's orientation. For instance, if a person who is blind is approaching a staircase, and the SWAN positioning is off by even a small error, it was still too great an error to be considered reliable and safe. Ten years later, after technological advancements, SWAN 2.0 includes a smart pedometer and has several unique features such as a very small camera, advanced indoor localization, and a prototyping environment to remediate the first-generation SWAN shortcomings.

Some of the participants inquired about where they could find resources for building accessible products. Dr. Walker noted that while there is a very active Reddit community that focuses on building accessible game controllers, some big companies appear to be hindering this collective form of do-it-yourself (DIY) activities, but that these communities can still be helpful. Other participants inquired about what it will take to "arrive" regarding accessibility in product development. Dr. Walker opined that it would require developers to do a lot of research and get these prototypes to market.

Session 3. The State of Stakeholder Engagement discussion addressed mechanisms for engaging consumer, industry, and governmental stakeholders in policy and technology development to advance access and inclusion. Karen Peltz Strauss facilitated the session with David Dzumba and Richard Ray as they discussed technology from the perspective of consumers, industry, and the government. They focused on how to ensure that accessibility is at the forefront of the technology conversation. In the 1980s, there was little coordination between industry and consumer stakeholders -- more of an "*Us* vs. *Them"* mentality with a lot of distrust and little engagement. While the disability market was collectively large, individually, different requirements based on disability type (e.g., blindness) were not seen as a large enough market to compel the industry to build in accessibility. One of the changes that occurred in recent years was a re-thinking of product markets due to universal design and, consequently, larger markets for inclusive products.

In the 1990s, new technologies such as cell phones were deployed without the needed accessibility, which was addressed through legislation and regulatory activities. Currently, society is in the fourth industrial revolution driven by digital technologies, including augmented reality, increased connectivity, artificial intelligence enhanced technology, data-driven predictive analytics, and 5G technologies. These innovations can enhance independence and privacy if they are designed with accessibility in mind. Addressing these issues legally is a delicate balance, as laws that are too specific can exclude future issues that arise with developing technologies, while too general laws become ineffective. Market-based approaches, conversely, also have problems. Markets do not always generate specific solutions. For instance, while large companies might address accessibility, this may not be the case with startups. Stakeholder engagement is the key, and collaboration-based outcomes are frequently effective, not hindering innovation but enabling it.

David Dzumba of Microsoft provided an industry perspective. He noted that Microsoft had objectives that included: (1) weaving accessibility into the fabric of the company; (2) hiring people with disabilities; (3) creating inclusive marketing materials and awarding people with accessibility action badges; (4) taking accessibility and running it like a business; (5) implement majority models, and leverage digital accessibility; (6) increasing representation of people with disabilities; (7) investing in strategies which build momentum; (8) embracing standards which help with scaling up and focusing on training and communications mechanisms; (9) procurement partnering with suppliers; (10) embedding accessibility in planning as an innovation; and (10) effectively telling accessibility stories.

During the question-and-answer portion, one participant asked, "What role should the city, state, and federal government play in facilitating collaboration between industry-government?" The panelists felt that it must be a collaborative process. One example of successful collaboration discussed was the Emergency

Access Advisory Committee's national survey on how people connect to emergency 911 services. One of the findings was that most people wanted to call 911 directly instead of going through a third party. As a result, EAAC made several recommendations to achieve direct access, including TTY transition to text-to-911, video-calling and communicate directly with 911, and functional requirements on using 911 using captioning services. The recommendations in 2012 were remarkable and were used repeatedly in accessible emergency communications rulemakings, including in the real-time-text proceeding.

Another audience concern noted that startups have accessibility requirement exemptions. The panelists were then asked do they think we [the country] need more legislation that covers startups. The response from the consumer perspective was yes. While many companies have volunteered to enact recommendations, others will only comply if the public applies pressure. From the industry perspective, concerns about mandates noted they often tend to focus on the minimum compliance standards. The panelists were then asked what accessibility efforts is the FCC planning to embrace? As represented on the panel, the consumer perspective is interested in RTT and issues with the CVAA regulations' exemptions.

The audience's penultimate question asked, "Why is there so much change in businesses' attitudes towards accessibility?" The panelists answered that some of the reasons include: the empowerment of the disability community and the growing need for accessibility due to technology advancements; the greater ease in incorporating accessibility than was the case in the past; legislative and regulatory changes; more working groups focusing on communication modalities; new software allowing easier updates; and permanently embedded accessibility features with minimal disruptions. The final question was, "What is the best way for people with disabilities to get the government to listen and resolve our issues?" The panelists suggest engaging with state commissions on disabilities, the mayoral offices on disabilities, local government agencies, and non-profit national organizations.

Overall, the first day of the SOT Forum provided a rich conversation between the panelists and the audience.

Day Two

The second day of the Forum began with highlights of selected papers from Wireless RERC researchers that addressed concepts such as social connectedness, the use of personas, and the role of robots and theatre. Dr. Claire Donehower highlighted research findings from the Facilitating Social Connectedness project. Donehower identified key focus group themes from their research with people with intellectual and developmental disabilities. These focus group themes included: the need for usable hardware and software, financial concerns over the cost of these needed technologies, the presence (or absence) of accessibility features, connectivity barriers, and concerns or fears about connectivity. Additionally, she noted concerns about devices breaking or being too fragile, safety concerns, inappropriate online interactions, not excluding the importance of outcomes of social connectivity, and reasons for connecting socially, such as isolation and desire for community. Jump to the full paper: The Impact of Wireless Technologies on the Social and Vocational Outcomes of Individuals with Intellectual and Developmental Disabilities.

Dr. Julienne Greer discussed the innovative research conducted by an interdisciplinary team at the University of Texas Arlington into the linkages between theatre and social robots and why it is so important for the robots to be engaging, authentic, and communicative for interacting with humans. These insights led to the exploration of interesting and unique characteristics such as having the robot's voice reflective of a peer relationship rather than an authoritative relationship. Jump to the full paper: Theatre and Robots - Envisioning Interdisciplinary Collaborations Beyond the Stage

Researcher Sarah Farmer discussed the application of *persona* tools for technology policy design, especially to protect the privacy of any one individual and foster empathy for the target population. She observed that personas could be used to kickstart the conversation between stakeholders and policymakers so that feedback that is most useful can better inform those most affected by the policies being created. Jump to the full paper: Inclusivity, Usability, and the Application of Personas for Technology Policy Design

The Perspectives Panel consisted of a Wireless RERC Advisory Board member, an industry executive, and a university professor who have been involved with the growth and innovation of the Wireless RERC projects for more than a decade. They were tasked with sharing their observations and providing key takeaways and recommendations on future directions for implementing wireless technology strategies. David Dougall, Avonne Bell, and Dr. DeeDee Bennett Gayle noted the rapidly evolving nature of wireless technologies over the last five years and the implications of this field's growth for people with disabilities. In particular, they observed that other sessions during the Forum also noted that consumers with disabilities were avid users of newer connected technologies such as Siri, Alexa, and Google Home, which greatly increased their independence and quality of life.

Ms. Bell described how the last several decades had seen a substantial increase in research and development of accessible wireless technologies and services, particularly recognizing the importance of incorporating features that enhance the customer experience and increase usability. In the past, consumers with disabilities had to rely on "fixed" adaptations and assistive technologies. More recently, industry was building upon the benefits of designing accessible features from the beginning of the development cycle by engaging with the disability community, which has led to more integrated tools.

Moreover, it was noted, continued advancements would result from the coordination and cooperation of industry, advocacy, and research communities. It was stated that many companies are new to accessibility and regulations. Outreach efforts, workshops, and conferences like the SoT are essential avenues for companies to present their technologies to various users and get inclusive design feedback.

The panelists further considered how hardware [like smartphones] can increase the safety of people with disabilities during emergency preparedness and response, and these technologies can increase the possibility that localities use emergency alerts and other wireless communication capabilities. Dr. Bennett noted that some localities are more innovative in their adoption, for instance, using wireless emergency alerts (WEA) to alert people about public safety issues like COVID, which may be helpful to some people with disabilities. Nonetheless, it was noted that the value of alerts could increase if barriers to receiving these public safety messages such as undefined acronyms, abbreviations, unfamiliar terminology, and low usability of WEA messages were diminished.

Mr. Dougall noted that to some extent, we have come to "over-rely" on new technologies, which provides an opportunity for hackers and criminal activity. Privacy is increasingly a social concern for all users, and people with disabilities are just as concerned with privacy issues. While the COVID pandemic has required a good deal of adaptability in the use of information technologies, it has also (as evidenced by the activities of the Wireless RERC) has provided an opportunity to reflect on and create new approaches to these concerns. Rather than just asking what we sacrificed to allow remote work and activities, these social changes may represent possibilities to re-structure a range of social and economic activities. For some people with disabilities, the rapid adoption of remote, telework, and work-from-home approaches has been a game-changer by allowing participation in a way unlike before. However, will a return to in-person communications reduce the opportunities for people with disabilities (e.g., employment, education)? Alternatively, given that remote work has been a long-time accommodation for people with disabilities, will their experience help inform how society will incorporate these benefits for all workers?

As the conversation continued, Dougall suggested that smartphones are an example of accessible technologies being integrated into in-person settings. The evolution of technologies dramatically increased access for people with disabilities. For instance, people with disabilities can use connected technologies such as telepresence robots and multimodal communication to enhance training or support sessions or use smartphones as ancillary controllers. He restated the statistics that suggest a higher use of smartphones by people with disabilities than the general public, indicating that smartphones' accessibility features aid in daily functions such as hearing aid compatibility, closed captioning, and integrated accessibility features. Moreover, the increased bandwidth of 5G technologies can enhance the ability of people with disabilities to transfer to and personalize other settings and applications such as vehicles, smart cities, and industrial applications.

During the Q&A, the discussion centered on how to drive change. The recommended course of action included increasing awareness of accessibility via a top-down approach with executives, staff, and the education of students, noting there must be a connection between accessible technologies and their broader applications, such as in hospitals, museums, and supermarkets. Finally, the dialog considered the importance of Environmental Social and Governance (ESG) or the social responsibility of inclusivity. For example, market research firms ask about diversity and inclusion (D&I) programs, but people with disabilities are often omitted from D&I initiatives. Therefore, when companies measure their success in inclusivity, it is usually marked by predetermined indicators, which further highlights the importance of integrating people with disabilities in the D&I conversation long before products are released to the market.

Overall, the panel conducted a robust conversation that underscored the significant changes that had occurred not only in the underlying wireless technologies in recent years but also in available applications for users with disabilities. Perhaps the most important change went beyond the research and development of wireless technologies and services – the "normalization" and recognition of the importance of incorporating features that enhance the customer experience and increase usability. This change in awareness extended beyond designers and developers to include carriers, as well as governments and large institutions. The bottom line was that with continued coordination and cooperation of industry, advocacy, and research communities, end users would see more innovative, accessible, and inclusive connected technologies.

The Keynote-themed session - "The Best Way to Predict the Future is to Invent It," was facilitated by Dr. Helena Mitchell. The following questions guided the panel discussion:

1. *What are the issues that researchers, technologists, and stakeholders believe need attention now?*

Dr. Brad Fain kicked off the conversation by discussing research conducted roughly a decade ago on mobile device features that people with disabilities desired. The findings suggested that they desired three things: long battery life, a strong signal, and device affordability. Dr. Fain observed that it should be no surprise that people with disabilities desired the same features that many non-disabled mobile users also wanted. Moving to the present day, he noted there is still a need for mobile devices that meet these criteria. The expanded expectations of mobile devices are that they can appropriately deliver emergency information, which has changed in light of the pandemic. He stated that there is a need to focus on coordinating emergency responses, starting at its root, providing access to emergency information in mobile devices to allow first responders to disseminate information and more effectively coordinate communications. This requires stakeholder engagement and a focus on accessibility topics, including with vendors who provide the networking and the hardware to be truly effective. It's also working with the people who are generating the databases that will feed into these channels.

Kay Chiodo maintained that the most salient issue is education for the general population. The COVID-19 response highlighted that social media is a great tool, but for people who depend on ASL—social media is not always helpful and being prepared for an emergency requires access to information. The COVID-19 pandemic brought to light the fact that there is insufficient national and mainstream attention given to people who rely on ASL. She stated that more attention needs to be paid to developing accessible media and web services. While basic ASL services have been in place, it comes down to emergency managers' implementation of communication channels based on the understanding that all of their communities must have access to governmental communications.

2. *What are the remaining challenges/opportunities for the future?*

Advisory Board member Joan Durocher identified a significant opportunity for the future could be a "Technology Bill of Rights," which would be enshrined as part of all newly developed laws and retroactively apply to existing laws. Paul Schroeder stated that a challenge for the future is providing mobile equipment accessible to people with disabilities. He noted that it is purported to be a simple solution, a program (like the Lifeline Program), yet it is a challenge in practice. Schroeder noted that devices *and* connectivity remain as challenges. He provided an example of how accessible the world becomes when people with disabilities have access to mobile equipment – the example is AIRA, which has a level of free service. AIRA Tech Corp is a technology company based in San Diego, using technology to connect people who are blind or have low vision with real, highly trained professionals who provide visual information on demand. That said, you have to have access to the technology yourself. Therefore, there is a need for an equipment distribution program that includes innovative access services like AIRA. Finally, Schroeder argues that privacy and security is a big deal for people with disabilities, and we need to tackle those challenges.

Dr. Mitchell then posed the question: "what do you see as the next frontier for reasonable accommodations?" Joan stated that we have to start moving into "unreasonable accommodations" or accepting that accommodations can be expensive. We must be groundbreaking on what we consider 'reasonable.' But of course, this raises the questions: How do we fund them? How do we make that happen? She provides the example of a high-level executive who needs a personal assistant to aid them in daily tasks – which can cost thousands a year. Schroeder suggests a lot more aggressive tax incentives to address the financial component.

3. What are the next steps to help define what lies ahead?

It is really important to understand the role of grant programs. This is critical to creating more programs that provide services for people with disabilities by providing funding avenues for the groups that need it the most. Grants are a type of contract between grantee institutions and federal agencies. Make sure your grant proposal includes terms that support your approach to technology, development transfer, and adoption

CHAPTER 1: POLICY & OUTREACH

Access, Inclusion, and Innovation in Wireless Communications Technologies: Before and After the Twenty-First Century Communications and Video Accessibility Act

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Abstract

Most Americans have become accustomed to having instant and wireless access to communication, information, and video programming in their homes, offices, and on the go. One need look no further for ways that modern, accessible wireless technologies have altered our lives than to consider our overwhelming reliance on these tools to perform even the most basic of daily tasks during the COVID-19 pandemic. When these technologies are not accessible to people with disabilities, the consequences can be dire – eliminating the ability to shop online, attend school, stay employed, get healthcare, and avoid social isolation. The 21st Century Communications and Video Accessibility Act (CVAA) and various federal accessibility laws that preceded it made significant inroads toward safeguarding access to current digital and wireless innovations. In addition, changing corporate attitudes have, in some instances, self-propelled improvements in accessibility beyond the CVAA's requirements – to afford

unprecedented access by millions of Americans to wireless services. As new information and communication technology (ICT) industries promise transformative levels of functionality and connectivity, they and the federal policies that guide them need to continue ensuring the full digital inclusion of people with disabilities.

Keywords: Information and Communication Technology (ICT), Accessibility, wireless services, connectivity, innovation, inclusion, wireless communication technologies

Inclusion: Historical Efforts to Safeguard the Accessibility of 20th Century Technologies

Our phones, tablets, and computers enable us to telework, learn, shop, play, and even visit our doctors. Fortunately, many of these technologies and services are now accessible to people with disabilities, but this did not happen without considerable efforts on the part of the disability community.

Although generally, competitive market pressures are enough to incentivize companies to develop effective technology solutions, for much of the 20th Century, market forces were not sufficient to eliminate access barriers confronting people with disabilities. The reasons for this were several. Collectively, people with disabilities make up a substantial portion of the population. However, each disability group (e.g., people who are blind, people who are deaf, etc.) is much smaller, has its own unique needs, and often has been unable to exert sufficient market pressure to motivate companies to address its needs. In addition, higher unemployment within these communities means lower incomes and consequently fewer dollars to influence companies. This is exacerbated by the challenges of finding, affording, and configuring adaptive equipment often needed for off-the-shelf devices that lack built-in access. Consequently, for much of the 20th Century, people with disabilities were excluded when new communication technologies were introduced to the general public and only succeeded in securing such access after long regulatory battles. For example, it took decades after the introduction of the telephone and television before Congress adopted federal mandates in the 1980s and 1990s requiring hearing aid compatibility,[1] telecommunications relay services,[2] accessible telecommunications products and services,[3] and closed captions.[4]

While the policy changes put into effect by these federal mandates reduced obstacles for previously underserved disability communities, the explosion of digital e-communications and information services occurring around the turn of the Century threatened to again leave people with disabilities behind. These earlier statutes simply

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[1] Telecommunications for the Disabled Act (TDA) of 1982, P.L. 97-410, codified at 47 U.S.C. §610; Hearing Aid Compatibility Act of 1988, P.L. 100-394, codified at 47 U.S.C. §610.
[2] Title IV of the Americans with Disabilities Act, P.L. 101-336, codified at 47 U.S.C. §225.
[3] Section 255 of the Communications Act, P.L. 104-104, codified at 47 U.S.C. §255.
[4] Section 713 of the Communications Act, P.L. 104-104, codified at 47 U.S.C. §613 (requiring TV closed captioning); Television Decoder Circuitry Act, 47 *U.S.C.* §§ 303(u) and 330(b) (requiring built-in captioning decoder circuitry on television apparatus with screens of at least 13 inches).

were proving unable to keep up with the sophisticated advancements in wireless, digital, and web-based innovations evolving in full force. The failure of some industries to incorporate accessibility solutions before rolling out their new technologies began to cause considerable hardship for people with disabilities. For example, flat screens with dynamic buttons were making wireless phones unusable for people who were blind and visually impaired. And the failure to weave closed captioning capabilities into digital television systems when first designed began causing people who were deaf and hard of hearing to lose television access – ironically, just a few years after this community finally had begun to secure such access through new federal laws and policies.[5]

In addition, it took around ten years after most Americans started enjoying feature-rich digital cellphones in the mid-1990s before hearing aid users could effectively use these devices. The problem was a technical one that the wireless industry had not addressed at the outset of developing these products. Although some analog cellular phones worked well enough with hearing aids, many digital wireless technologies emitted electromagnetic waves that produced annoying interference for hearing aid wearers, negating the benefits obtained through inductive and acoustic coupling. Unfortunately, the Federal Communications Commission (FCC), which had the authority to mandate hearing aid access under the Hearing Aid Compatibility Act of 1988,[6] opted first to allow the wireless industry to do so voluntarily and at its own pace. The result was a long delay in accessibility that took a heavy toll; by the turn of the Century, more than 40 percent of the American public were using digital technologies, with an additional 20 percent making the switch each year.[7] The resulting lack of digital access left clunky and expensive analog devices as the only effective mobile communication option for people who were hard of hearing. When the Commission finally addressed this deficiency with new regulations in 2003, it adopted benchmarks that did not start for another two years and only covered a percentage of wireless handsets.[8] By then, 88 percent of wireless phone users in the United States were digital wireless subscribers.[9]

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[5] 47 U.S.C. §613; 47 C.F.R. Part 79.

[6] This 1988 statute amended an earlier hearing aid compatibility law by expanding the categories of covered landline phones, adding cordless phones to scope of mandated phones, and authorizing the FCC to cover wireless phones.

[7] SHHH (2000, October 7). Comments submitted in response to the Wireless Access Coalition Request to Reopen the Petition for Rulemaking, RM 8685, page 5; cited in Peltz Strauss, K. (2006). *A New Civil* Right*: Telecommunications Equality for Deaf and Hard of Hearing Americans,* page 331. Washington DC: Gallaudet University Press, ISBN 1-56368-291-5.

[8] Federal Communications Commission (2003, August 14). *Section 68.4 (a) of the Commission's Rules Governing Hearing-Aid Compatible Telephones*, Report and Order WT Docket. 01-309, FCC 03-168. https://docs.fcc.gov/public/attachments/FCC-03-168A1.pdf; 47 C.F.R. § 20.19.

[9] Peltz Strauss, K. (2006), page 336.

Innovation: The CVAA's Response to Ensuring Access to Advanced Technologies

In 2007, seeking to avoid more accessibility setbacks, consumers with disabilities returned to Congress, this time joining forces under a newly created Coalition of Organizations for Accessible Technology (COAT). Members of COAT had a single mission: to ensure that people with disabilities would have full and equal access to the power and breadth of new wireless and digital interconnected technologies that were destined to take the place of their 20th-century predecessors. Although the communication accessibility laws of the 1980s and 1990s had made substantial progress in breaking down barriers, these laws applied to legacy, public switched networks rather than the more versatile Internet-based technologies and wireless devices that began to populate retail shelves, including cellphones, tablets, and laptops. As an expanding number of products and services made this transition, access became increasingly critical to allow adults and children with disabilities to remain integrated, independent, and self-sufficient. By the end of 2008, communication over wireless phones had become indispensable to a majority of Americans.[10] In addition, approximately 17.6 million Americans had started using their shiny new smartphones to watch video programs, up from 11.2 million just one year earlier.[11] Yet the American Foundation of the Blind described access to mobile handsets as "bleak" for people who were blind and visually impaired; few phones offered any auditory feedback for their visual displays, screen magnification, or tactile controls.[12] Similar accessibility gaps were widening the digital divide for Americans with other types of disabilities.

An interest in closing these widening gaps, along with a desire to bring disability protections in line with evolving technologies – produced a groundswell of consumer interest in securing regulatory protections, as reflected in COAT's exponential growth. Initially founded with only ten national disability organizations, COAT grew to 60 organizations within its first month and ultimately secured the membership of over 300 national, regional and community-based groups. It took three years and considerable negotiations between consumer and industry stakeholders for the coalition to achieve its objective, but on October 8, 2010, President Obama signed the CVAA into law, establishing landmark legislation with sweeping mandates that updated and applied the critical safeguards of earlier accessibility laws to the onslaught of emerging technologies.[13] Upon the law's enactment, Congress explained that although the communications marketplace had undergone a "fundamental transformation" since the

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[10] Pew Research Center, (2019, June 12). *Internet & Technology Mobile Fact Sheet*. Accessed on August 27, 2020, https://www.pewresearch.org/internet/fact-sheet/mobile/; Statista (2011, September 8). *Mobile wireless penetration in Northern America from 2008-2020*. https://www.statista.com/statistics/232665/mobile-wireless-penetration-in-northern-america.

[11] Stelter, B. (2010, May 3). *It's the Show, Not the Screen*, New York Times, B1.

[12] Telecommunications Daily (2010, September 17). *Disability Community Gives Industry Low Marks for Accessible Devices*.

[13] P.L. 111-260, P.L. 111-265—technical amendments (Oct 8, 2010), codified in various sections of Title 47 of the United States Code.

mid-1990s, people with disabilities often had not been able to share in its benefits.[14] To remedy this failure, the Act imposed swift and rigorous deadlines on the FCC to oversee the Act's implementation. From 2010-2018, the FCC accepted this challenge, producing an extensive compilation of rules requiring access to the vast array of communications and video programming technologies that were rapidly changing the technological landscape.

CVAA: Communications Access Mandates

The FCC's efforts to implement the CVAA began with the creation of the National Deaf-Blind Equipment Distribution Program, which allows for up to $10 million to be used annually from the agency's Telecommunications Relay Services Interstate Fund for the distribution of wireless and other communications equipment to low-income people who have combined hearing and vision loss.[15] Commonly known as "iCanConnect," this program allows local entities certified by the FCC to provide both off-the-shelf and adaptive ICT, supplying these individuals with the tools they need to get jobs, educational instruction, and skills training, and to stay connected with family, friends, and colleagues.[16] To enhance the program's effectiveness, FCC rules also permit a portion of its funding to be used for program outreach, individual skills assessments, and personalized equipment training.[17]

The Commission next tackled the CVAA's comprehensive requirements for access to advanced communication services (ACS) and end-user devices used to access these services.[18] Congress defined ACS broadly to include interconnected and non-interconnected voice over Internet protocol (VoIP) service, electronic messaging,

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[14] U.S. Senate (2010, December 22). Report No. 111-386 of the Committee on Commerce, Science and Transportation on S. 3304, Twenty-First Communications and Video Accessibility Act of 2010, page 1. https://www.congress.gov/congressional-report/111th-congress/senate-report/386/1?q=%7B%22search%22%3A%22communications+and+video+accessibility%22%7D; U.S. House of Representatives (2010, July 26). Report No. 111-563 of the Committee on Energy and Commerce on H.R. 3101, Twenty-First Communications and Video Accessibility Act of 2010, page 19. https://www.congress.gov/congressional-report/111th-congress/house-report/563/1?q=%7B%22search%22%3A%22communications+and+video+accessibility%22%7D.

[15] Section 105 of the CVAA, codified at 47 U.S.C. § 620; http://www.icanconnect.org/.

[16] Although iCanConnect has been contributing to the societal integration of thousands of people who are DeafBlind, some consumer groups complain that this program's statutory income limitation unfairly requires DeafBlind individuals to choose between equipment access and job opportunities.

[17] Federal Communications Commission (2016, August 4). *Implementation of the Twenty-First Century Communications and Video Accessibility Act of 2010, Section 105, Relay Services for Deaf-Blind Individuals,* Report and Order, CG Docket 10-21, FCC 16-101. https://docs.fcc.gov/public/attachments/FCC-16-101A1.pdf; 47 C.F.R. § 64.610 *et seq;*

[18] 47 U.S.C. § 617. Federal Communications Commission (2011). *Implementation of Sections 716 and 717 of the Communications Act of 1934, as Enacted by the Twenty-First Century Communications and Video Accessibility Act of 2010; Amendments to the Commission's Rules Implementing Sections 255 and 251(a)(2) of the Communications Act of 1934, as Enacted by the Telecommunications Act of 1996*, Report and Order and Further Notice of Proposed Rulemaking, CG Docket 10-213; WT Docket 96-198; CG Docket 10-145, FCC 11-151. https://docs.fcc.gov/public/attachments/FCC-11-151A1.pdf; 47 C.F.R. Part 14.

such as email, SMS text messaging, instant messaging, chat functions, and interoperable video conferencing service.[19] The scope of the ACS mandates is far-reaching – extending beyond traditional telephone-like services to communications between individuals that take place over social media platforms, gaming systems, and even autonomous cars. ACS providers and manufacturers of smartphones, tablets, computers, and similar devices used to access ACS must make their offerings accessible by either building access into their products or using third-party solutions or peripheral devices at nominal cost to the user. This flexibility departs from the CVAA's predecessor, Section 255 of the Communications Act, which required every telecommunications product to have built-in accessibility for every type of disability. Many companies found compliance with that strict obligation quite challenging in the late 1990s, before software advancements and the ability to customize individual devices made it easier to build universally accessible devices.

Also, a departure from Section 255 is the standard used in the CVAA to determine whether a company is obligated to provide accessibility features in its products or services. Section 255 requires covered entities to incorporate access only if it is "readily achievable" to do so, *i.e.*, "easily accomplishable without much difficulty or expense."[20] Many have criticized this standard as giving too much leeway to industry and for imposing on consumers the burden of proving that inclusion of an accessible feature would not be arduous. By contrast, the CVAA requires companies to provide access so long as this is "achievable," that is if they can do so "with reasonable effort or expense." The new standard shifts the burden to covered entities to demonstrate why it would *not* be achievable for them to provide access and makes it harder to be excused from the law's obligations.[21] Both standards, however, generally employ the same factors, directing covered entities to consider the type of access that needs to be included and to weigh the costs and burdens associated with such access against the technical and economic impact on a company and its product or service offering. By way of example, most companies have found it achievable to make text menus on their mobile devices audible to people who are blind through text-to-speech.

When it is not achievable to make an offering accessible, covered products and services must be compatible with assistive equipment commonly used by people with disabilities.[22] In the above example, if it is not achievable to make a text-based function accessible to someone who is DeafBlind, making it compatible with a refreshable Braille reader might be sufficient to meet the consumer's accessibility needs. In considering whether a company's CVAA compliance is achievable, the FCC may also consider the extent to which the company offers other accessible products with varying degrees of

[19] VoIP services include services that enable people to make *or* receive calls over the Internet and the telephone system or enable real-time voice communications solely over the Internet. Electronic messaging services enable real-time or near real-time text messages between individuals over communications networks. Interoperable video conferencing services include real-time video communications, including audio, to enable users to share information.
[20] 47 U.S.C. §255(b).
[21] 47 U.S.C. § 617(g).
[22] 47 U.S.C. § 617(c).

functionality and features and at different price points.[23] Finally, like Section 255, the CVAA requires ACS companies to ensure that their products and services are "usable" by consumers through accessible user guides, bills, technical support and call centers.[24]

It is important to note that the ACS obligations reach only functions that enable communication services between individuals; they stop short of requiring access to other information-type services, even on multi-function devices, such as iPads or computers. Nevertheless, a separate section of the CVAA requires companies to make the Internet browsers on their mobile devices accessible to and usable by people who are blind and visually impaired for all purposes (not just communications) unless not achievable.[25] In this manner, the Act guarantees access to the "virtual ramp" that escorts these users to websites and requires that such persons be able to manipulate a device's flat-screen menus to get to those sites through interfacing features such as zoom, refresh, and forward.[26] While industry again has the option to either build in this capability or comply by using third-party solutions at nominal cost to the purchaser, to date, it appears that most, if not all, companies are opting to incorporate accessibility features directly into their devices' internal functions.

In the CVAA, Congress also took the opportunity to revisit the hearing aid compatibility mandates, this time to ensure that these mandates would apply to telephones used with ACS. The FCC responded with various actions to expand its rules to frequency bands and air interface technologies used in evolving digital technologies. For example, the Commission updated the technical standards by which wireless manufacturers and service providers evaluate their phones for inductive and acoustic coupling with hearing aids,[27] expanded coverage of the FCC's rules from only a subset of commercial mobile wireless networks to nearly all categories of mobile telephone services used by the public,[28] increased the percentage of hearing aid

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[23] 47 U.S.C. § 617(g)(4).
[24] 47 C.F.R. § 14.20(d).
[25] 47 U.S.C. § 618.
[26] Federal Communications Commission (2013, April 26). *Implementation of Sections 716 and 717 of the Communications Act of 1934, as Enacted by the Twenty-First Century Communications and Video Accessibility Act of 2010; Amendments to the Commission's Rules Implementing Sections 255 and 251(a)(2) of the Communications Act of 1934, as Enacted by the Telecommunications Act of 1996*, *In the Matter of Accessible Mobile Phone Options for People who are Blind, Deaf-Blind, or Have Low Vision*, Second Report and Order, CG Docket 10-213; WT Docket 96-198; CG Docket 10-145, FCC 13-57. https://docs.fcc.gov/public/attachments/FCC-13-57A1.pdf; 47 C.F.R. § 14.60 *et seq*.
[27] Section 102 of the CVAA, codified at 47 U.S.C. § 610; Federal Communications Commission (2012). *Amendment of the Commission's Rules Governing Hearing Aid-Compatible Mobile Handsets*, Third Report and Order, WT Docket 07-250, DA 12-550 (WTB/OET). https://docs.fcc.gov/public/attachments/DA-12-550A1.pdf; Federal Communications Commission (2020). Federal Communications Commission (2021, February 16). *Amendment of the Commission's Rules Governing Standards for Hearing Aid-Compatible Handsets*, WT Docket 20-3, FCC 21-28. https://docs.fcc.gov/public/attachments/FCC-21-28A1.pdf.
[28] Federal Communications Commission (2015, November 20). *Improvements to Benchmarks and Related Requirements Governing Hearing Aid-Compatible Mobile Handsets, Amendment of the*

compatible phones that wireless providers and manufacturers must make available,[29] and added a requirement for wireless handsets to include volume control suitable for consumers with hearing loss.[30] Additionally, to take advantage of modern advances in wireless mobile technologies that have reduced electromagnetic interference for mobile air interfaces, the FCC is exploring whether to require hearing aid compatibility on 100% of all mobile phones by 2024. At present, CTIA-The Wireless Association reports that 90 percent of wireless handsets are hearing aid compatible,[31] and a consumer-industry HAC Task Force is exploring the achievability of crossing this finish line.[32] After receiving the Task Force's recommendations, the Commission will consider the impact that a 100 percent hearing aid compatibility wireless mandate would have on both the costs and benefits to telephone users and on future technology.[33]

The communications section of the CVAA also gave the FCC authority to adopt rules, technical standards, protocols, and procedures to ensure access by people with disabilities to an Internet-protocol-enabled emergency 911 network.[34] In 2013, the FCC relied partly on this authority to adopt rules governing the carriage of text calls to 911 by wireless telephone carriers.[35] This was the first of many steps needed to ensure the accessibility of Next Generation 911 (NG-911) technologies, which will enable the sharing of text, photos, data, and videos in 911 emergencies. All of the major wireless carriers now have text-to-911 capability, but at this time, only approximately 20 percent of the nation's 6000 emergency call centers have the capacity to receive and handle such calls. Individuals can find out whether their local 911 center or public safety answering point (PSAP) is capable of receiving text messages by visiting the FCC's Text-to-911 Registry at https://www.fcc.gov/files/text-911-master-psap-registryxlsx. In 2021, the FCC again relied on the CVAA's emergency access directive to propose a requirement for the carriage of text calls to 988, the 3-digit dialing code that it had

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Commission's Rules Governing Hearing Aid-Compatible Mobile Handsets, Fourth Report and Order and Notice of Proposed Rulemaking, WT Docket 15-285, WT Docket 07-250, FCC 15-155. https://docs.fcc.gov/public/attachments/FCC-15-155A1.pdf.

[29] Federal Communications Commission (2016, August 5). *Improvements to Benchmarks and Related Requirements Governing Hearing Aid-Compatible Mobile Handsets*, Report and Order, WT Docket 15-285, FCC 16-103. https://docs.fcc.gov/public/attachments/FCC-16-103A1.pdf.

[30] Federal Communications Commission (2017, October 24). *Access to Telecommunication Equipment and Services by Persons with Disabilities, Amendment of the Commission's Rules Governing Hearing Aid-Compatible Mobile Handsets, Comment Sought on 2010 Review of Hearing Aid Compatibility Regulations,* Report and Order and Order on Reconsideration, CG Docket 13-46; WT Docket 07-250; WT Docket 10-254, FCC 17-135. https://docs.fcc.gov/public/attachments/FCC-17-135A1.pdf.

[31] Leggin, S. on behalf of CTIA-The Wireless Association (2020, April 14). Comments submitted in response to the Public Notice on the 2020 CVAA Biennial Report Tentative Findings [CG Docket No. 10-213]. Federal Communications Communication: Washington, D.C. https://ecfsapi.fcc.gov/file/104140307801766/200414%20CTIA%20Comments%20for%20CVAA%20Biennial%20Review%20-%20FINAL.pdf.

[32] ATIS, Hearing Aid Compatibility Task Force. https://hac.atis.org.

[33] Federal Communications Commission (2016), ¶¶ 34-47.

[34] Section 106(g) of the CVAA.

[35] Federal Communications Commission (2013, May 8). *Facilitating the Deployment of Text-to-911 and other Next Generation 911 Applications, Framework for Next Generation 911 Deployment*, PS Docket 11-153; PS Docket 10-255, FCC 13-64. https://docs.fcc.gov/public/attachments/FCC-13-64A1.pdf.

recently designated for accessing the National Suicide Prevention Lifeline. The Commission commented that taking this action would help increase the effectiveness of suicide prevention efforts for at-risk groups, including people who are deaf, hard of hearing, deafblind, or have speech disabilities. This proceeding is pending at the time this goes to print.[36]

In May of 2021, the FCC issued a Public Notice inviting consumer, industry, and other stakeholders to comment on the need for updates to any of the above CVAA rules, given changes in technology, industry practices, and consumer experiences during the intervening years. The feedback received, it said, would help determine the need for additional measures to fulfill the CVAA's goal of making communications services accessible for persons with disabilities.[37]

While not mandated by the CVAA, a discussion of federal policy on communications access would not be complete without mentioning the FCC's 2016 ruling to allow wireless service providers and equipment manufacturers to support real-time text transmissions in lieu of TTY communications over IP-based wireless voice networks.[38] Real-time text allows text to be transmitted to the receiving party as soon as it is generated (either by typing or speech-to-text), eliciting a natural flow of conversation between the parties. This technology, which also allows voice to be sent simultaneously with the text, requires no specialized end-user equipment and is superior in terms of speed, latency, reliability, and ease of use to TTY technology. In particular, RTT is useful in emergencies, when a person in need of immediate assistance may not have the time or ability to press the "send" or "enter" button typically required for other types of texting. However, like other forms of text, this technology has yet to be adopted by most of our country's public 911 safety answering points. In March of 2021, the FCC added to its Text-to-911 Registry the list of PSAPs nationwide that can receive RTT messages.[39]

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[36] Federal Communications Commission (2021). Implementation of the National Suicide Hotline Improvement Act of 2018, WC Docket 18-336, FCC 21-47. https://docs.fcc.gov/public/attachments/FCC-21-47A1.pdf.

[37] Federal Communications Commission (2021, April 7). Consumer and Governmental Affairs, Media, and Wireless Telecommunications Bureaus Seek Update on Commission's Fulfillment of the Twenty-First Century Communications and Video Accessibility Act, GN Docket 21-140, DA 21-405. https://docs.fcc.gov/public/attachments/DA-21-405A1.pdf.

[38] Federal Communications Commission (2016, December 15). *Transition from TTY to Real-Time Text Technology, Petition for Rulemaking to Update the Commission's Rules for Access to Support the Transition from TTY to Real-Time Tet Technology, and Petition for Waiver of Rules Requiring Support of TTY Technology*, Report and Order and Further Notice of Proposed Rulemaking, CG Docket 16-145, GN Docket 15-178, FCC 16-169. https://docs.fcc.gov/public/attachments/FCC-16-169A1.pdf

[39] Federal Communications Commission (2021, March 12). Public Safety and Homeland Security Bureau Announces Availability of Updated PSAP Text-to-911 Certification and Readiness Form and Registry to Facilitate Real-Time Text, PS Dockets 10-255 and 11-153, CG Docket 16-145, GN Docket 15-178, DA 21-301. https://docs.fcc.gov/public/attachments/DA-21-301A1.pdf.

CVAA: Video Programming Mandates

During the COVID-19 pandemic, many of us have turned to television programming on both traditional platforms and streaming services as our primary source of entertainment – an activity that is safe to do from the comfort of our homes. The CVAA contains wide-ranging provisions that significantly expand upon the scope of earlier television safeguards for people with disabilities. Chief among these is a grant of authority to the FCC to require audio description, a feature that provides television access for people who are blind or visually impaired.[40] Audio description inserts narratives about a program's visual content into the natural pauses of a program's audio; the narratives are then transmitted to viewers through a device's secondary audio stream. Although the FCC attempted to require some audio description through mandates adopted in 2000,[41] this effort failed when, just two years later, a federal court overturned the Commission's action for lack of sufficient authority.[42] Utilizing its new authority under the CVAA, in 2012, the FCC reinstated its original rules, requiring description on 50 hours of programming each calendar quarter (about four hours per week) in the top 25 viewing markets on the four major broadcast networks (ABC, NBC, CBS, and Fox) and the top five national nonbroadcast networks (determined by ratings every three years).[43] A few years later, after fulfilling its statutory mandate to conduct a public inquiry on the availability, use, and benefits of audio description, the FCC increased the amount of mandated description and the number of covered markets to current totals of approximately seven hours of audio description per week on covered channels in 60 markets.[44] In 2021, after conducting a second inquiry, the FCC expanded even further the number of designated markets required to transmit description to an additional ten localities each year for the next four years, to reach a total of 100 markets in four years.[45] After that, the CVAA authorizes the FCC to continue phasing in an additional ten markets each year until all markets eventually are covered by the audio description rules. While the number of television programs containing audio descriptions still falls far below those with closed captions, this accessibility feature is growing in popularity and use and is now available on several video streaming services in addition to more traditional television platforms.

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[40] Section 202 of the CVAA, codified at 47 U.S.C. § 613(f).

[41] Federal Communications Commission (2000, July 21). *Implementation of Video Description of Video Programming*, Report and Order, MB Docket 99-339, FCC 00-258. https://docs.fcc.gov/public/attachments/FCC-00-258A1.pdf.

[42] Motion Picture Ass'n of Am., Inc. v. FCC, 309 F.3d 796 (D.C. Cir. 2002).

[43] Federal Communications Commission (2011, August 24). *Video Description: Implementation of the Twenty-First Century Communications and Video Accessibility Act of 2010*, Report and Order, MB Docket 11-43, FCC 11-126. https://docs.fcc.gov/public/attachments/FCC-11-126A1.pdf ; 47 CFR § 79.3.

[44] Federal Communications Commission (2017, July 11 *Video Description: Implementation of the Twenty-First Century Communications and Video Accessibility Act of 2010*, Report and Order, MB Docket 11-43, FCC 17-88. https://docs.fcc.gov/public/attachments/FCC-17-88A1.pdf.

[45] Federal Communications Commission (2020, October 27). *Video Description: Implementation of the Twenty-First Century Communications and Video Accessibility Act of 2010*, Report and Order, MB Docket 11-43, FCC 20-155. https://docs.fcc.gov/public/attachments/FCC-20-155A1.pdf.

The CVAA also mandates an aural equivalent for emergency information shown visually on television. Prior to the CVAA, FCC rules already had required visual access to emergency information for people who are deaf and hard of hearing as well as aural access for people who are blind and visually impaired, but the latter only when such information appeared as part of a newscast. The new law covers emergency programming even when it interrupts regularly scheduled television shows and adds new requirements to ensure the pass-through of this information to viewers.[46]

To ensure that people with disabilities can access television services, the CVAA imposes various obligations on manufacturers of video devices. If achievable and technically feasible, video devices of any size that receive, playback, or record video programming simultaneously with sound must decode and make secondary audio streams available to provide audio description and aural access to emergency information and have built-in circuitry to display closed captions, the latter a considerable expansion of the Television Decoder Circuitry Act's thirteen-inch screen limitation.[47] Video device manufacturers also must ensure that their devices have an easy way to activate each of these accessibility features on television sets and navigation devices; features to enable people who are blind and visually impaired to access the device's user interfaces, including visual indicators (if achievable); and, if requested, aural access to on-screen text menus and guides used for the selection and display of TV programs (if achievable).[48] These new mandates have made it possible for Americans with disabilities to watch television programming from a wide variety of wired and wireless devices.

Last, the CVAA requires closed captions on full-length video programs and clips of these shows when they are distributed via Internet protocol if such programs have been shown on television.[49] This measure is critical to ensuring that people who are deaf and hard of hearing continue to have television access as these programs migrate to online platforms. Although the CVAA stops short of reaching programming that originates on the Internet, other laws, such as the ADA, have been used by advocates to convince streaming services, such as Netflix, Amazon Prime, and Hulu networks, to make their programs accessible through captioning and in some cases, audio description.

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[46] Section 203 of the CVAA, amending 47 U.S.C. §§ 303(u) and 330(b) and adding 47 U.S.C. §§ 303(z), implemented at 47 C.F.R. §§ 79.100-79.106 (requiring video apparatus and associated interconnection mechanisms, such as cables, to pass through and display this emergency information).

[47] Section 203 of the CVAA, amending 47 U.S.C. § 303(u).

[48] Sections 204 and 205 of the CVAA, adding 47 U.S.C. §§ 303(aa) and 303(bb), implemented at 47 CFR §§ 79.107-79.110; Federal Communications Commission (2013). *Accessibility of User Interfaces, and Video Programming Guides and Menus, Accessible Emergency Information, and Apparatus Requirements for Emergency Information and Video Description: Implementation of the Twenty-First Century Communications and Video Accessibility Act of 2010*, MB Docket 12-108, MB Docket 12-107, FCC 13-138. https://docs.fcc.gov/public/attachments/FCC-13-138A1.pdf.

[49] Section 202(b) of the CVAA, amending section 713 (c) of the Communications Act, 47 U.S.C. § 613.

CVAA Success: Innovation, Stakeholder Engagement, and Accountability

Since the passage of the CVAA, many ICT companies have embraced the opportunity to meet the accessibility challenges presented by the Act's mandates. As discussed below, gaps do remain, but in many respects, the CVAA has been more successful than many of its predecessors in achieving its mission of inclusion. Several major companies now have dedicated accessibility teams with defined missions to evaluate and integrate accessibility features early on and throughout their development processes – when it is efficient and achievable to do so.[50]

A study by the Rehabilitation Engineering Research Center for Wireless Inclusive Technologies (Wireless Inclusive RERC) affirms that recent years have witnessed significant improvements in the accessibility of advanced mobile communications technologies.[51] Likewise, CTIA-The Wireless Association has noted that in the decade since the passage of the CVAA, the wireless industry has delivered "countless innovations through mobile wireless services and devices," transforming the wireless experience for people with disabilities by meeting their varying needs.[52] Voice activation, audio input, magnifiers, hands-free settings, video calling capabilities, captioning and screen reader features, interface, and keyboard customization – all unimaginable when smartphones were first released – have become routine and integral features on a range of wireless devices. Just as importantly, changing corporate attitudes have resulted in a number of accessibility improvements to wireless products that fall outside the CVAA's coverage, such as non-ACS functions performed by intelligent virtual assistants. Taken together, these various efforts are affording unprecedented access by millions of Americans to all types of wireless and wireline communication and information services. In addition, some industries, initially hesitant to incorporate accessibility, have eased their opposition in recent years. A case in point is the gaming industry, which, in 2012, sought an eight-year waiver of the ACS rules for all gaming consoles, online gameplay services, and software. The FCC responded with a partial exemption for three years,[53] shrinking this to a single year for smaller industry segments in subsequent years. Though some consumers maintain that the industry still

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[50] For example, ACB has praised the integration of screen readers into Internet browsers by various manufacturers, noting that some of these browsers, such as Apple Safari and Google Chrome, allow for "a robust web experience" when navigating with Apple VoiceOver and Google Talk Back. Rachfal C. (2020, April 14).

[51] Mitchell, H. on behalf of the Wireless Inclusive RERC (2020, August 4). Comments submitted in response to the Public Notice on the 2020 CVAA Biennial Report Tentative Findings [CG Docket No. 10-213]. Federal Communications Communication: Washington, D.C. https://ecfsapi.fcc.gov/file/1080426285659/Aug%202020%20wRERC%20Comments-%20CVAA%20Preliminary%20Findings%20(Final).pdf.

[52] Leggin, S. (2020, April 14).

[53] Federal Communications Commission (2020, October 15). *Sections 716 and 717 of the Communications Act of 1934, as Enacted by the Twenty-First Century Communications and Video Accessibility Act of 2010, Entertainment Software Association, Petitions for Class Waivers of Section 716 and 717 of the Communications Act and Part 14 of the Commission's Rules Requiring Access to Advanced Communications Services and Equipment by People with Disabilities,* CG Docket 10-213, DA 12-1645. https://docs.fcc.gov/public/attachments/DA-12-1645A1.pdf .

has a long way to achieve full accessibility, over the past few years, many gaming companies have introduced novel accessibility solutions that have been welcomed by people with disabilities.[54]

It is noteworthy that the FCC received no court challenges to its extensive set of CVAA regulations. Likewise, over the past several years, the FCC's Disability Rights Office has successfully resolved all alleged violations of the CVAA's communications mandates through its "Request for Dispute Assistance" (RDA) program. This unique dispute resolution process requires consumers to bring concerns about potential violations to the FCC's Disability Rights Office before filing an informal complaint regarding an alleged accessibility breach.[55] DRO works with the consumer and company to reach a mutually agreeable resolution over a 30-day period, which can be extended in 30-day increments at the consumer's discretion. Only when this process is complete does the consumer have the right, if they remain dissatisfied, to file an informal complaint, which the FCC's Enforcement Bureau must then resolve within 180 days. Since it began, this mediation and negotiation process has negated the need for costly and adversarial confrontations that typically accompany complaints and litigation.

There appear to be at least three factors that have contributed to the successful implementation of the CVAA. First, since the Act's passage, major advances in communications and software technologies have made it far easier and less expensive than ever before to incorporate accessibility features into products and services through software modifications, enabling consumers with disabilities to customize their wireless devices to meet their distinct accessibility needs. Increased processing power, greater memory capacity, longer battery lives, and other technological advances also continue to facilitate access to new generations of products and services. This contrasts sharply with communication technologies built in the 20th Century when incorporating accessibility features often meant having to incur substantial costs and burdens associated with overcoming difficult technical challenges to modify or retrofit one-size-fits-all hardwired devices.

Second, from the start of its CVAA work, the FCC has collaborated closely with consumer and industry representatives to ensure that its rules would be equitable and

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[54] Mut, C. (2019, October 8). *Accessibility finally matters to the game industry – but it needs to do better/* GamesBeat - Venturebeat.com. https://venturebeat.com/2019/10/08/accessibility-finally-matters-to-the-game-industry-but-it-needs-to-do-better; Stoner, G. (2020, February 25). *How accessibility consultants are building a more inclusive video game industry behind the scenes,* Washington Post. https://www.washingtonpost.com/video-games/2020/02/25/how-accessibility-consultants-are-building-more-inclusive-video-game-industry-behind-scenes/; Kaika, E. on behalf of TDI et al. (2020, April 14). Comments submitted in response to the Public Notice on the 2020 CVAA Biennial Report Tentative Findings [CG Docket No. 10-213]. Federal Communications Communication: Washington, D.C. https://ecfsapi.fcc.gov/file/10415049237300/Comments%20for%202020%20CVAA%20Biennial%20Report.pdf. Comments by TDI et. al. were jointly filed by Telecommunications for the Deaf and Hard of Hearing, Inc., National Association of the Deaf, Deaf and Hard of Hearing Consumer Advocacy Network, Hearing Loss Association of America, Cerebral Palsy and Deaf Organization, American Association of the DeafBlind, Deaf/Hard of Hearing Technology-RERC, and the Universal Interface & Information Technology Access-RERC.

[55] 47 CFR §§ 14.32 (consumer dispute assistance); 14.34-14.37 (informal complaints).

embraced by all stakeholders. The daunting task of implementing the CVAA's far-reaching provisions within an extremely tight timeframe might have been a reason for this. Even in anticipation of the Act's passage, the Commission took steps to gather public feedback on the law's mandates, for example, by holding a workshop in May of 2010 with disability representatives, industry, academia, and non-profit organizations to learn about mobile communication accessibility issues and solutions.[56] Similarly, in June of 2010, the FCC's Consumer and Governmental Affairs Bureau invited representatives of the deafblind community to discuss their accessibility barriers, the first of many such meetings to take place with this community over the next several years.

Continuing to chart novel territory once the law was passed, the FCC spent the next several years incorporating face-to-face meetings, negotiations, and forums into its various CVAA rulemakings. This allowed the agency to weave together essentially consensus documents that sought a fair balance of interests on matters such as the CVAA's scope of coverage, compliance deadlines, exemptions, and enforcement. In addition, the FCC relied heavily on recommendations made by stakeholder-led advisory committees – the Video Accessibility Advisory Committee or VPAAC, which developed recommendations on closed captioning and audio description,[57] and the Emergency Access Advisory Committee or EAAC,[58] which delivered recommendations on text-to-911 and related NG 911 accessibility issues. In December 2014, the FCC also established the Disability Advisory Committee (DAC), which has provided opportunities for continued dialogue among consumer, industry, and governmental stakeholders on the CVAA and other accessibility matters.[59] Since its inception, the DAC has provided comprehensive recommendations to the FCC on issues such as closed captioning, real-time text, accessible wireless emergency alerts, and telecommunications relay services, several of which have been adopted by the Commission. In addition, in 2018, the FCC established the North American Numbering Council's Interoperable Video Calling Working Group, a body tasked with exploring ways to facilitate interoperable video calling using 10-digit numbers, including application of this technology by sign language and telecommunications relay users.[60]

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[56] Wireless Telecommunications Bureau and Consumer and Governmental Affairs Bureau of the Federal Communications Commission (2010, May 13). *Expanding Disability Access with Wireless Technologies;* Federal Communications Commission (2010, July 19), *Wireless Telecommunications Bureau and Consumer and Governmental Affairs Bureau Seek Comment on Accessible Mobile Phone Options for People who are Blind, Deaf-blind, or Have Low Vision*, Public Notice DA-1324, CG Docket 10-145.
[57] Federal Communications Communication, Video Programming Accessibility Advisory Committee. https://www.fcc.gov/general/video-programming-accessibility-advisory-committee-vpaac-0.
[58] Federal Communications Communication, Emergency Access Advisory Committee. https://www.fcc.gov/general/emergency-access-advisory-committee-eaac.
[59] https://www.fcc.gov/disability-advisory-committee.
[60] Federal Communications Commission (2018, September 27). *FCC Announces Membership of the North American Numbering Council Interoperable Video Calling Working Group, and the Nationwide Number Portability Working Group's Technical Subcommittee,* Public Notice, CC Docket 92-237, DA 18-995. https://docs.fcc.gov/public/attachments/DA-18-995A1.pdf.

Finally, in part, the CVAA's success may be attributed to the law's accountability and enforcement provisions. Unlike prior U.S. communications access laws, companies must now keep records of their accessibility efforts, including their consultations with people with disabilities and descriptions of their products' accessibility and compatibility features, and further, must make these records available to the FCC upon request if deemed necessary to resolve a complaint.[61] For this purpose, the FCC established the "Recordkeeping Compliance Certification and Contact Information Registry," a repository for companies to file annual certifications affirming the availability of these records, along with contact information of company representatives authorized to handle RDAs and consumer complaints.[62]

But Some Gaps Remain. . .

Notwithstanding the CVAA's achievements in bringing about an array of accessible wireless communication and video programming options, accessibility gaps remain, some of which have surfaced as a result of our migration away from in-person communications during the COVID-19 pandemic. Many of these have been highlighted by consumers in response to the FCC's request for comments on its 2020 Biennial Report to Congress, a report that assesses the level of compliance with CVAA's communications mandates every two years.[63] A case in point is video conferencing, on which we have come to rely for work, socializing, and learning. Although some conferencing platforms offer high-quality video, keyboard shortcuts, screen reader compatibility, and captioning capabilities,[64] Telecommunications for the Deaf, Inc. and other leading deaf and hard of hearing organizations (TDI et al.) have pointed out that accessibility obstacles remain, including challenges associated with adding a telecommunications relay service operator to a video conference call and the inability to simultaneously view a person using sign language and an interpreter using the "active speaker" function.[65] Data caps and throttling practices also can have a disproportional impact on consumers who need large amounts of data for video communications.[66]

According to the Wireless Inclusive RERC survey, some consumers with disabilities also continue to have difficulty locating information about accessible phone

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[61] Section 717(a)(5) of the Communications Act, codified at 47 U.S.C. § 618 (a)(5).

[62] 47 U.S.C. § 618(a)(5)(B); 47 CFR § 14.31; Recordkeeping Compliance Certification and Contact Information Registry, https://apps.fcc.gov/rccci-registry/login!input.action.

[63] Sec 717 (b) of the Communications Act, codified at 47 U.S.C. § 618(b).

[64] Zoom, https://zoom.us/accessibility; BlueJeans, https://www.bluejeans.com/accessible-online-video-conferencing-features; Leggin, S. (2020, April 14).

[65] Kaika, E. on behalf of TDI et al. (2020, April 14).

[66] Kaika, E. on behalf of TDI et al. (2020, August 4). Comments submitted in response to the Public Notice on the 2020 CVAA Biennial Report Tentative Findings [CG Docket No. 10-213]. Federal Communications Communication: Washington, D.C. Available at https://ecfsapi.fcc.gov/file/108050590610412/FINAL%20-%20TDI%20et%20al%20FCC%20Comments%20on%202020%20CVAA%20Findings%20Public%20Notice%20(8-4-2020).pdf.

features, complicating their ability to compare and select the right phone for their needs.[67] TDI et al. confirm this, noting, in particular, the challenges that people with both hearing loss and mobility disabilities have trying to find larger devices for easier manipulation.[68] In addition, although there appears to be a general consensus that ICT companies have expanded their efforts to consult with people with disabilities, TDI et al. maintain that these efforts do not regularly reach the DeafBlind community.[69] The FCC has acknowledged that wireless feature phones generally remain inaccessible to people who are blind and that some telecommunications and ACS apps are still not compatible with screen readers.[70]

With respect to video programming, there are no federal mandates for audio descriptions or captions on Internet-generated video programming. In addition, as noted above, the CVAA's mandates for audio-described programming reach only a fraction of television shows. Moreover, it remains challenging for audio description users to activate this feature on many video platforms and devices and determine which programs are equipped with description. Finally, as was the case for closed captioning, as the number and variety of audio description service providers proliferate, the need for quality-of-service standards intensifies.

Last, to date, no federal law covers the accessibility of websites. This matter generally falls within the U.S. Department of Justice (DOJ) jurisdiction as the oversight agency for the Americans with Disabilities Act (ADA). Although, as noted above, the CVAA mandates that consumers with vision loss be able to reach websites using their wireless devices, all too often, these persons are unable to access the content of or interact with the site's webpages once they have arrived. The lack of screen reader compatibility, alternative text descriptions for images, font enlargement features, high color contrast, and captions on many such sites has resulted in a plethora of lawsuits in recent years alleging violations of Title III of the ADA's mandates for places of public accommodation to provide disability access.[71] Although DOJ has acknowledged that the ADA applies to these websites,[72] the agency has not adopted universal standards for their accessible design, such as the Web Content Accessibility Guidelines (WCAG).[73] The consequences of not having universal standards can be severe. In a survey conducted by the Partnership on Employment & Accessible Technology, almost half (46 percent) of the respondents indicated that the process to apply online for a job

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[67] Mitchell, H. (2020, April 14).

[68] Kaika, E. (2020, April 14); Kaika, E. (2020, August 4).

[69] *Ibid.*

[70] Federal Communications Commission (2020, July 21). *Consumer and Governmental Affairs Bureau Seeks Comment on Tentative Findings for the 2020 Twenty-first Century Communications and Video Accessibility Act Biennial Report*, CG Docket No. 10-213, DA 20-768. https://docs.fcc.gov/public/attachments/DA-20-768A1.pdf.

[71] Vu, M.N., Launey, K.M. & Ryan, S. (2019, January 31) *Number of Federal Website Accessibility Lawsuits Nearly Triple, Exceeding 2250 in 2018*, Seyfarth. https://www.adatitleiii.com/2019/01/number-of-federal-website-accessibility-lawsuits-nearly-triple-exceeding-2250-in-2018/.

[72] Boyd, S. (Assistant Attorney General, DOJ) (2018, September 25). Letter to U.S. Congressman Ted Budd. https://www.adatitleiii.com/wp-content/uploads/sites/121/2018/10/DOJ-letter-to-congress.pdf

[73] https://www.w3.org/WAI/standards-guidelines/wcag/.

was “difficult to impossible,” and 40 percent indicated not being able to complete tests or assessments needed for the job screening.[74] Additionally, with as many as seven in ten employees working from home either part or full time during the COVID-19 pandemic, people with disabilities who are employed are likely to need access to websites to perform their job functions.[75]

Technology Transformation: An Uncertain but Promising Future

It has been said that we are on the precipice of the fourth industrial revolution, whose use of superior computing power, utilization of vast amounts of data, and convergence of our physical, digital, and even biological worlds will dramatically change virtually every aspect of our lives – promising to make our daily affairs easier and more rewarding. According to one source, “[t]he possibilities of billions of people connected by mobile devices, with unprecedented processing power, storage capacity, and access to knowledge, are unlimited. And these possibilities will be multiplied by technology breakthroughs in fields such as artificial intelligence (AI), robotics, the Internet of Things, autonomous vehicles, 3-D printing, nanotechnology, biotechnology, materials science, energy storage, and quantum computing.”[76] 5G technologies already offer lower latencies, faster speeds, and ubiquitous broadband capabilities that can seamlessly connect devices throughout our homes, offices, and vehicles. Interconnected devices are presenting themselves in smart thermostats, light bulbs, door locks, and other household items, enabling their activation and control with fingerprints, smartphones, and cloud-based voice services.

Applications using AI, which employ highly advanced machine learning, predictive technology, object detection, voice-activated digital assistants, and facial recognition, can be transformative for disability communities, providing boundless opportunities to enhance self-sufficiency. Automatic speech recognition tools with high accuracy rates can facilitate remote and in-person communications for people who are deaf and hard of hearing,[77] assist people with atypical speech patterns to communicate with others,[78] and perform household and computerized tasks for people with vision loss or limited mobility through voice-activated digital assistants.[79] Monitoring technologies

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[74] DIVERSEability Magazine (Spring/Summer 2018). *Debunking the Myths*, pages 16-20.
[75] Hickman, A. & Saad, L. (2020, May 22). *Reviewing Remote Work in the U.S. Under COVID-19.* Gallup.com. https://news.gallup.com/poll/311375/reviewing-remote-work-covid.aspx
[76] Schwab, K. (2016, January 14). *The Fourth Industrial Revolution: what it means, how to respond*. World Economic Forum. https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/.
[77] Examples are Microsoft’s Azure and IBM’s Watson Speech-to-Text.
[78] An example is Google’s Project Euphonia, https://sites.research.google/euphonia/about/; https://www.youtube.com/watch?v=OAdegPmkK-o.
[79] Rachfal, C. on behalf of American Council of the Blind (2020, April 14). Comments submitted in response to the Public Notice on the 2020 CVAA Biennial Report Tentative Findings [CG Docket No. 10-213]. Federal Communications Communication: Washington, D.C. https://ecfsapi.fcc.gov/file/10414096457141/FCC%20CVAA%20Biannual%20Report%20to%20Congress%20ACB%20Comments.pdf.

capable of detecting, analyzing, and reporting motion from remote locations can help families stay informed about the daily activities of aging relatives with cognitive disabilities. Advancements in location accuracy and mapping wayfinding technologies – some machine-driven and others human-assisted – can provide information about remote visual environments to facilitate public navigation by people who are blind and visually impaired. Relatedly, AI-enabled devices can help people with limited sight identify products through a device's camera.[80]

Augmented reality (AR), which allows for the layering of graphics, audio, video, and other computer-generated enhancements on top of reality, can help people with intellectual and developmental disabilities learn essential life, social, and safety skills.[81] AR also can provide people with vision loss shopping independence through smartphone apps that can identify objects in unfamiliar environments. Likewise, by simulating a real-life environment, **virtual reality can acquaint** people in wheelchairs with accessible routes in unfamiliar cities. High-definition voice on telephone calls can significantly improve sound clarity for people who are hard of hearing, reducing the need for third-party assistance, especially if supplemented with real-time text. Autonomous vehicles can be life-altering for people who are blind or have other types of disabilities that prevent them from driving.[82] This list can go on and on.

While the extraordinary capabilities of the Internet and the freedoms empowered by mobile devices promise to take Americans to a whole new level of connectivity, these benefits will only be realized by people with disabilities if they are accessible.[83] A person who is blind will be able to use an AI-powered robotic application to mow a lawn only if it can be controlled through audio output and speech input. An intelligent cooking assistant offering guided cooking from a remote location will be useful to someone who is deaf only if it provides text along with aural instruction.

Although the drafters of the CVAA attempted to future proof its safeguards by referencing "successor protocol[s]" to Internet protocol technologies, the extent to which the law's protections will reach the avalanche of evolving wireless technologies remains to be seen. In the years to come, the need for disability safeguards will continue to intensify, as an increasing number of older Americans with advancing hearing, vision, and cognitive loss live longer and stay active and employed well into their senior years. The ability of transformative and remarkable technologies to enhance the lives of these

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[80] An example is Google's Alexa Show and Tell, https://www.amazon.com/b/?node=21164393011&tag=googhydr-20&hvadid=451761580261&hvpos=&hvexid=&hvnetw=g&hvrand=14623929908314522332&hvpone=&hvptwo=&hvqmt=e&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9061285&hvtargid=kwd-829777555330&ref=pd_sl_9sm000maud_e.

[81] Gonzalez (2017, October 18). *Augmented and Virtual Reality Will Benefit the Disabled People*, Technology for the Disabled. https://www.thegenius.ca/augmented-virtual-reality-benefit-disabled-people/.

[82] It is notable that makers of self-driving cars are reportedly consulting people with disabilities to assess their needs as these cars are being built. Perry, David M (2020).

[83] Perry, D. M. (2020, July 14, July 20). *Disabled Do-It-Yourselvers Lead Way to Technology Gains.* Nytimes.com. https://www.nytimes.com/2020/07/14/style/assistive-technology.html?searchResultPosition=1.

individuals will be determined by the commitment of companies to incorporate accessibility as they innovate. By now, it is a common refrain that when accessibility needs are addressed early on in the design process with active stakeholder involvement, the promises of independent living, full inclusion, and social integration can be achieved at lower costs and with better results. Twenty-first digital and wireless technologies already have proven to be liberating for millions of Americans with disabilities, offering greater independence, enhanced productivity, and the freedom of mobility. The recently heightened awareness of the need to incorporate accessibility features – in part achieved through the implementation of the CVAA – offers a promise that ICT companies will continue to advance these accessibility objectives. Policymakers should be standing by to step in where this does not occur.

While not mandated by the CVAA, a discussion of federal policy on communications access would not be complete without mentioning the FCC's 2016 ruling to allow wireless service providers and equipment manufacturers to support real-time text transmissions in lieu of TTY communications over IP-based wireless voice networks.[84] Real-time text allows text to be transmitted to the receiving party as soon as it is generated (either by typing or speech-to-text), eliciting a natural flow of conversation between the parties. This technology, which also allows voice to be sent simultaneously with the text, requires no specialized end-user equipment and is superior in terms of speed, latency, reliability, and ease of use to TTY technology. In particular, RTT is useful in emergencies, when a person in need of immediate assistance may not have the time or ability to press the "send" or "enter" button typically required for other types of texting. However, like other forms of text, this technology has yet to be adopted by most of our country's public 911 safety answering points. In March of 2021, the FCC added to its Text-to-911 Registry the list of PSAPs nationwide that can receive RTT messages.[85]

[84] Federal Communications Commission (2016, December 15). *Transition from TTY to Real-Time Text Technology, Petition for Rulemaking to Update the Commission's Rules for Access to Support the Transition from TTY to Real-Time Tet Technology, and Petition for Waiver of Rules Requiring Support of TTY Technology*, Report and Order and Further Notice of Proposed Rulemaking, CG Docket 16-145, GN Docket 15-178, FCC 16-169. https://docs.fcc.gov/public/attachments/FCC-16-169A1.pdf

[85] Federal Communications Commission (2021, March 12). Public Safety and Homeland Security Bureau Announces Availability of Updated PSAP Text-to-911 Certification and Readiness Form and Registry to Facilitate Real-Time Text, PS Dockets 10-255 and 11-153, CG Docket 16-145, GN Docket 15-178, DA 21-301. https://docs.fcc.gov/public/attachments/DA-21-301A1.pdf.

Wireless RERC Retrospective: Policy Initiatives to Accelerate Development and Adoption of Accessible Wireless Technologies

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Abstract

The Wireless RERC team has diligently examined regulatory activities, conducted research on telecommunications and accessibility, and offered recommendations on inclusive federal policies. This paper provides an overview and discussion of regulatory filings that the RERC has produced, including device access, wireless connectivity access, expanded broadband, and accessible data and formats. The RERC has also informed policy at the federal level, influencing final rules and, by extension, industry practices. Specifically, this paper explores the subject matters that the RERC's input has most influenced, namely emergency communications, emergency services, and emergency alerts information.

Keywords: Accessibility, broadband, wireless, smart devices, smart technologies, people with disabilities, inclusive telecommunications

Introduction

Since the Rehabilitation Engineering Research Center for Wireless Inclusive Technologies (Wireless RERC) inception 20 years ago, our work has informed the development of wireless technology policy and regulations, so they are inclusive of the needs of people with disabilities. This is accomplished by monitoring regulatory activities, providing written comments, and collaborating with experts from the wireless industry on wireless policy and procedures' technological aspects. Furthermore, in consultation with disability community stakeholders and the research and Wireless RERC development teams, summations of user feedback on possible technical solutions have facilitated policy discussions and informed filings and *ex parte* presentations before regulators. As a result, 77 empirically supported federal regulatory filings have been produced, and Wireless RERC research and recommendations have been cited within the resultant rulemakings 248 times.

Informing Regulatory and Policy Rulemakings

The need for rules and regulations that encompass future technologies, known and unknown, creates a greater burden on all stakeholders to stay engaged in the process. Involvement in the "process" has been a critical task of the Wireless RERC. It is extremely important to ensure that the accessibility provisions outlined in technology rules and regulations are broad enough to be applicable throughout this century yet contain enough detail to sufficiently guide the wireless and adjacent industries beyond compliance to be inclusive in their creation of accessible devices, software, and services.

Data to Inform Policy Recommendations

In addition to using the data generated by the Wireless RERC's research and development projects and extant research from the field, the Policy Initiatives project conducted research to generate data to inform policy recommendations. Perhaps most notably, a biennial analysis of mobile phone accessibility. The biennial analysis results have been used to inform the FCC's evaluation of industry compliance with the Twenty-First Century Communications and Video Accessibility Act of 2010 (CVAA) and in other proceedings, such as the Wireless Emergency Alerts Enhancements. Research conducted by this project resulted in the release of several research briefs and reports, including:

- Biennial analysis of mobile phone accessibility: Comparative analyses reveals pain points and progress
- The Federal Communication Commissions' Response to COVID-19
- Mobile Phone Accessibility Review
- Save Lives, Withstand Catastrophe, and Stimulate the Marketplace
- FM Radio and RBDS-Based Emergency Alerting

Regulatory Filings

This section highlights the filings published by the Wireless RERC since October of 2016. This collection of filings can be cataloged into three distinct categories: Accessible Devices, Accessible Data and Formats, and Process Recommendations.

Accessible Devices. The Wireless RERC published, Accessibility Gains and Gaps Found in the Biennial Analysis of Mobile Phone Accessibility, on August 4, 2020, in response to the FCC's Public Notice Consumer and Governmental Affairs Bureau Seeks Comment On Tentative Findings for the 2020 Twenty-First Century Communications and Video Accessibility Act Biennial Report [CG Docket No. 10-213]. The FCC's Tentative Findings Report cited the Wireless RERC nearly fifteen times based on our initial comments in April, which discussed the preliminary findings of the 2019/2020 Mobile Phone Accessibility review. In the August 2020 filing, we provided a complete analysis of mobile phone models available through February 2020 from the top four wireless carriers, one prepaid carrier, and five Lifeline Carriers. Additionally, the comments were informed by our cornerstone survey results on wireless technology use by people with disabilities, the Survey of User Needs (SUN).

Overall, the comments indicated the industry's growth in the accessibility and affordability of advanced communications technologies, as evidenced by the increasing presence and richness of new accessibility features on mobile devices, resulting in greater usability of these devices. However, some access gaps remain, particularly regarding new communications technologies. Based on the data presented in the comments, the Wireless RERC offered the following seven recommendations for improvement of accessibility to mobile phones:

- As new features are developed, mobile phone manufacturers are encouraged to continue incorporating users with disabilities into all stages of the design process so that accessibility and consequential usability are intentional within digital designs instead of a fortuitous byproduct of innovative technology.
- Increasing the percentage of phones with excellent M and T ratings (M4/T4) would better ensure a quality experience with voice calls for people who use hearing aids and cochlear implants.
- Given the rate of people with disabilities reporting more than one disability and the disparity between the availability of accessibility features based on disability type, increasing the percentage of more universally accessible devices would be good for manufacturers and end-users alike.
- Increasing the percentage of WEA-capable non-smartphones would better ensure access to emergency alerts for users with disabilities that prefer non-smartphones.
- For continuity of the accessibility experience through app and OS updates, development efforts should allow a way to ensure that system updates do not reset to the default status and maintain accessibility preferences, impacting not only accessibility but also (1) the security of the device, and (b) the optimal operation of the device or app, as it would have the latest fixes and features.
- Voice input devices such as digital assistants and smart speakers may be more capable than users believe the case, suggesting the need for more informed or more expanded help/guidance functions. This speaks to the need for the design process to expand beyond minimal accessibility features to incorporate outcome-based design, such as increased usability.
- To address barriers experienced by customers with disabilities during point-of-sale transactions, we recommend (1) disability awareness/etiquette and information about accessibility features be a standard part of sales associate training, and (2) providing a stable method for customers with disabilities to obtain in-store support (e.g., video remote interpreting services).
- In April of 2020, the Wireless RERC submitted Accessibility of New Communications Technologies and Lifeline-Provided Mobile Phones, in response to their Public Notice In the Matter of The Accessibility of Communications Technologies for the 2020 Biennial Report Required by the Twenty-First Century Communications and Video Accessibility Act [CG Docket No. 10-213]. The Wireless RERC provided input based on an analysis of a subsample of Lifeline-provided mobile phones and SUN data concerning new communications technologies. Based on the data presented in these comments, the Wireless RERC offered the following recommendations:

- To improve total access to the systems and devices, companies should explore and develop solutions for how one who is blind would be able to set up the technology independently.
- Increased attention should be paid to ensuring access by people who are Deaf to smart speaker technologies that have a screen (e.g., Amazon Echo Show), such as developing a gesture interface that understands ASL.
- To improve access by those with non-standard speech to smart speakers and voice input on mobile devices, we encourage the inclusion of AI trained to understand those with atypical speech patterns.

The Wireless RERC submitted reply comments to the FCC's Further Notice of Proposed Rulemaking *Improving Video Relay Service and Direct Video Calling* **[CG Docket No. s 10-51 and 03-123**] on September 4, 2019. The Wireless RERC supported consumer and provider stakeholders' opposition to requiring a login for users of enterprise and public videophones. As asserted by the Consumer Groups, such a requirement runs counter to functional equivalency as defined by Section 255 of the Americans with Disabilities Act, the Telecommunications Act of 1996, and the Twenty-First Century Communications and Video Accessibility Act of 2010. The Wireless RERC also supported several other assertions made by Consumer Groups, including the inaccessibility of VRS telephone numbers for users with cognitive disabilities and continuing the practice of disconnecting calls that do not need ASL to communicate.

Accessibility of Communications Technologies, published in May of 2018, was in response to the FCC's Public Notice *In the Matter of The Accessibility of Communications Technologies for the 2018 Biennial Report Required by the Twenty-First Century Communications and Video Accessibility Act* [**CG Docket No. 10-213**]. As in the 2020 comments, the accessibility of advanced communications technologies improving was noted, and supporting data was provided. However, we also noted that a perennial barrier to access, device set-up, which allows the user to gain entry to the device, requires addressing to move the needle forward on people with disabilities' independently accessing advanced communications technologies and services.

Accessible Data and Formats. On September 17, 2020, the Wireless RERC's filing, *Comments on the NTIA Survey Questionnaire*, was drafted in collaboration with Georgia Tech's Center for the Development and Application of Internet of Things Technologies and the Center for Advanced Communications Policy (CACP). These comments were in response to the NTIA's request for comment: *NTIA Internet Use Survey Questionnaire Development* [Docket No. 200813-0218]. This Internet Use Survey is a long-standing questionnaire distributed to approximately 50,000 homes across the United States. It supplements the periodically administered Current Population Survey (CPS) that gauges national labor force statistics and provides information on digital use. The Wireless RERC's comments noted concerns about the nature of some of the survey questions that may cause respondents to provide less than accurate answers due to social standing. Other concerns related to how questions were worded. They may not be clear to people with mild cognitive impairments, learning disabilities, or for whom English is a second language. The RERC also recommended that NTIA include additional questions that address the use of IoT technologies.

Survey Dissemination via a WEA Message was in the form of a letter to the FCC on October 21, 2019, in response to their notice, *Information Collection Being Reviewed by the Federal Communications Commission: Enhanced Geo-Targeted Wireless Emergency Alerts* [**WT Docket No. 10-254: DA 12-1745**]. This letter articulated support for the FCC's initiative to collect data on WEA messages' geotargeting capabilities using an embedded link to the survey within the message. Comments asserted that the proposed data collection method would improve the survey results' ecological validity, as the survey would be taken in an uncontrived setting. The letter also recommended that the FCC, at a later date, consider collecting data on factors impacting WEA efficacy for people with disabilities.

Multimedia Content in WEA Messages was in response to the FCC's Public Notice inviting stakeholder input to *Refresh the Record on Facilitating Multimedia Content in Wireless Emergency Alerts (WEA)* [**PS Docket Nos. 15-91 and 15-94**]. The Wireless RERC reply comments filed on June 11, 2018, were in general agreement with comments that supported the inclusion of multimedia content in WEA messages. Despite sometimes having different rationales, many commenters indicated the importance of multimedia message content in motivating people to take appropriate protective actions and/or advancing accessibility of WEAs to people with disabilities. In our reply comments, we urged wireless stakeholders to continue to embrace the changing expectations of public safety officials and the public with regards to an expanded suite of WEA capabilities.

Process Recommendations. This category includes letters, filings, and comments that either urge, propose, reject, or recommend the FCC to respond to a policy or initiative in a particular way based on data and scholarly literature. The first filing, in response to the FCC's Public Notice, *Improving the Wireless Resiliency Cooperative Framework* [PS Docket No. 11-60], was submitted in May of 2019. The comments commended the wireless industry's voluntary actions and investments for strengthening their networks to withstand disaster events. However, we contended that more could be done to ensure that people with disabilities are included in the planning, deliberations, and consequential actions of the Framework. Specifically, the Wireless RERC agreed with Verizon's assertion that "the Framework also should continue to preserve wireless providers' ability to determine, based on sound engineering principles and objective factors like available coverage and traffic demands, where and how to allocate their assets and services in a locality to most effectively and efficiently respond to a disaster.[1]" We also recommended that the criteria for mutual aid and service restoration not rule out areas that have been deemed to have no user access. Our recommendation was based on research findings showing that people with disabilities and the elderly often remain in these areas despite mandatory evacuations.

On October 3, 2016, comments were submitted in response to the FCC's Public Notice, *Request for Comment on the Commission's Policies and Practices to Ensure*

Compliance with Sections 504 of the Rehabilitation Act of 1973 **[CG Docket No. 10-162].** The FCC sought public input on their programmatic access. Wireless RERC comments asserted that baseline accessibility is consistently impacted by access to customer service and print and electronic materials furnished by industry and policymakers alike. To improve access to programs and services, we recommended addressing fundamental issues of disability awareness and accessible formats. Further, work remains to expand access to the rulemaking process. One part of the FCC's Section 504 Handbook stipulated that the Commission will not transcribe or translate comments submitted in alternative formats. The Wireless RERC urged the Commission to reconsider this position.

Policy Impact

As mentioned in the introduction, Wireless RERC regulatory input has been cited more extensively in rulemakings and congressional reports. The citations have served to help frame the discussion around proposed rules' implications for people with disabilities, influenced final rules, and thus, industry practices, and contributed to the development of proposed legislation, as well as assessing the effect of legislation and subsequent implementation via FCC regulations. Our input has been particularly influential in the domains of emergency communications and mobile phone accessibility.

Emergency Communications. Regulatory agencies and policymakers have responded to the wireless trend to ensure emergency communications are more inclusive, as evidenced in rulemakings concerning access to alerts and other emergency information for people with disabilities. A major step occurred in 2005 when EAS rules were amended to create "a sound emergency communications system that includes the needs of people with disabilities.[86]" And again in 2010, with the signing of the Twenty-First Century Communications and Video Accessibility Act of 2010, which established the Emergency Access Advisory Committee with a remit "*to determine the most effective and efficient technologies and methods by which to enable equal access to emergency services by individuals with disabilities as part of the nation's migration to Next Generation 911 (NG9-1-1), and to make recommendations to the Commission on how to achieve those effective and efficient technologies and methods.[87]"* These proceedings point to the necessity of optimizing the ability of people with disabilities to receive alerts and warnings from emergency management sources, as well as to contact emergency services from their mobile device independently.

Emergency Services: Text-to-911 and NG 911. Regarding access to emergency services, we are particularly interested in the efficient and effective

[86] Federal Communications Commission (2005). *Amendment of Part 73, Subpart G, of the Commission's Rules Regarding the Emergency Alert System, First Report and Order and Further Notice of Proposed Rulemaking* [FO Docket 91-301/FO Docket 91-171]. Washington, DC.

[87] FCC (2016). Emergency Access Advisory Committee (archived web page). Available at https://www.fcc.gov/general/emergency-access-advisory-committee-eaac.

coordination and implementation of Next Generation 911 (NG 911) services. The consumer group that stands to benefit the most is people with disabilities; particularly, people with hearing loss and speech disabilities. People with speech/communication difficulties are a large and diverse group that includes individuals with Autism, traumatic brain injury, stroke, physical trauma to the vocal cords, cleft lip or palate, and others with difficulties vocalizing. However, rather than designing NG9-1-1 for a specific group, it is critical to ensure the NG9-1-1 platform and services are universally designed. In the May 29, 2013, Report and Order (*R&O) In Matter of Facilitating Deployment of Text-to-911…* [PS Docket No. 11-153], the Wireless RERC was cited and/or included in the body of the document 15 times, impacting final rules requiring all commercial wireless and interconnected text providers to enable bounce back messages to consumers in areas where text-to-911 is not available. We asserted that this requirement would help manage the public expectation regarding text-to-911 availability as deployment will be on a rolling basis.

In an FCC Congressional Report, released on February 22, 2013, *Legal and Regulatory Framework for Next Generation 911 Services,* the Wireless RERC was cited and referenced throughout the document. In preparation for the Report, the FCC issued a *Public Notice* that sought public comments on the issues related to the legal and regulatory infrastructure needed for the transition from legacy 911 to Next Generation 911 (NG911). The Wireless RERC was referenced regarding its support of NG911 deployment being governed at the state and local level and favoring new 911 funding mechanisms. The current system is thought to be outdated and inefficient for supporting the transition to NG911. Concerning how 911 funds should be collected, the Wireless RERC comment was included that noted the importance of a fee-based approach ensuring that "non-voice-enabled services contribute their fair share to 911 funding." The Report also included Wireless RERC recommendations on specifically increasing the role and authority of the Emergency Access Advisory Committee (EAAC), expanding the Public Safety Interoperable Communications (PSIC) grant program to include technologies that advance NG911, and enhancing the Master Public Safety Advisory Point (PSAP) Registry to provide an interactive map showing each PSAP's NG911 capability.

Emergency Alerts Information. Access to emergency alerts information has long been an issue addressed by the Wireless RERC. Beginning in 2004, the FCC initiated new rulemakings to review the Emergency Alert System (EAS), seeking comment on how EAS could be improved given the move from analog to a digitally based alert and warning system and the proliferation of advanced technologies, such as wireless. The Wireless RERC's early work in mobile-EAS is present in a 2004 filing before the FCC, and we have since been an integral player in forming what is now the Wireless Emergency Alert (WEA) system. In the *Notice of Proposed Rulemaking In the Matter of Improving Wireless Emergency Alerts (WEA) and Community-Initiated Alerting,* prior ex parte comments filed by the Wireless RERC in November 2015 were used to help frame the discussion on the WEA 90-character limitations and prohibition of URLs in WEA messages impact on the accessibility of the content of the message for people with disabilities.[88] Due to our input, all stakeholders had the opportunity to address the following FCC requests:

We also seek comment on how an increase in the length of WEA messages would affect the accessibility of such messages by individuals with disabilities, senior citizens, and persons with limited English proficiency.

We also seek comment on the efficacy of using embedded URLs to enhance the accessibility of WEA for people with disabilities, senior citizens, and persons with limited English proficiency, in addition to the general public.

The outcome of stakeholder input, including our own, on the above-referenced rulemaking, was the release of a Report and Order[89], amending WEA rules to, among other things:

- Effective May 1, 2019 – Increase the maximum WEA character length from 90 characters to 360 characters on 4G LTE and later networks;
- Effective May 1, 2019 - Adding a fourth message type, "Public Safety Message," allow alerting authorities to send information concerning shelter locations, boil water advisories, and other pertinent life and property saving information that comes in the wake of an initial emergency message;
- Effective May 1, 2019 - Enabling local authorities to test the WEA system;
- Effective January 3, 2017 - Require the geotargeting of WEA messages to be more precise; and
- Effective November 1, 2017 – Support embedded references such as Uniform Resource Locators (URLs) in the WEA message. Early adoption of this amendment is allowable and may begin as early as December 1, 2016.

As per our research findings, the above amendments will enhance WEA messages' utility for people with disabilities. As such, our policy input impacts wireless industry response to comply with the rulemaking, alerting authorities to do the same, and user access to actionable, relevant, and comprehensible message content. Further, the FNPRM section of the rulemaking sought input on WEA message preservation, the inclusion of wearables and tablets in the WEA/IPAWS environment, more granular and time-defined opt-out options, and the ability to modify the attention signal and vibration cadence of WEA notifications. The Wireless RERC previously submitted research supported comments on all of the above-mentioned factors.

Wireless RERC input on accessible emergency information and text-to-911 was included in the *Report and Order (R&O) In the Matter of Accessible Emergency Information and Apparatus Requirements…Video Description…* [**MB Dockets No. 12-107 and 11-43**] of April 9, 2013, influencing final rules requiring the simultaneous provision of visual and audio emergency information conveyed during non-newscast programming. Findings from Wireless RERC research supported the recommendation

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[88] FCC (2015). Improving Wireless Emergency Alerts and Community-Initiated Alerting [PS Docket No. 15-91]. Federal Communications Commission: Washington, DC, November 19, 2015.

[89] FCC (2016). Report and Order: Improving Wireless Emergency Alerts and Community-Initiated Alerting [PS Docket No. 15-91]. Federal Communications Commission: Washington, DC, September 29, 2016.

that for any alerting modality: traditional broadcast, wireless, or otherwise, to ensure accessibility by people with vision loss, audio presentations must be present.

Mobile Phone Accessibility. Over the years of the Wireless RERC, we have seen an increased focus by Congress and regulatory agencies on the needs of people with disabilities, looking into issues of accessibility to both traditional and newer technologies. Areas of heightened attention include access to advanced communications services and devices and the ever-increasing role of wireless, smart, connected devices in everyday life. As innovations in access have proliferated, the Wireless RERC has celebrated the wins yet steered away from the notion that we've attained our goal of universal access and inclusion. We are well on the way, but much work remains. Much work is created with every new wireless invention that hits the market. Our inclusion in the FCC's Congressional Reports to Congress concerning the CVAA goes back to their 2014 report. However, let's focus on the most recent activity. The FCC submitted their ***2020 Biennial Report to Congress*** [**CG Docket No. 10-213; DA 20-1164**] required by the *Twenty-First Century Communications and Video Accessibility Act of 2010* (CVAA). **Wireless RERC comments** have been referenced thirty-three times throughout the Report. The first set of Wireless RERC observations included in the Report concerned smartphone accessibility. The Wireless RERC is referenced regarding its comment that its study included people who have "vision, hearing, cognitive, and mobility disabilities" and that the accessibility and usability of devices have "steadily increased," but that "some gaps remain." The Wireless RERC observation that voice technology helps people with cognitive disabilities send texts and emails is also noted. Regarding smart speakers, the Wireless RERC statement that the "inability of smart speakers to understand atypical speech patterns presents an accessibility barrier" is quoted. Additionally, Wireless RERC observations on Google's Project Euphonia are noted -- how the project is seeking to make speech recognition systems accessible to people with atypical speech patterns through improved speech-to-text transcription for people who have significantly slurred speech.

The next set of Wireless RERC comments included are about alternative smart technologies. The Wireless RERC finding that successful technologies developed on smartphones are being replicated in other use cases is included, noting that our Survey of User Needs included questions on smart speakers, tablets, smartwatches, and smart eyeglasses. The Wireless RERC finding about the recent inclusion of voice assistants with smart devices is also noted. Next, the Report includes the Wireless RERC's note that smart speakers can enable users who are blind to access news and information and control smart home technologies independently. Further, the Report includes the Wireless RERC comment that despite this, some smart home devices still require users with vision disabilities to rely on sighted assistance and that improving voice controls to match in-app options would improve device accessibility. Finally, this section of the Report recognizes the Wireless RERC's assertion that users need more guidance on the available features that can be activated through voice control.

In relation to mobile phones pairing with peripheral devices and related functionality, Wireless RERC support for the continued incorporation of "device-to-device connectivity" is noted. As the Wireless RERC states, inter-device connectivity allows people with disabilities to use external assistive technologies, boosting their use of Internet of Things (IoT) devices that advance independent living and social inclusion. The Wireless RERC observation that biometric login is being included more broadly and limits dependency on memory and mobility/dexterity when unlocking a device is also noted. Following pairing, comments about improvements in accessibility are also included. The Wireless RERC noted that accessibility and usability have generally improved for "people with vision disabilities."

Further, the Wireless RERC commented that feature phones include various accessibility features like built-in text-to-speech, full access screen reader, braille access, and more are included in the Report. Regarding software updates in feature phones, the Wireless RERC statement that system updates have negatively impacted the user's configuration of accessibility options was included in the Report to Congress. Overall, the Wireless RERC findings highlighted that mobile phones' accessibility has continued to improve, with most smartphone users using them without help from other people.

The Wireless RERC statement that sometimes providers do not provide an easily discoverable way to locate relevant information about accessibility features is quoted: "difficulty in locating information about specific features is in itself an important result, […] as people with disabilities may have functional limitations [in comparing phone models] that necessitate certain accessibility features for the phone to be usable by them (e.g., video calling capabilities, HAC, screen reader, AT connection." To address this barrier, the Report includes the Wireless RERC recommendation to train in-store employees about disability etiquette and accessibility features and provide a stable method of in-store customer support for those with disabilities.

Finally, concerning continued industry partnerships, the Report highlights the Wireless RERC encouragement for mobile manufacturers "to continue to incorporate users with disabilities into all stages of the design process" to improve accessibility and usability.

Conclusion

With the exponential growth of connected technologies that bridge the digital and physical environments, the industry charges forward with the release of services, devices, and applications that transform how we live, learn, work and play. Regulatory agencies realize that the release of new technology often outpaces the regulatory process, and therefore, agencies are soliciting greater public input. For some people, policymaking may be perceived as remote to their daily lives, but many decisions that affect access to technologies, services, and programs are made at the federal level. In particular, the Federal Communications Commission (FCC), U.S. Department of Homeland Security, National Telecommunications & Information Administration, U.S.

Department of Labor, and the Access Board. These policy initiatives are not unilateral decisions. Stakeholder input is sought and assessed in efforts to create rules that both protect the consumer and encourage innovation, investment, and market competition. These sometimes-competing priorities may present unbalanced representation in the FCC's record. Industry positions are well documented, but engagement and input of disability access viewpoints are often underrepresented. As communications technologies continue to be interwoven into the fabric of our culture, a greater responsibility falls to consumer stakeholders to engage in the process, where their voices can be heard, and concerns reflected in rulemakings and multiple agency policy decisions. All stakeholders must be vigilant to ensure that regulations that encompass current and future technologies – the anticipated and the unknown – are inclusive of the experiences and expectations of consumers with disabilities.

Meeting the Needs of People with Disabilities in our Nation's Emergency Alerting Systems: Past, Present, and Future

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Abstract

National emergency alerting systems are utilizing more wireless technologies that offer more inclusive design and usability features. Each generation features enhancements on consumer devices that increase more timely and accurate location-sensitive alerts. The national alerting system has evolved over the last 70 years to represent a multitude of systems that can reach all Americans everywhere, all the time. Important to its evolution has been understanding how alerting systems work, the capabilities of devices which receive alerts, and then through exploration, gaining knowledge on what operating parameters of a device best fit an individuals' needs, lifestyles, and modes of receiving the emergency alerts and notifications rapidly. The vested cooperation and work of government, industry, research institutions, people with disabilities, Non-Government Organization (NGO) representatives, and the emergency management community will continue to advance solutions that ensure inclusivity and usability by all Americans.

This paper will provide a snapshot of the development of our nation's emergency alerting systems to explain where they came from, where they are and where they may be in the future via a historical framework of the origins of national, state, and local alerting. Next, it will present how stakeholders are working together to enhance alerting capabilities, particularly by addressing the critical need to include people with disabilities from the beginning of planning, training, service, and system development. Finally, it will suggest areas for future alerting authorities to examine and future research to be conducted. Some key questions include: What improvements should the government and industry make to enhance alerting capabilities, especially for people with disabilities? Are there multimodal platforms that have helped to advance inclusiveness? Will 5G, Internet of Things, wearables, and next-generation technological efforts change things?

Keywords: national emergency alert systems, EAS, WEA, FCC, people with disabilities, wireless technologies, emergency management

Introduction

The first national alerting system, CONELRAD (Control of Electromagnetic Radiation), was established in 1951 to allow President Truman to address the nation in the event of a foreign attack (CONELRAD, 1951). The system was designed to prevent enemy missiles from using broadcast signals to reach target locations. It required all broadcast stations to cease normal programming so that the President could deliver a national emergency message.

CONELRAD was replaced in 1963 by the Emergency Broadcast System (EBS). Under EBS (FCC, 1963), the Federal Communications Commission (FCC) required all broadcast stations to install and operate special EBS equipment starting in 1976. EBS used an over-the-air alert signal that consisted of a special two-tone attention signal followed by a two-minute audio message to the public. In later years, the FCC, Federal Emergency Management Agency (FEMA), National Weather Service (NWS), and industry started an interagency cooperative program that resulted in the voluntary development of hundreds of state and local EBS plans. A nationwide EBS monitoring structure was developed using the EBS plans. These plans defined how state and local officials could access EBS and send early warnings and alerts to their localities and communities for natural and human-made emergencies. In 1994, by Report and Order, the FCC passed rulemaking to transition EBS into the Emergency Alert System (EAS) (FCC, 1994). Between 1994 and 1997, multiple rulemakings were undertaken to make EAS a solid replacement by expanding beyond traditional broadcast to include cable and wireless cable systems, with an architecture flexible enough to allow for future technology changes. EAS required provisions for persons with hearing and visual disabilities (Mitchell, 2005), including text, audio alerts, activation of alerts on NOAA Weather Radio (NWR) owned by blind individuals and others as a personal way to receive targeted weather information. These radios were tuned to local radio station subcarriers.

Modernizing National Emergency Alert Systems

It was not until 1997 that the first EAS was activated. The EAS had to meet a Presidential Requirement to make the nation’s broadcast and cable systems available within 10 minutes for a Presidential national emergency message. It required a shorter EBS attention signal, the same two-minute audio message, but added a digital signal so that television stations and cable systems could display a text of the critical elements of the alert. Stations and cable systems use the elements to produce a text crawl on their video screens. EAS equipment could operate unattended and automatically for receipt and broadcast of alerts. Station personnel could program the EAS equipment for certain alerts that affected their audiences. The digital signal also contained location codes that specified the locations of the emergency. Alerts could then be targeted to only areas affected by the emergency. The FCC maintained a list of the many different critical elements that made up the digital signal. The list is updated in coordination with FEMA and NWS and through FCC rulemakings.

The EAS equipment continuously monitored the over-the-air signals of other radio and television stations for receipt of emergency and test messages. Broadcasters were required to monitor at least two over-the-air broadcast signals for alert messages so that there is more than one path for receipt of alerts. It set up a nationwide monitoring system similar to the EBS.

With the creation of the EAS, EBS state and local plans were updated to reflect the new capabilities of the equipment. Nonetheless, when it was implemented, there was no viable internet. The nationwide EAS monitoring structure operated independently of the internet, and it linked to FEMA and all state officials through the EAS plans.

A few of the updated plans contained input from organizations representing people with disabilities. Also, one of the field tests for the new EAS protocol conducted in Baltimore was attended by organizations representing people with disabilities to demonstrate the new EAS text component for use as a crawl on television screens. Previously there was no method available to develop a text for display automatically. This was an important inclusion because vulnerable populations are often those most seriously injured or die during emergencies, often outliers to incidents that directly impact their ability to take protective actions. It was further enriched with the FEMA Implementation Guide, which in Section 3.5.4 provides direction on developing text to speech (Paragraph 25).

Under EBS and EAS, FEMA has had a program to provide protection and emergency power to selected broadcast stations. These stations play a key role in the EAS monitoring structure. Additionally, certain tests allow state and local officials to participate with their own on-air messages. They have proved their importance by providing emergency information to the public during large-scale disasters such as hurricanes and widespread power outages and wildfires.

Official government alerts are developed by accredited officials using special protocols and equipment on secure systems. Two of these systems are the National Weather System (NWS) which issues weather warnings, and FEMA's Integrated Public Alert and Warning System (IPAWS), created in 2006, which is internet-based. The Emergency Alert System (EAS) and the Wireless Emergency Alert (WEA) system are two main delivery systems. To receive alerts from the above systems requires a device that can get your attention. These include television and radio receivers, landlines and wireless devices, cable systems, sirens, wearable devices, and select appliances. Social networks such as Facebook, Twitter, Instagram, etc., and local private systems also disseminate alerts. Some of these non-governmental alerts may not be fact-based or reliable. Innovative and transformative devices that stimulate emergency communication conveyance will continue to be improved and developed to ensure a robust future of wireless technology and next-generation delivery of messages and alerts to everyone.

Incorporation of Inclusive Emergency Alerting

By 2004 and for another decade, concerns of the FCC with issues regarding public safety during emergencies were accompanied by more than a dozen Executive Orders, Federal statutes, and rulemakings to further the goals of assuring that individuals with disabilities were included in accessibility to wireless alerts (Mitchell et al. 2008; FCC, 2011). Major progress towards inclusion occurred with a major policy shift at the FCC, amending their rules in 2005 "to ensure that people with disabilities have equal access to public warnings (FCC, 2005). Overarching legislation played a key role in moving the dial on inclusivity, especially the Americans with Disabilities Act, Titles II, III, and IV, which had provisions to ensure accessibility to emergency communications for people with disabilities (ADA 1990). Two decades later, the 21st Century Communications and Video Accessibility Act of 2010 codified the rights to accessible emergency information now and in the future (CVAA 2010).

Role of regulators. Other important entities working to include access and inclusivity were regulators such as the Department of Justice and Department of Homeland Security, who addressed preparedness and access during emergencies to ensure equity to people with disabilities. The U.S. Access Board, National Organization on Disability (NCD); the private sector such as CTIA-the wireless association, the National Association of Broadcasters; disability advocacy organizations such as Telecommunications for the Deaf and Hard of Hearing, Inc., National Federation of the Blind, are examples of conscientious multi-stakeholder organizations involved in efforts to ensure inclusion. In particular, key recommendations of the National Council on Disability (NCD) echoed what these and other entities stated as critical to emergency management communities, which was - to ensure that government, state, and local authorities should incorporate the needs of people with disabilities into all parts of emergency planning documents and practices (NCD, 2014).

The 2019 FEMA IPAWS subcommittee also included a few organizations representing people with disabilities. This, in part, led to the subcommittee report under Recommendation 13 stating: "Ensure alerts can be multilingual and understandable to all, including persons with access and functional needs, and people with limited English proficiency. For example, vibrations and light can be used to get the attention of deaf or hard-of-hearing persons, videos can be captioned, and American Sign Language (ASL) interpretation can be included and available to transmit alert messages (FEMA, 2019).

Role of Technology. On the technology side, in the early 2000s, wireless technology was on the cusp of becoming a revolution, and WIFI was still considered a novelty. Today, it is ubiquitous, impacting every aspect of our daily lives. The first handheld cellphone was introduced in 1983, today more than 96% of American adults own a cellphone, and 89% always have it in reach (CTIA, 2020).

A Survey of User Needs (SUN) by the Wireless RERC in 2018 found that ownership or use of a smartphone by those individuals with a disability was 88%, an increase as compared to 71% in 2015-2016 and 54% in 2012-2013 (Moon, 2020). These data indicate that adoption rates are continuing to increase. One critical aspect of wireless technology remains its role in emergency communications during disasters. Many individuals with disabilities depend on their devices during an emergency to provide lifesaving information. Recognizing the need for more accurate and timely alerts during emergencies has been a challenge for those most involved in developing response and recovery solutions.

Industry also sought to create inclusive tools for individuals with disabilities. In 2019, CTIA relaunched www.accesswireless.org to keep pace with the latest information about wireless resources and tools available for people with disabilities, seniors, veterans, and their families and caregivers. The Global Accessibility Reporting Initiative (GARI) database allows users to search and compare devices and apps, while the CTIA database of industry resources is a detailed list of the devices and services offered by wireless carriers and our community partners (CTIA, 2020).

On the front line of delivering critical emergency notifications was the National Weather Service (NWS), which collaborated with the FCC and FEMA and adopted the EAS digital signal so that broadcasters and cable systems could directly monitor the over-the-air NOAA Weather Radio (NWR) signals with their EAS equipment. NWS maintains over 1,000 NWR transmitter stations covering all 50 states, the US Territories, and adjacent coastal waters. There are people with disabilities who rely on NOAA radios to provide information during weather emergencies.

The wireless revolution and adoption of handheld devices moved national alerting systems to a new level of importance. In 2008, the FCC issued regulations to implement the Wireless Emergency Alert (WEA) system. WEA allows those who own wireless phones and other enabled mobile devices to receive geographically targeted alerts. The alerts are text messages that inform users about the imminent threats to safety in their area. WEA uses the original EAS attention signal plus a new vibration sequence to get the attention of cell phone users. Almost all commercial mobile service providers have voluntarily agreed to participate in WEA as per FCC regulations. They include receiving and transmitting four classes of alert messages, Presidential Alert, Imminent Threat Alert, Child Abduction Emergency/AMBER Alert, and Public Safety Messages. All alert messages must meet certain criteria with respect to urgency, severity, and certainty. WEA Amber alerts must meet certain law enforcement requirements. Cell phone users can opt out of receiving some alerts, but not the Presidential alert.

Today, participating providers must support the transmission of a WEA alert message that contains a maximum of 360 characters of alphanumeric text. They are also required to support alert messages that include an embedded Uniform Resource Locator (URL), which refers to an address to a resource on the internet or an embedded telephone number. The geo-targeting capability for alerts is addressed in the FCC regulations, as well as transmitting Spanish-language characters. NWS is a WEA message alert originator. The FCC has allowed state and local officials to send tests of WEA to ascertain its effectiveness. A small number of properly trained governors, county and city officials have become authorized alerting authorities. Some cell phone carriers may not have the facilities to provide total signal coverage to all areas of the country.

Other important actions have been implemented to extend the reach of emergency messages and alerts. FEMA established the IPAWS program in 2006 by Presidential Executive Order 13407 (FEMA & IPAWS, 2020). Its mission is guided by the IPAWS Strategic Plan: Fiscal Year 2014-2018 to provide integrated services and capabilities to federal, state, local, tribal and territorial authorities that enable them to alert and warn their respective communities via multiple communications methods" (IPAWS Mission statement 2020). Executive Order 13407 further mandates that the federal government "include in the public alert and warning system the capability to alert and warn all Americans, including those with disabilities and those without an understanding of the English language." The Integrated Public Alert and Warning System office is working endlessly to build a stronger and more inclusive alert and warning system (FEMA, EO13407).

FEMA IPAWs has worked through the years on assuring alerts are accessible to all, including its improvement of the delivery system so that people with hearing and vision disabilities are able to receive emergency alerts in multiple formats. "Using an alert system called the Common Alerting Protocol (CAP), videos, audio and links can be included in alert messages, allowing people with disabilities to access the same messages as everyone else receives" (FEMA, 2020). IPAWS has become the alerting framework, though in most cases, alert systems, such as EAS, WEA, and NWS, work cohesively to provide emergency messages to the public using the full capabilities of the internet and over the air monitoring.

Role of Social Media. Social media sites have become an additional resource by which emergency information is shared (American Red Cross, 2008). It is estimated that more than 4,000 different social media sites exist with thousands of additional subnetworks. The book, Disasters 2.0 takes a deep dive into the intersection of social media and emergency management. It notes the potential for rumor and misinformation to spread more quickly because of social media's informal structure and, therefore, the ability to send unverified posts (Crowe, 2012). Facebook and Twitter are among the most highly used tools. By contrast to traditional media, they often "report" on incidents faster than traditional emergency outlets like FEMA, which must vet the dissemination of an incident before posting (NRC, 2011). Some posts lead to public confusion on what actions to take, and therefore the term "trust but verify" becomes more important during situational incidents.

Crowdsourcing goes by many definitions. Most commonly in emergency management, it is recognized as a way in which a collective of individuals addresses a challenge that could not be done by any single individual or community/organization. The aggregated findings often provide action steps helpful to emergency management's effective response to a disaster (Crowe, 2012). Usually, the activities of the "crowd" will self-correct as the event changes over time. Regarding disaster response, it can be categorized into groups, including virtual volunteers, business and non-governmental organizations, traditional media, and local volunteers. This has proved beneficial domestically and internationally, especially in impacted areas or with cohesive groups sharing common bonds, such as communities of people who are deaf, blind, mobility challenged, or elderly. By example, the need for transportation or shelter. While crowdsourcing can be the fastest conveyance of critical disaster-related information, it must be tempered and analyzed properly. It is still somewhat rare for crowdsourcing to be formally used by emergency managers (Crowe, 2012). It is often viewed as unvetted and therefore not as reliable in disaster operations by government agencies. Further, it is important to recognize that false information from unauthorized officials can occur on social media platforms. Hence, verifying social media alerts is imperative. The alerts transmitted on the aforementioned government systems should be used to verify alerts. After receiving social media alerts, consumers are always encouraged to access other media outlets such as local radio and television stations.

Other systems provide alerts through apps on cell phones, computers, and other mobile devices. Taking advantage of these resources can add a layer of information as they use different sources to access and transmit alert messages, such as satellites, GPS, or emergency management communications facilities. Some states, cities, and private industries have established their own alert systems. People can sign up to receive these alerts on their cell phones or other mobile and home devices. In addition, many communities continue to maintain and utilize sirens to alert the public.

Charting a Transformational Inclusive Future

Emergency communications systems must afford vulnerable populations the ability to have access to lifelines during emergencies by using multiple platforms and delivery networks. Interoperability and flexible systems can and should be adapted for emergency management and the public to receive timely, user-friendly emergency messages and alerts on any device. Redundancy and reliability are crucial aspects of emergency notifications and alerts.

Trusting the source has also proved important to how individuals do or do not take protective action when they receive an emergency alert on their device. Several studies of the Wireless RERC have indicated this is particularly true among people with disabilities. One study on WEA and people with disabilities hypothesized that greater awareness and exposure to WEA messages would increase trust and appropriateness of individual responses to alerts. The results supported the hypothesis. Respondents who had prior knowledge about WEA were more likely to take immediate action based on the information in the message, less likely to be uncertain about what actions to take, and less likely to doubt whether the emergency alert applied to them (LaForce, 2016)

Between 2014 and 2015, the Department of Homeland Security, Science and Technology Directorate (S&T) awarded Georgia Tech’s Center for Advanced Communications Policy a grant to research and develop how to optimize the ability of message receipt by people with disabilities. The key technical aspects were investigating and testing vibration, audio, and light cadences and strengths on mobile devices to increase the perceptibility of alert notifications by people with sensory disabilities. In undertaking this project for the S&T directorate and in the previous year under contract with IPAWS Project Management Office, several similarities surfaced regarding making alerts and warnings more viable for people with disabilities. For example, conclusions and recommendations in both noted (1) the importance of the use of ASL during emergencies; (2) improving geographic accuracy in transmission of alerts; (3) including people with disabilities in the design phase of alert features; (4) increasing public awareness and education of WEAs; (5) improvements needed to WEA alerting signals; and (6) the need for incorporating ASL into message content (U.S. Dept. of Homeland Security, October 2015). Both projects also suggested that additional WEA related features should be investigated for next-generation WEAs, including (a) enhancing the WEA attention signals (light, sound, vibration strengths, and customizable pitch) to optimize accessibility to people with sensory disabilities, (b) applying a vibration (V-Rating) scale to WEA-capable devices, (c) providing maps within WEA, (d) adding links to get further information or ASL videos, (e) effective translation software, (f) ability to distinguish severe and extreme alerts, consistent on all phones, (g) customizable by the time of day for AMBER alerts and (h) opt-out feature resets after a year.

Regarding S&T, outgrowths of findings from the focus groups (Mitchell, July 2015) and refinement of the prototype based on user needs feedback, especially for people with hearing loss, provided important findings. Focus group results showed that subtle changes in the smartphone design impacted usability for people with disabilities. Data concerning the vibration, sound, and light attention signals indicated a strong need for manufacturers to improve handset effectiveness for people with and without disabilities. Assistive technology device alerting mechanisms and WEA-enabled cell phones have a wide range of amplitude, frequency, cadence, and duty cycles in their sound, vibration, and light signals. Implementing a V-Rating would better determine the compatibility of a wireless device with their abilities and, therefore, optimize their receipt of WEA messages. These would have included designing future phone models with the goal of increasing the effectiveness of vibration and the other signaling features in mind. It was also recommended that the FCC release a rulemaking that included prescribing a specific light cadence for WEA messages. A visual light alert would enable all lighting sources on the phone (e.g., power light, screen flash, picture flash), and these light sources should encompass both the top and bottom range of the device. Incoming WEA messages should be transparent and detectable by the mobile phone's Bluetooth system so that the alert can be transmitted to wearables and other connected devices.

The deliverables and extended outgrowths provided an opportunity to better analyze the WEA landscape and anticipate where the positive changes in research, technology development, and industry practices could set an agenda for future activities regarding access to WEA messages, thus saving more lives during life-threatening events (Mitchell, October 2015). Comments filed before the FCC used evidence from Wireless RERC, IPAWS, and DHS S&T-funded research. The comments identified gaps in WEA effectiveness along what we termed the WEA Message Continuum (i.e., message creation, sending, and receipt) (Mitchell, January 2016). This included considering limitations potentially introduced by the system itself, the alert originators, the device on which the messages are received, and the recipients. Additionally, groundbreaking work on the importance of ASL in emergency alerts hopefully contributed to IPAWS' ability to inform the general public and people with disabilities and contribute to the education of emergency managers. Takeaways from both projects included new smartphone applications and devices that could enable alerting authorities to send more detailed information. The detailed information from mobile applications could include maps, hyperlinks, and lengthy text (LaForce, October 2016). It was viewed then and still is today as important for federal agencies like DHS, IPAWS, FEMA, and the FCC to continue working with researchers, industry, and end-users to create more robust forms of multimodal alerts and warnings.

A faster, more efficient future. Improvements in technology continue to change and enhance the usability of multiple platforms during emergencies. Next-generation technologies such as wearables and high-performance transmissions such as 5G systems are now being deployed for commercial use by businesses and the public. 5G will provide increased speed for cell phone messages, including receipt of emergency information and alerts. 5G will also provide a quicker download speed of message content.

An interview conducted by T-Mobile and shared on their news website said, "Imagine 5G connected smart glasses that harness the power of artificial intelligence and give the person real-time audio feedback to help navigate a supermarket, eliminating the need to ask for assistance from someone at the store. With greater network speeds and capacity because of 5G, these data-driven solutions will only lead to greater independence and efficiency for people with disabilities. New advances like facial recognition will tell them who is approaching, bus and train routes will be easily accessed, food on shelves in the supermarket identified. The world really opens up" (T-Mobile, 2019).

CTIA, in comments filed at the FCC, noted their position that partly because of faster speeds and reduced latency, 5G networks would particularly benefit people who are blind or have low vision because of its ability to provide enhanced location accuracy while navigating different venues. It also has the capacity to support real-time, location-based information, which can be relayed directly to users. Through the Internet of Things, home automation systems will boost independent living options such as audio assistants like Google and Apple, smart voice commands to activate lights, interact with homecare and healthcare providers at higher speed rates, those who communicate using American Sign Language and a plethora of wireless applications (CTIA, 2018).

FEMA continues to train officials in the protocols for using IPAWS so that they can successfully develop accurate messages for transmission on IPAWS. FEMA is working on expanding IPAWS to include new services and industries via the Internet of Things.

FEMA's IPAWS Program Management Office (PMO) has identified emerging technologies and assistive technology products that support or provide direct alert and warning capabilities for people with disabilities, including braille readers, ASL, and video remote interpreting. The IPAWS PMO is also encouraging industry and academia to meet the needs of all people (FEMA, Assistive Technologies, 2020).

We also have new internet-connected appliances and wearables. Appliances and wearables connected to the above alert systems may provide consumers with emergency alerts. Consumers should determine if any new device they purchase is connected to the internet and the above alerting systems. Engineers are in the early research stages of designing 6G systems but focusing on 5G is most likely viewed as a future endeavor by mobile wireless companies. Some of its offerings will be even higher speeds, lower latency, and masses of broadband. Researchers and scientists are talking about 6G going beyond a "wired" network, with devices acting as antennas using a decentralized network not controlled by a single operator. If everything connects using 5G, 6G will set these connected devices free, as the higher speeds and lower latency will make instant device-to-device connectivity possible (Boxall, 2020). As things move closer to the reality of 5G and 6G integration, industry, working with the government, will define the regulations.

Exploring all options. What can we do to get alerts when the internet or WIFI networks are unavailable? Part of the EAS system operates independently of the internet. It relies on the monitoring of over-the-air broadcast signals for receipt and transmission of alerts. This part of the EAS nationwide monitoring structure does not use the internet or WIFI to receive alerts from authorities. Therefore, radio and television stations and cable systems, and NOAA Radios have access to alerts outside of the internet and WIFI through the EAS. Likewise, if cell service is unavailable for receipt of WEA messages, broadcast stations and cable systems still likely have the capability to send alerts.

The FCC and FEMA have been conducting tests of IPAWS and EAS (with and without the internet) to over 25,000 broadcast stations, cable systems, and national networks. They have found that the test results show audio and text (TV crawl) presentation problems that need to be corrected by radio and television stations and video providers. For example, sometimes the audio is incomplete or low volume, the video crawl is unreadable, or it goes by too fast on the screen. The FCC is working to address these problems. The FCC also has a reporting system for the tests and the State EAS Plans.

In closing, training, while not addressed in this paper, remains of great import because it holds promise for the utilization of aggregated technology to train both emergency management but also the public to quickly institute the timeliest response solutions during a crisis, whether human-made or natural. The best advice is to stay connected to your devices and be aware of your environment. Ensure that your devices are programmed to receive alerts. Verify alert messages by accessing other media sources. If you hear that bad weather may be near, check that you can receive alerts on your devices, including during the overnight hours.

The goals of the Wireless RERC have always been that everyone must have access to alerts anytime, anywhere and that all consumer devices should be inclusive of all people with disabilities. In doing so, everyone is connected. While we cannot reduce the number of annual disasters, we can increase the coordination, reliability, and effectiveness to maximize response and safety for emergency management and the public. Working toward a common goal of providing fast, reliable, trusted emergency notifications will enable people with disabilities to take appropriate protective actions in an emergency. So, keep tuned in. Your life may depend on it.

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Stakeholder Outreach and Engagement Initiatives

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Abstract

Stakeholder participation and engagement is one of the key aspects of the Wireless RERC's mission. The RERC values feedback from stakeholders to ensure the integration of wireless technologies into society to enhance individuals with disabilities' ability to achieve independence and quality of life. Our model emphasizes receiving input from people with disabilities and other experts in the field because of the perspective and knowledge that they possess. Therefore, this paper focuses on the Wireless RERC's efforts to engage with vested stakeholders through our monthly newsletter, online newsroom, social media, workshops, and the State of Technology (SOT) event. This paper also highlights themes over the years in regulatory filings and our monthly newsletters to synthesize our efforts and envision the future direction of the research team.

Keywords: policy initiatives, regulatory filings, technology, design, user needs, accessible wireless technologies, broadband, disability

The Policy Initiatives project encompasses stakeholder outreach and engagement to inform interested actors on regulatory and policy initiatives. The dissemination project is responsible for the Technology and Disability Policy Highlights (TDPH) newsletter, maintaining the Wireless RERC online newsroom, managing social media presence, and developing and producing workshops and the State of Technology event. These efforts are meant to share knowledge about technical, policy, and practice solutions for accessible wireless technologies and services to facilitate a dialogue amongst stakeholders, provide specific design elements and user needs feedback, and reconcile differences for the optimal delivery of accessible wireless technologies and services. Through engaging existing partnerships and networks and cultivating new ones, the Wireless RERC maximizes the reach and impact of communication efforts on policy, practice, and the research community. For example, the TDPH reaches 2800 subscribers directly via email and extends to a much greater audience through social media. At the time of this writing, we engage 1,271 followers on Twitter (@CACPGT_wRERC), and 424 follows on Facebook (Wireless RERC), with over 890 members in our LinkedIn Group (ATPG), and 417 subscribers to the Wireless RERC YouTube Channel with more than 230,000 views. From October 2016 to October 2020, the Wireless RERC's social media presence on Twitter alone reached 543,745 profiles/people directly (i.e., the number does not include retweets).

This paper focuses primarily on the TDPH and the workshops, providing a summary keyword analysis of the TDPH issues from 2016-2020 to illustrate the breadth of topics covered. Workshop summaries are also detailed to highlight the collaborative nature of engagement, bringing together stakeholders with differing perspectives and common interests to tackle wireless access, equity, and inclusion challenges and opportunities for advancement reported in this SoT Forum Proceedings.

Technology & Disability Policy Highlights Newsletter

A vital element of the Wireless RERC's success in the policy realm relates to its continual monitoring, assessment, and evaluation of legislative, regulatory, and policy initiatives related to influencing technology access, technical accessibility, usability, and inclusive outcomes. The TDPH tracks and reports on local, regional, and national public policy events and recent wireless technological advances that have implications for individuals with disabilities. Over the years, it has created a loyal following and led to discovery evidence and collaborations with other stakeholders on areas of mutual interest.

Figure 1: Word Cloud from Keyword Analysis (2016-2020)

Over the last four years, the top ten most prominent themes/keywords in TDPH content included access, emergency, accessible, research, services, devices, conference, assistive, Act, and digital. These trends indicate that the phrase "accessibility" became less abstract since its entry on the top five list in 2016 (Table 1). The industry, and its vested stakeholders, replaced this broad term with actionable and concrete terms such as research, technology, devices, conferences, and broadband. An assessment of the terms highlights that the field of accessible wireless technology has focused its efforts on expanding access to mobile phones, emergency services, telehealth, websites, consumer products, and autonomous vehicles. The field has also worked diligently to increase its research and knowledge based on the experiences of people with disabilities to ensure greater inclusion. The exponential growth of research and assistive technology since 2016 indicates a shift of funding priorities on a local, state, federal, and private level to explore effective systems of self-monitoring for students with learning disabilities, technology as a mechanism to create social connectedness for people with disabilities, best practices for virtual meeting experiences, smart environments that support independence, and many more topics related to wireless technology accessibility for people with disabilities.

Table 1. List of Top 5 Most Common Words For 2016, 2017, 2018, 2019, 2020

2016	2017	2018	2019	2020
disability	disabilities	emergency	access	access
wireless	wireless	services	policy	services
accessibility	information	research	conference	accessible
communications	technology	communications	research	assistive
FCC	FCC	inclusive	devices	broadband

The keyword "smart" did not make it into the top ten, suggesting that the smart technologies domain within the field of access and inclusion may still be emerging. Alternatively, the absence of this keyword could indicate that other forms of technological advancements, such as artificial intelligence (A.I.), took priority during this time. However, the content analysis did show that developers have expanded innovative "smart" technologies into home life, with many of these technologies aiming to increase independent living. The last four years have seen technological advances from startups, major technology companies, and scientists. Some of these developments include Mapp4All, Right Hear, Hopkins PD App, AlterEgo, Social Robots, TalkBack, "Smart" prosthetics, smart city applications, and advanced assistive garments such as gloves, glasses, and pants (The National, 2018; MIT News, 2018; Gearburn, 2020; Benton Institute for Broadband & Society, 2020). The "smart" home technologies primarily focused on increasing independence for people with disabilities and older adults (Georgia Tech News Center, 2017; TechSAge, 2020a; TechSAge, 2020b). These technologies increase independence by automating specific tasks and making it easier for these populations to navigate their homes without assistance. These developments, some on the market and others still in the development phase, show great promise for improving access and inclusion of individuals with disabilities.

The 2016 annual TDPH content analysis showed a push to next-generation communication with the emergency services system, namely text-to-911. By 2020, several cities, such as Santa Barbara (CA), 34 of 97 Minnesota cities, Denver (CO), and most cities in Texas had done so. However, this progress in integrating text-to-911 is not yet widespread across the country. However, the FCC has developed a registry of localities and counties that accept text-to-911 calls (Public Safety Answering Point (PSAP) Registry, 2021).

In 2017, the rapid acceleration in developing wearable and assistive technology maintained its momentum throughout 2020, despite a global health pandemic. Devices such as Echo, Alexa, wearable gloves, pants, and glasses have increased mainstream and trade media presence. In 2017, a sampling of the keyword "disabilities" showed that wearables and assistive technology were covered in this order: vision, hearing, mobility, and cognitive. However, the TDPH newsletters have since demonstrated a slightly different trend in development. A sampling of the keyword "disabilities" from 2017 to 2020 indicates that wearable and assistive technologies were developed for hearing and speech disabilities and subsequently covered in the TDPHs almost the same number of times. Thereafter, mobility-related assistive and wearable technology and then cognitive devices were covered.

Figure 2: Word Cloud form 2017 Keyword Analysis

2017 saw the rapid acceleration of research, development, deployment in sensor technology, wearables, and digital communication. Content covered under the wireless, information, technology, and FCC topics reflect these advancements, covering artificial intelligence (AI), augmented reality (AR), virtual reality (VR), the internet of things (IoT), 3D printing, robotics, wearables, emergency communications access, and autonomous vehicles. In 2017, Nucleus 7, the first cochlear implant fully integrated with the iPhone, was approved by the U.S. Food and Drug Administration. A Google Glass app was created to work as a communication assistant for children on the autism spectrum. Sign-To-Text, a prototype Smart Sign Glove, is advancing the goal of bridging the communication gap between people who primarily communicate using ASL and people that use spoken languages.

Augmented reality and virtual reality continued to advance rapidly, with new technologies allowing for great increases in resolution, computational power, and portability. Relúmĭno, launched in 2017, is a Samsung Gear VR app that pairs the headset with the user's smartphone camera to make images more accessible through magnification, color contrast adjustment, outlining objects, and screen filtering. Microsoft's second HoloLens featured a built-in AI co-processor to make mixed reality[90] smarter. The AI co-processor will allow the device to perform more functions without relying on the cloud, faster processing times, and increased mobility. Meanwhile, Apple announced its new augmented reality platform, ARKit, a free programming framework that lets developers and consumers create their augmented reality applications. 2017 also saw virtual reality used in immersive digital therapy to reduce phantom pain in people with spinal cord injuries. Artificial intelligence boomed in 2017 like few other areas in tech, with big tech companies like Google, Apple, Microsoft, and Facebook have invested heavily in AI. Companion robots that science fiction had promised finally hit the U.S. Leading the way was robot assistants, like Mayfield Robotics' Kuri. Kuri is a companion robot that can offer users various personalized reminders and

[90] According to Microsoft (2020), mixed reality is “a blend of physical and digital worlds, unlocking the links between human, computer, and environment interaction” (p. 1).

communication options, such as home security surveillance and a virtual assistant for various tasks through a small, human-centered form factor and interface.

2017 marked the implementation of many of the previous administration's regulatory rulings between 2010-2016. In 2017, there is an evident upward trend of adopting and integrating previous rules on access and inclusion in the digital space for minoritized, rural, and disability populations. This growth is evident by the top five most common words used. In 2017, the word "information" rose twenty spots from 2016. This rise of "information" highlights the prevalence of Federal Register notices for stakeholder input documented in the TDPH. Much of the legislative and regulatory activities reported in the TDPH were responsive to advances in technology. For example, the FCC addressed the granularity at which wireless emergency alerts could be geographically targeted. Through the last quarter of 2016 to 2017, the FCC also sought stakeholder input on regulatory, technical, and consumer issues related to the fusion of broadband and health care delivery, mobile coverage across rural America, access to 9-1-1, transitions from legacy text telephone communications (TTY) to Real-Time Text (RTT), enhancing emergency alerts, hearing aid compatibility of wireless devices, and of course, the decision to partially repeal the 2015 Open Internet Order, reclassifying internet once again as an information service.

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In 2018, the accessibility and prevalence of emergency alerts came under fire in response to the 2017 increased incidences of hurricanes and wildfires. In response to many people, particularly those with disabilities, either not receiving proper emergency notifications or inaccessible alerts, the FCC published the *WEA Second Report and Order and Second Order on Reconsideration* [15-91; 15-94] requiring wireless providers to deliver emergency alerts to more granularly targeted geographic areas. Based, in part, on the Wireless RERC's research findings, the Order also mandated that all emergency alerts be retrievable and remain on the consumer device for at least 24 hours (FCC, 2018a). Also, drawing from the Wireless RERC's recommendations, the

Order reestablished the importance of accessible emergency information for people with disabilities. The Fall 2018 TDPH shared feedback from partners on the WEA messages during a national test. Commonly reported issues with the WEA test included: the lack of accessibility, inconsistencies based on carrier and or device, and the message format. Though significant strides have been made, national tests of the WEA system show that much progress remains. The FCC now routinely updates its FAQs on WEA alert accessibility.

The applicability of the Americans with Disabilities Act of 1990 (ADA) (as amended) to websites, much to the dismay of many stakeholders, particularly consumers and digital businesses, has long been interpreted by the federal courts with the burden of proof falling on the individual or group that has experienced differential access to websites. This burden of proof on consumers stems from the fact that the ADA does not explicitly address access to websites for people with impairments and disabilities. As a byproduct of this remiss guidance, the federal courts are often split on addressing website accessibility if there is no corresponding physical location for the business. Some courts concur that the ADA covers website services even if there are no corresponding brick and mortar locations. At the same time, other courts indicate that there must be a physical location attached to the website for the ADA protections to be employed. Secondly, even if the ADA does apply, businesses do not have explicit standards to adhere to and to what extent these standards must be followed. Presently, the primary guidance available to companies is the Web Content Accessibility Guidelines 2.1 (WCAG) developed by the World Wide Web Consortium (W3C), not a government agency. Moreover, the WCAG 2.1 guidance has a range of guidelines that can be met, making it difficult for companies to know how much of WCAG's standards they should follow to be accessible and avoid lawsuits.

Figure 3: Word Cloud form 2018 Keyword Analysis

It is worth noting that the Department of Justice (DOJ) has consistently (in letters and amicus briefs) taken the position that coverage of "public accommodations" includes digital and virtual settings, including websites. Unlike some federal courts, the DOJ also has not included the caveat that website accessibility must be attached to a physical location to be enforced. This issue remains a complicated concern, leading to countless attempts to legally implement safeguards for vulnerable populations such as people with disabilities.

In 2018, several senators wrote a letter to Attorney General Jeff Sessions, urging his office to issue guidance and regulations for whether website accessibility obligations included protection under the ADA. The senators assert that the ADA's provision to ensure physical access to "any place of public accommodation" should extend to digital platforms. Without any official guidance from the Department of Justice, the senators argued that the number of plaintiff lawyers who have exploited the law's ambiguity and filed lawsuits against small and medium-sized businesses had risen 521% from 2005 to 2017. The concerned senators request that the Department of Justice brief the Senate clarifying whether the ADA extends to website accessibility and file statements of interest in ongoing litigation involving this matter. With the requested guidance still forthcoming, numerous state court cases are weighing in on this matter.

In 2020, the *Online Accessibility Act* [**H.R. 8478**] was introduced in Congress by Congressmen Lou Correa (D-CA) and Ted Budd (R-NC). The *Online Accessibility Act* (OAA) aims to amend the ADA to include a website accessibility compliance standard and limit private parties' lawsuits until other remedies are exhausted. In recent years, the number of online retailers has drastically increased as digital commerce continues to grow. However, along with this growth have come substantial website access lawsuits. More website access lawsuits have been filed against retailers than any other type of business. COVID-19 has underscored the consequences of the government negating to employ website compliance regulations so that consumers can use online services for basic needs. The Act aims to provide a "predictable regulatory environment" for online commerce to ensure equitable access to all customers. Current website accessibility compliance available to retailers is the Web Content Accessibility Guidelines (WCAG). However, WCAG is not explicitly required by any federal law. The OAA will give these guidelines the force of law by deeming online businesses and websites compliant with accessibility standards if their site achieves "substantial compliance" with WCAG guidelines. The OAA is under review in the House Energy and Commerce Committee, but phrases like "substantial compliance" have yet to be defined. As these policies and regulations remain under consideration,

The collective content analysis also demonstrates the incremental growth of accessibility in the democratic process. In 2019, Colorado passed the *Modifications to the Uniform Election Code* (**HB19-1278**) and *Voting Access for People with Disabilities* (**SB19-202**) Acts granted Coloradans with disabilities the ability to vote independently privately using nonvisual or low vision access technologies. In 2020, the COVID-19 pandemic spurred alternative methods to in-person voting. This major shift in voting policy for most states is of particular interest to our TDPH content analysis because before 2020, this concept almost does not appear at all. Both keywords, “access” and “services,” contain several articles about increasing access for people with disabilities and other eligible voters to voting during the pandemic. For years, disability advocates have recommended alternative ballots as a reasonable accommodation as voting places are often inaccessible. In 2019, when Colorado passed the vote by mail legislation for all voters, it was considered progressive and radical. Now, it is viewed as a necessity for public safety. 2020 may herald the coming of more accessible, app-based voting options in more progressive regions in the country. While in other regions of the country, 2020 also saw proposed bills aiming to curb voting access, which could have adverse consequences for people with disabilities if passed.

Finally, the rise of the term "broadband" in our TDPH over the last four years is encouraging. In 2014, broadband, as a public utility, was reclassified from an information service to a telecommunications service. This reclassification granted broadband protections under Section 255 of the Telecommunications Act, requiring equitable access by people with disabilities. Despite this progress, by Fall 2017, FCC Director Ajit Pai removed regulations and restrictions on broadband companies regarding disclosure and transparency of service caps.[91] In addition, forty-five Congressmembers penned a letter in response to the FCC's *Notice of Inquiry Concerning Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion* [**GN Docket No. 17-199**]. The stakeholders expressed concern on several matters. One such matter that expressed opposition is the weakening of high-speed internet by allowing mobile broadband to be considered equivalent to fixed broadband. In addition, it seemed that accessibility to reliable broadband was being undermined by the rollback of the network neutrality rules by the FCC in 2017. During this period, there were few protections against broadband data caps, throttling, and delays.

For the next couple of years (2018 and 2019), the term Broadband did not make the top 100 topics and was counted only 62 times between these two years. Many of these citations appear towards the latter half of 2019. In October 2019, the FCC published an *Order on Reconsideration* [**WC Docket No. 10-90**] to increase high-speed broadband networks to underserved Americans through the Connect America Fund. Thereafter, proposed modifications to the Lifeline Program in December 2019 addressed increased broadband by making broadband adoption a potential goal of the Lifeline program. As a result, the term Broadband increased dramatically and rose to number five in 2020. Though the COVID-19 pandemic did spur much of this dialogue, it is promising to see the commitment of service providers to ensuring connectivity.

Leadership Workshop: Using Technology R&D to Effect Policy Change

The Wireless RERC convened Using Technology R&D to Effect Policy Change on April 24, 2018, at the Georgia Institute of Technology. Twenty-nine (29) individuals

[91] Disclosure and transparent service caps refer to the FCC's transparency rule that requires "Internet service providers (ISPs) to disclose information about its broadband Internet access services in one of two ways: (1) by providing it on a publicly available, easily accessible website of its' choosing or, (2) by submitting it to the FCC" (FCC, 2018b, p. 1). If a company chooses to cap certain broadband Internet access services (such as GB caps), they must disclose that; however, FCC Director Pai removed regulations that monitored this process.

from academia, state agencies, and service organizations attended the event. The event's purpose was to examine the practicalities of using R&D findings to:

- Participate in the policymaking process by submitting recommendations in response to proposed rules and regulations of government entities.
- Inform federal technology policies so that they are inclusive of user experiences.
- Contribute to the dialogue on inclusive technology policy as a strategy for advancing organizational missions and goals.
- The Leadership Workshop consisted of panels and presentations in the morning and group discussions in the afternoon. The speakers shared perspectives on the importance of participating in policymaking, how and where to begin, and how to engage leadership in policy initiatives, among other topics. Following are highlights from each session.

Helena Mitchell, Ph.D., moderated the **Importance of Stakeholder Engagement in Policymaking** panel. Helena opened the session with a brief overview of the regulatory process and then the moderated panel discussion. The panelists included Robert Knotts, Donna Platt, and Hamish Caldwell. There was agreement among the panelists around the need to utilize data to inform policy development more consistently and for decision-making. However, access to the data relies on those conducting the research or generating the data to coordinate with officials and the industry. Discussion ensued about data privacy and sharing. Of this, Hamish Caldwell remarked, "Legal frameworks for sharing of data will be more impactful," suggesting that there is not a lack of data but insufficient legal guidance on how best to share data privately and securely. Absent this legal framework, coordination across agencies and optimal use of data in the policy forum are diminished. When asked, *What is the key driver for policy activity, given that you are in the private sector?* Hamish responded, "It's important to bring outside input from stakeholders. Industry-wide representation such as CTIA is critical."

Robert Knotts, Office of Government & Community Relations at the Georgia Institute of Technology, spoke from the academic perspective, specifically that of a research institute. When asked which policy domains he thought should be prioritized, Robert indicated that research policy is essential to detail why conducting research is a crucial activity and address how to explain the data best and transfer that knowledge to the general public. If academia and other researchers do not engage with policy, "More time and effort is spent in the regulatory process which isn't great in the long run." An attendee asked, W*hat drives policy? Is it carrot or stick?* Robert's response, "Consensus is important, and that drives policy. The [critical components require] more people to engage and be organized, [that] really drives policy." Strange bedfellows make a difference. This plays out at all levels."

Donna Platt, North Carolina Division of Services for the Deaf and the Hard of Hearing, spoke from the perspectives of both a representative of a state agency and a person who is Deaf. Donna's answers to the questions centered on providing accessible emergency communications, including text technologies and American Sign Language (ASL) interpreters during disaster response communications. When asked why it is important to engage in policymaking, Donna stated that her continued contact with state and national policymakers "made the difference when my organization needed interpreters." Though it is sometimes difficult to convince organizational leadership to support policy activities, Donna stressed that sustained pressure was key to "convinc[ing] them to change their minds."

Hamish Caldwell, Wireless Insiders Network, provided insight from his experiences working in the wireless industry. In keeping with the idea that scaffolding must be in place to support the technology and policy construction, Hamish's comments centered on collaboration between policymakers and academics, requisites for increasing the power of data, and federal policy as a driver of industry activities. Regarding the latter, Hamish stated, "Policy is the best forum so that the country can operate at a scale we [industry] want to work in." However, he asserted that "It's always great for policymakers to have a tap on what's going on in the educational realm…connecting policymakers to people with in-depth knowledge."

Salimah LaForce presented **The Mechanics of Policy Input**, a brief overview of the value of engaging in the policymaking process and getting started. Salimah emphasized that commenting on federal rulemakings can (a) help frame the issues that all stakeholders will have an opportunity to respond to and (b) inform the development of final rules. Using the Wireless RERC's comments submitted to the FCC as an example, Salimah shared how incorporating the results of their hearing aid compatibility (HAC) survey research into the comments resulted in requirements for wireless volume control standards "to provide effective communication through amplification." She then explained the far-reaching impacts that policy engagement can have on the <u>industry</u> through guidance on accessible technology development and inclusive business practices; and the <u>market</u>, by encouraging the deployment of accessible features in mainstream technologies, which affects the <u>user experience</u> through improved access to and utility of the devices and services, resulting in increased technology adoption and decreased abandonment. In turn, increasing adoption of these technologies by people with disabilities signals to industry that investing in access features benefits the bottom line. The goal is to maintain the reciprocal effect of market changes and user experiences.

Attendees were assigned to participate in one of three small group discussions. They were tasked with distilling the discussion into three takeaways to share with the whole group. The following is a summary of small group discussion topics and takeaways.

Data Sources at Your Disposal – organizational data that could provide support for policy recommendations. Group members began discussing the use of data to inform decision-making in their respective fields. For example, regarding assistive technology (AT) service delivery, one group member stated that "Counselors are making decisions, but often in the absence of data." This reality represents a missed opportunity because many long-term clients generate a "goldmine of data" concerning AT use and its impacts on their lives. The group distilled their discussion into three takeaways:

1. The quality of data matters, and we must take steps to ensure trust and objectivity in the collection and analysis of data and privacy and security.
2. The "politics" of data matters—there must be a willingness to invest in data collection, which means long-term gains over short-term gains.
3. How data is presented matters—presenting data in ways that everyone can understand is key, explaining why data is collected, how data is collected, and the "so what" regarding data collection.

Disability Access Policy Priorities - policy domains that should be on the regulatory agenda to improve parity of access by people with disabilities. As part of awareness of disability access issues, a detailed discussion ensued on interagency coordination. The group members felt that there had been many important achievements in federally funded research and development that apply to policy, technology development, and business processes and practices across federal agencies, state-level organizations, and industries. The group distilled their discussion into the following three takeaways:

1. Awareness – The group suggested that the substrate of inequity across domains was due to a lack of awareness of the experiences of people with disabilities. This inexperience prevents developers, policymakers, employers, healthcare providers, educators, and others from being inclusive.
2. Employment and Training – The group concurred on the need for improving employment outcomes for people with disabilities, targeting the training of both employees and employers on accessible workplace technologies.
3. Inter/intra-agency coordination – The group lamented the time and efforts lost due to a lack of coordination between government programs. One example included service extensions that should bridge the transition of youth and emerging adults with disabilities from K-12 into higher education and the workforce.

Engaging Stakeholders - strategies for encouraging people with disabilities and non-governmental organizations (NGOs) to participate in federal rulemaking. The group discussed the tools available to facilitate engagement. All agreed that a mix of communication tools was needed, and the goal should be to "Meet them where they communicate." Communication is about enhancing how NGOs communicate with stakeholders and facilitating the ability of stakeholders to communicate with each other. The group discussed how this would help build relationships between organizations, especially those with competing ideas or policy agendas. The group distilled their discussion into the following three takeaways:

1. Strategy Innovation – start with *both* a vision (top-down) and with the insights/input of key stakeholders (bottom-up). Then, draw on both for direction and engagement.
2. Have a relatable leader or champion to help bring people to the table.
3. Employ a mix of communication tools common to the target stakeholders. One size (or channel) does not fit all. "Meet people where they communicate."

A representative from each small group presented their three takeaways to the whole group, and all attendees had the opportunity to weigh in on the other group's topics. Finally, the day closed by going around the table and allowing each attendee to state their one takeaway from the workshop. A few of the attendee takeaways/takebacks (to their organizations) included:

- There is a need for more collaborative efforts between state agencies, especially regarding employment policy, since employment is a large part of independence.
- Accessibility stakeholders must find a common language to empower service providers to make a case for inclusion.
- The research field needs to represent data in a way that makes sense to all types of stakeholders because what works for academia may not be appropriate in the policy domain or among practitioners.
- There must be a greater initiative to get people with disabilities and other citizen stakeholders to participate in FCC rulemaking. For example, there needs to be an educational video or tutorial on how to file comments.
- Involve more diversity by plugging into the broader equity issues, including race, class, and gender, and have more diverse representation at the leadership level.

Leadership Workshop: Contexts of Connectivity Leadership Luncheon

The Wireless RERC convened a Leadership Luncheon, Contexts of Connectivity, on April 25, 2019. The luncheon topic focused on how smart connected devices enhance access to public and private environments and support the independent living of people with disabilities. Presenters included Maribeth Gandy Coleman, Associate Director Interactive Media, Institute for People and Technology (IPaT); Liz Persaud, Training and Outreach Coordinator, Center for Inclusive Design and Innovation; Douglas Guthrie, Senior Vice President, Comcast – Big South Region; and Ben Jacobs, Accommodations Specialist, Center for Inclusive Design and Innovation.

Gandy's presentation, **Fostering Awareness, Understanding, and Trust in Smart Environments via Personal Context-aware Tools**, addressed optimizing the value of IoT systems to people with disabilities through design that fosters a trusting relationship between the user and the technology. Gandy asserted that "The overall goal of those technologies is to provide this just in time service or information. Anticipating what you need and then engaging with you at the right time and the right way such that it helps you rather than distracts, annoys, or impedes you." Examples included augmented and mixed reality overlays in the physical environment that support users at different stages of engagement.

Persaud's presentation, **Technology, Teamwork, and Tenacity**, shared her personal and professional journey and the role of assistive and accessible technologies in achieving her goals. "Assistive technology has been absolutely part of my life. Technology is changing. It's removing social barriers, physical barriers helping me make my journey endless while fighting the overall obstacle of independence every day," said Persaud. "If you can control your computer, you can control your environment," she continued and detailed many of the technologies she uses in the home and office to attach documents to emails, type, adjust lighting, open doors, and so on.

Guthrie's presentation, **Comcast: Commitment to Accessibility**, detailed the ways Comcast has risen to the accessibility challenge, particularly for bringing non-visual access to media with voice remote and environmental controls via Xfinity Home's voice commands for lights, thermostat, home security, and cameras. Guthrie noted that at Comcast, accessibility is considered in creating new products so that customers can fully experience offerings. Guthrie stated that "One-third of our households have a disability. We have 1 in 5 people over 65. Twenty-nine percent of Americans are a caregiver. Two million X1 customers have voice control in their homes. That was over a billion voice commands last year. So, it's amazing how these are coming together. We think of accessibility as being at the forefront of creation, listening to our customers."

The program closed with Ben Jacobs' demonstration of the Tools for Life Environmental Controls Lab. Jacobs demonstrated lights with voice controls (Amazon Echo, Google Home), Philips Smart Hue bulbs, Fire TV cube, smart security, video doorbell, smart thermostats, and smart outlets. Jacobs discussed how these devices, though many not explicitly designed for people with disabilities, are nonetheless quite helpful, more affordable than specialized devices and equipment, and more easily attainable, being that they are mainstream consumer technologies. "A lot of times, the consumer technology is more affordable than your medical solutions, which you may have to go through insurance for. Also, it's more accessible walking down to Target or Walmart and bringing the solution home. Another reason why I look at consumer technology is that a lot of times they tend to be just as effective or more effective than a lot of the medical solutions available," said Jacobs. Attendees had many questions for all the speakers but were particularly enthralled with the technology demonstration. However, a central concern was the perceived privacy and security of smart devices. One attendee stated that she found it exceedingly difficult to get some of her veterans with disabilities to accept these new technologies — *Trust*, as Gandy pointed out in the opening presentation, is the barrier to adoption.

Moving Forward

The State of Technology Forum was strategically placed in year five of the funding cycle to serve as a mechanism for outlining critical research, development, and stakeholder engagement activities needed to propel positive change in the field of wireless information technology access, usability, and community, and economic inclusion. Looking at how wireless technologies have diffused into the market among many users can help understand how change occurred and facilitate setting guideposts for what we hope to accomplish going forward. The SoT Forum served both as a systematic retrospective and as a focusing initiative to help "inclusively design" the future of the field. Based on consumer, academia, and government stakeholder input at the Forum, these SoT Forum proceedings propose new research and innovation agendas in the field of wireless access and inclusion (see Chapter 5: Transformations).

In closing, increasingly smart devices can sense, collect, store, and often act upon, or induce user actions based on data received and displayed, bridging physical and digital environments and allowing for innovative approaches to health promotion, community integration, and independent living. With the data exchanged via connected devices and their growing popularity, the Wireless RERC, through outreach and engagement initiatives, contributes to the discourse on the health, wellness, and sociopolitical implications of these technologies, examining how people with disabilities, and by extension society, can reap the benefits of technology, now, and onwards.

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CHAPTER 2: INCLUSIVE DESIGN

Supporting a Transdisciplinary Design Process for Accessible Multimodal On-Body Human-Computer Interfaces

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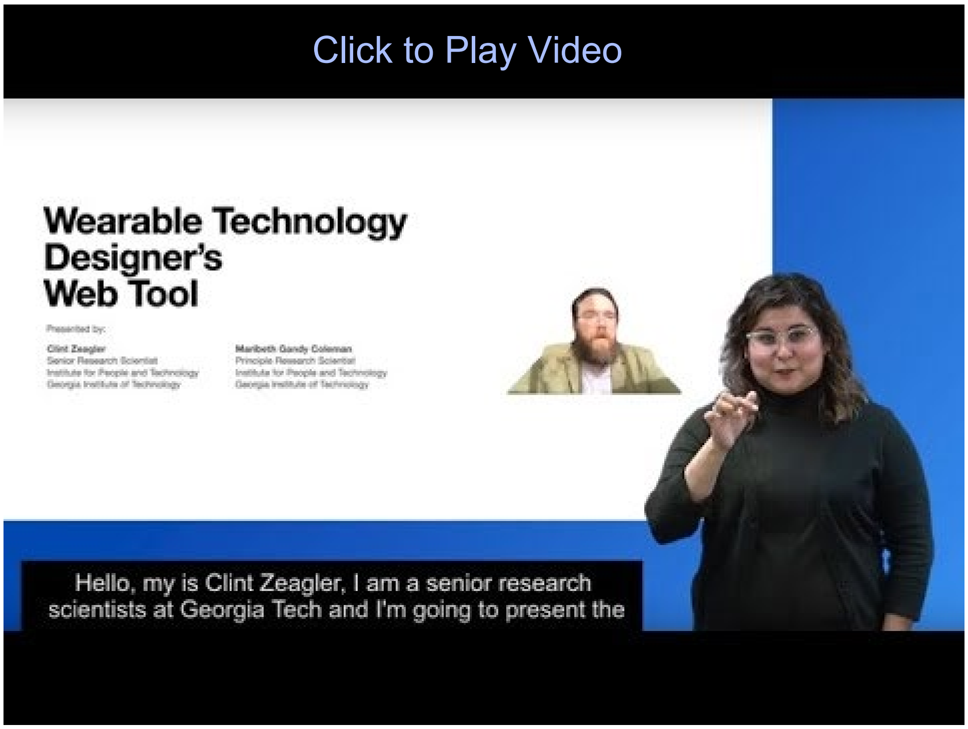

Abstract

With continuing advancements in computing hardware and software, “smart” textiles, and manufacturing techniques, it is now possible to create powerful wearable computing devices. And the ubiquity of wireless networking capabilities provides the critical communication services between sensors, computing devices, and “the cloud” that allow us to create accessible and transformative applications in domains such as healthcare, education, and assistive technology. While there is considerable opportunity for these personalized multimodal interfaces to empower users with disabilities, product designers still face challenges when attempting to design user experiences that are truly accessible. The development of an accessible, wearable device requires more than technical expertise; it must be designed around the capabilities of individual users, the environmental and social context of use, as well as the specific tasks the device is intended to support. Therefore, such a product must be co-designed with inputs from human factors experts, psychologists, assistive technologists, occupational therapists, as well as fashion designers. Presently, there are considerable barriers to translating fundamental knowledge from these fields into specifications for a new wearable product. Therefore, we have synthesized the vast body of existing academic research into a knowledge base ("Body Maps") that practitioners can use to help them make critical design decisions such as sensing approaches, body placement, and input/output modalities. In our current development phase, we are building an interactive software tool that further supports this transdisciplinary knowledge translation to wearable product designers.

First and foremost, this tool considers individual users' physical, cognitive, and sensory abilities; its goal is to help teams create more accessible products. In this paper, we report on how years of transdisciplinary collaborations in the wearable computing domain revealed to us the current barriers related to knowledge translation from one discipline to another and ultimately prompted us to develop the pipeline we present in this paper: from fundamental research to synthesis of a knowledge base, to the creation of an interactive knowledge translation tool utilizing that knowledge. This synthesizing transdisciplinary knowledge into an approachable and powerful web-based expert system tool helps designers explore design alternatives. Lastly, we also discuss our next steps, including short- and long-term analysis of the users and products that result from our tool's use and an annual trend report on wearable product design in industry and academia.

Keywords: wearables, universal design, design, multimodal interfaces

Introduction

The work discussed in this paper is in the tradition of a long history of academic researchers creating toolkits designed to support practitioners and designers from other domains in working effectively with emerging technology. For example, "The Context Toolkit" provided developers with easy access to contextual information and operations to manage it (Dey, Salber, & Abowd, 2001). "The Phidget toolkit" (Greenberg & Fitchett, 2001) aimed to make tangible devices available to designers. Alice (Conway et al., 2000) was focused on lowering the threshold of entry into the world of 3D graphics and virtual reality (VR) programming. The "Designer's Outpost" project found that web designers often used pens, paper, walls, and tables during the early design phases (Klemmer et al., 2001). Landay and his collaborators (Landay & Myers, 2001) built a variety of authoring tools such as "Suede," which supported informal prototyping of speech interface (Klemmer et al., 2000) and (Li, Hong, & Landays, 2007) Wizard-of-OZ prototyping of location-based applications.

Our work has also been informed by our previous experiences creating authoring tools to support practitioners in creating augmented reality (AR) experiences (Gandy & MacIntyre, 2014) as well as the work of others in the AR field. These AR systems required minimal programming and were more available to non-technologists. Examples include APRIL (Ledermann, 2011), AMIRE (Abawi et al., 2004), CATOMIR (Zauner & Haller, 2004), and MARS (Guven & Feiner, 2003).

More recently, industry has been developing knowledge translation products such as Google's "People + AI Guidebook," an online resource for designers creating human-centered AI products. Our work is similar in spirit, intending to translate and synthesize complex research findings into guides and tools for practitioners.

While wearable devices do not necessarily require wireless connectivity, this allows for enhanced capabilities such as coordination between devices, complex computations performed via distributed cloud computing services, sharing of data across applications and platforms, personalized, accessible interfaces for public systems, and communication between humans as well as computers.

The Design Process

This line of research began with creating a policy-first design process (see Figure 4), informed by our formative transdisciplinary collaborations with subject matter experts (SMEs) from fields such as dance, music, and assistive technology.

Figure 1. Multiple versions of embroidered on-body interfaces

These early collaborations led us to explore processes that might help such teams work together more effectively and produce more inclusive useful wearable products. Since 2015, we have been developing an interdisciplinary, inclusive policy-based approach as input into participatory design activities (Baker, Gandy, & Zeagler, 2015; Gandy, Baker, & Zeagler 2017; Zeagler, Gandy, & Baker, 2018). This framework allows transdisciplinary teams to proactively include the potential policy, legislative, and sociological implications in developing technology platforms and the services they provide, helping them proactively anticipate the consequences of the real-world adoption of wearable technology. Ultimately, the knowledge translation tools we create are intended to support the flow of ideas and information between the different stages of this process.

Fundamental Research

The first two years of this project involved performing fundamental research in on-body interfaces, specifically exploring proprioceptive interfaces and the use of vibrotactile displays (Zeagler, 2017). Figure 1 shows examples of the embroidered touch interfaces we created that were designed to support users with vision impairment.

These interfaces were created via design research methods utilizing participatory design and lab-based experiments (Zeagler, 2017). Following this engineering and human factors-centric work, we then focused our research on understanding how people would use this technology in the community as well as how doing so might affect their social and practical lives. For example, how do people around them accept this technology, and does it change their perceptions of the human user? In this study (See Figure 2), we worked with people with sensory disabilities through a participatory design process (see Figure 3) to understand the kinds of assistive technology they've used in the past and what they would like to see designed in the future. Additionally, we conducted an experiment with confederates with sensory impairments and participants from the Georgia Tech student pool to understand people's interpretations of wearable assistive technologies in day-to-day interactions. In the protocol, our participants collaborated in a series of game-based tasks that required communication and collaboration. The participant with vision impairment was wearing and interacting with our wearable device throughout. We collected objective (e.g., response times and device interactions, performance in the game tasks) and subjective (e.g., participants' attitudes towards each other, the nature of their verbal communications) measures during this study. This research produced results that reveal the true needs of this user group and how they think this technology will impact their daily lives, in both social contexts and the assistive domain.

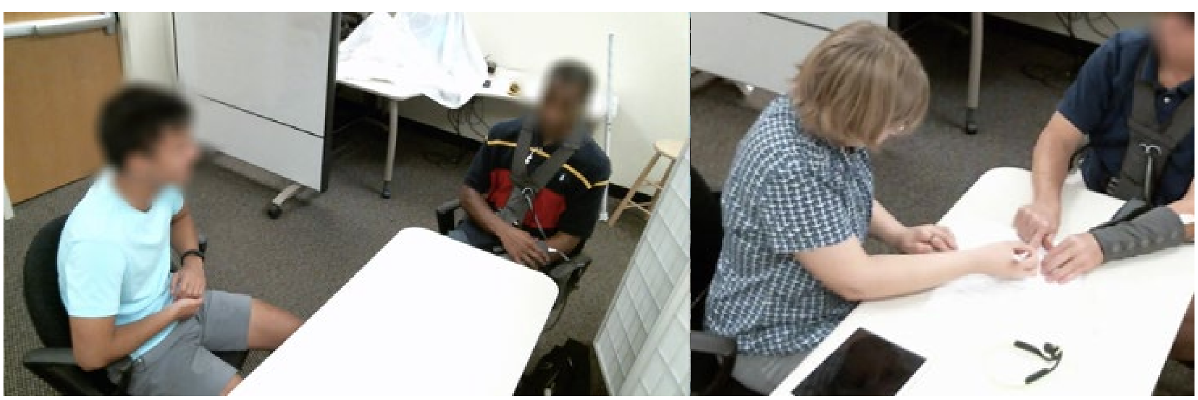

Figure 2. (a) Participants in our socio-technical experiment examining the impact of an assistive wearable for people with vision impairment on interpersonal communication, collaboration, and attitudes. (b) A GT researcher works assists a participant with vision impairment to interact with a tactile version of a survey

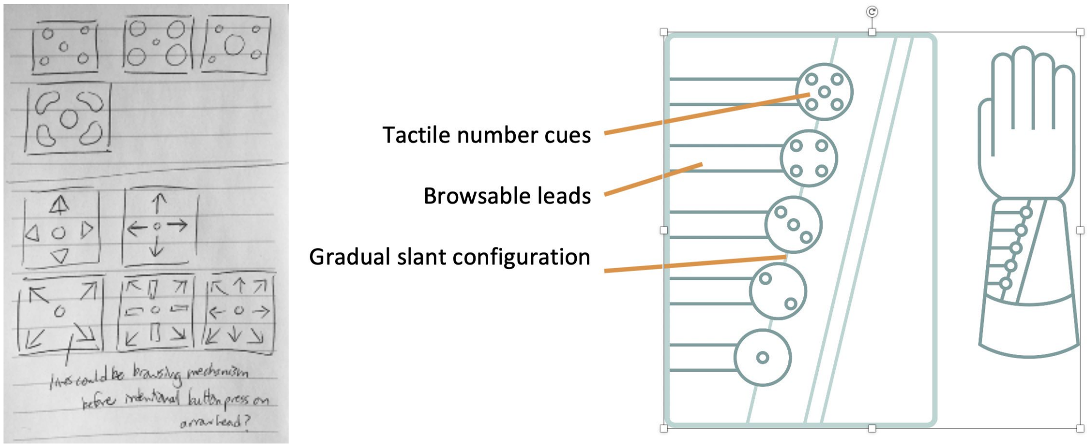

Figure 3. Potential re-designs of on-body interface for assistive wearable based on participatory design experimental results

This process of technology development, participatory design of user experience, and subsequent re-design following our socio-technical experiment highlighted the challenges of designing an accessible wearable that is also appropriate for the user, environmental, and social context. Many industrial product designers do not have the access, domain expertise, or experience to incorporate all of these considerations into their designs. There was a need to develop a knowledge base synthesized from decades of wearable research (hardware, human factors, textile engineering, biomechanics, psychology, sociology, etc.) that could provide guidance to these designers. Which led to the development of "Body Maps."

Building a Knowledge Base

Wearable Technology Design is truly a transdisciplinary endeavor, with teams that can consist of computer scientists, computer engineers, designers, and performers (Zeagler, Gilliland, Fisher, Boyle, & Levy, 2017; (Zeagler, Gandy, Gilliland, Moore, Centrella, 2017). For designers (we will consider all members of a team a designer) to work together effectively, it can be important to create a shared meaning over terms, workflow, and deliverables. In the past, members of our team have developed boundary objects in the form of electronic textile swatch books to help creatives and engineers build understanding over an artifact that lives in the vernacular of both worlds (Gilliland, 2010).

Because the design process in many ways is visual and graphics can aid in creating shared meaning across disciplines, our team developed a set of *Body Maps* with associated design and accessibility considerations (Zeagler, 2017). With access to the body maps, a design team could work together to figure out where on the body a wearable technology device might go and how it might function to be the most useful to most people, including those with disabilities. Because we wanted to bring accessibility considerations to the front of the design process, it was important that these body maps also act as a boundary object for policymakers and experts. In doing so, we integrated the design process into the policy-making process, working out where and when policy experts should work with designers. Policy and design are not separate, but we set out to make the process visible (see Figure 1).

The information contained in the Body Maps is based on a synthesis of over 100 academic papers from the last 50 years on how technology can be and should be worn on the body for optimal use.

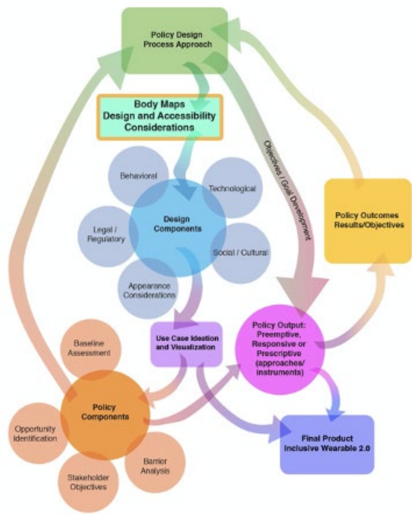

Figure 4. Incorporating Body Maps and Accessibility Considerations into the collaborative policy wearable tech-nology design framework. (Baker et al., 2015; Gandy et al., 2016)

The primary target audience for the Body Maps includes developers and designers of wearable technology. Ultimately, our goal was that all those who design connected wearable technology begin the design process with a better understanding of how their choices affect the accessibility and, more broadly, the usability of the wearable devices they create.

The knowledge base is organized around a list of considerations that designers and creators of wearable technology should take into account as they develop wearable products. These considerations are organized by the requirements of certain types of on-body technology with respect to the types of sensing and input/output the systems utilize and the locations where devices might be worn on the body. The Body Maps are diagrams of the human body with regions highlighted where appropriate on-body devices might be worn (see Figure 5). Some information (such as thermal tolerances) is dictated by the human body, while others (such as networking) are limitations in technology when combined with the human body. Many of the wearable lessons incorporated within the Body Maps come from insights generated while developing assistive technology (Ghovanloo & Huo, 2014), and a large majority of the design considerations have a direct impact on the design of new assistive technology.

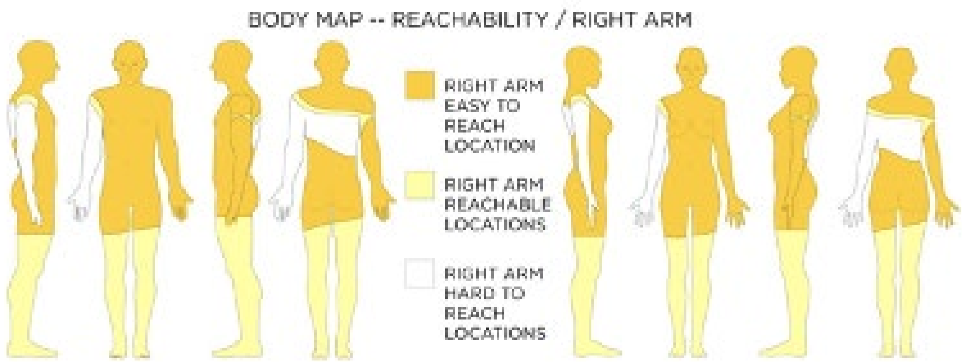

Figure 5. "Body Map 8" – Map of Ease of Reach of Body Locations – Right Arm - When it comes to reach-ability, there are easy-to-reach locations (where your hand can reach without any body movement), reachable locations (where you can move a part of your body to your hand to be able to reach it), and hard to reach locations (such as your center back).

Designing a Knowledge Translation Tool

The Wearable Technology Designers Web Tool (WTDWT) is for anyone working on a Wearable Technology device or project. By answering a set of questions about a potential project (see Figure 6), the tool will create a document full of information, academic resources, tips and tricks, and design methods to help in developing your wearable technology. The tool will highlight places on the body where the device might be worn most effectively (see Figure 7). The questions will also guide thinking about everyone who might use the proposed wearable tech and how to design for the most users to use the wearable technology, making the device more accessible and usable.

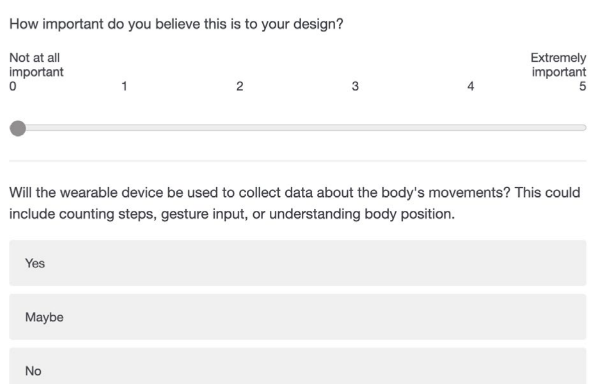

Figure 6. One of the survey questions the designer answers at the beginning of their design process using our tool

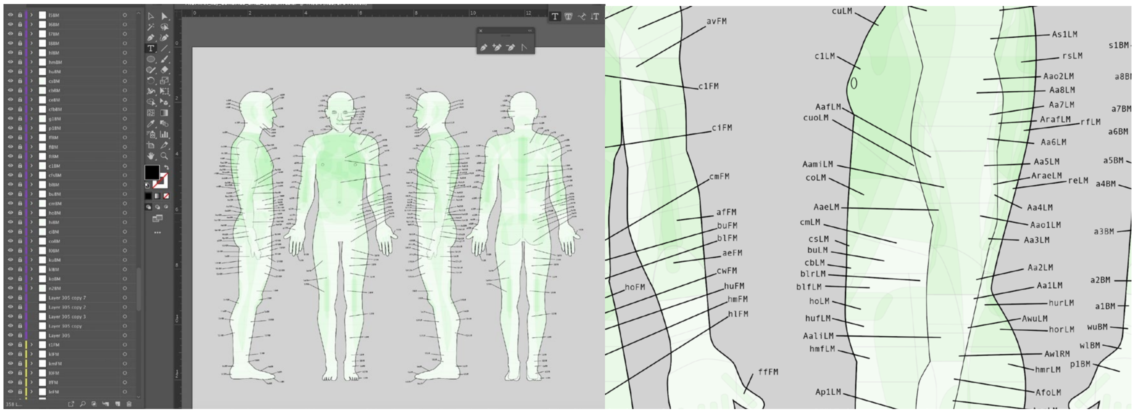

Figure 7. Image assets with metadata which encode the knowledge base information that is then utilized in the interactive designer interface software.

The Wearable Technology Designer's Web Tool: User Experience

The Wearable Technology Designer's Web Tool WTDWT uses knowledge gathered and created during earlier phases of this project to create an application for designers to aid them in working through the design process. The tool is essentially a web survey set up to lead designers to positive and inclusive outcomes by navigating them through the requirements of their proposed device with respect to its intended purpose. The WTDWT is intended to support the team at the formative stage of their product design work. The designer answers questions about a wearable tech concept via the survey. The interactive system will then present a visualization of the human body, highlighting the areas that might be best suited for the device. This real-time interactive graphic helps designers begin to understand how their choices impact the nature of their design.

The WTDWT also highlights in real-time through notifications and additional related questions how those with disabilities would be affected by the designers' choices. For example, suppose a designer answers that they will have a visual display interface. In that case, the system will prompt them with an additional question about how those with vision impairments would be able to interact with the device. In this way, the WTDWT will endeavor to make universal design and accessibility concerns important in the early stages of the design process, thus baking in these concepts into the core of the product rather than requiring additional accessibility add-ons *post hoc*.

Upon completing the survey, the WTDWT produces a report complete with the specialized body map created for the design and all appropriate design along with accessibility considerations. The report will also include academic references for further research and, eventually, wearable tech construction demonstrations and example code.

The Wearable Technology Designer's Web Tool: Underlying Technology

As designers answer the survey questions presented by the Web Tool, the history of answers highlights regions on male and female body maps where the wearable technology being designed might effectively be located. Answers to these branching-logic questions progressively influence the body map presentation. Each answer triggers an associated positive or negative scalar influence factor to be applied to an affected list of male and female body regions. These scalar influence factors are additively combined for each associated body region and are visualized, in real-time, as highlighted regions on the male and female body maps to indicate the degree of suitability of these regions, in terms of reachability, thermal load, weight, social acceptability, etc., for placing the wearable technology under development on the body. The body map visualizations are a type of heat-map of acceptable/unacceptable body locations and are rendered progressively as the designer completes the survey.

Our prototype WTDWT implementation consists of the following components:

- Qualtrics adaptive survey to generate, progressively, the scalar body region influence factors as well as a set of rules to create a design report
- Database and web API to collect survey results and drive a body map visualization web app
- Body map visualization app developed using the D3 JavaScript data visualization library

Conclusion and Next Steps

We plan to distribute the WTDWT to a large and diverse set of users. The WTDWT will be free to use by signing up for the system and completing a short demographic survey covering topics such as education, career, and skillsets. We are currently collecting feedback on the tool prototype from university instructors of wearable product design and the use of the software with students in design and computer science courses. Long term, we will utilize techniques from our previous research in tool deployment (Gandy & MacIntyre, 2014), which includes fostering an active online community of tool users and creating quarterly "touchpoints" (e.g., surveys and interviews) with a subset of users which allows us to collect rich data regarding what types of designers are using the tool, what products they are creating with it, and what emergent strategies the community has developed for getting the most value from the tool. A core mission of this work is that the WTDWT positively impacts the design and engineering community by making the accessibility of wireless, connected devices an important consideration early in the design process. This long-term data collection will allow us to map how tool usage impacts the future accessibility of the resulting wearable products.

We also anticipate comparing users' web tool results against their demographics to look for trends in the industry. This trend report will answer questions such as What kinds of wearable devices are currently interesting designers or industry? (Berglund 2016) What kinds of products are academics researching? What kinds of products are students and artists interested in? Are designers concerned with creating accessible wearable technology? These types of questions and their answers will be important and valuable to industry and academics alike. For this reason, we hope to eventually create a yearly trend report from the web tool's use and data.

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Assessing Wireless Assistive Product Usability with Mixed Reality Technologies

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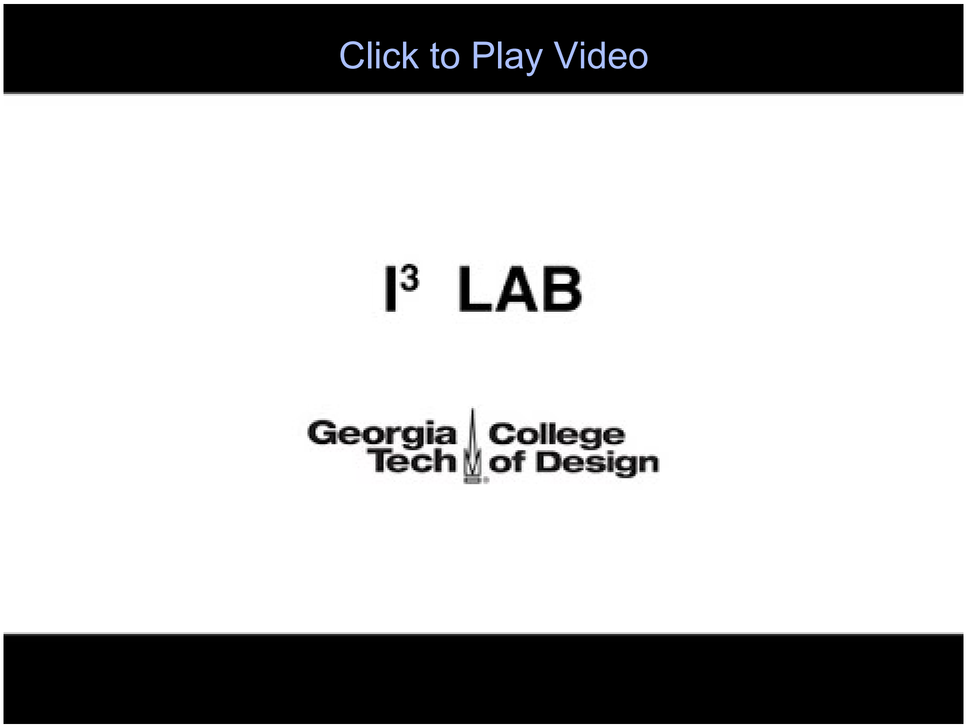

Abstract

This paper focuses on using mixed reality tools, specifically Augmented Reality (AR) and Tangible Augmented Reality (TAR), for evaluating design concepts and soliciting feedback in the design of assistive products. AR and TAR are tools that allow a person to look at an environment where computer-generated elements are dynamically shown alongside real objects. In the context of product development, it allows a 3D model of a product (such as an appliance on a countertop) to be viewed within a real environment. Additionally, it can allow a user to move, operate, and interact with the virtual product. Technologies such as AR and TAR have become more accessible to regular users as computing power has become smaller and more powerful. While use by consumers is still somewhat limited, AR is already finding uses in design. This paper will present the current challenges that must be addressed related to using AR, including implementation and use of AR by designers, the level of validity in representing a product to users with disabilities, and the ability of users to use the technology to provide useful/accurate feedback on a concept compared to manufactured physical prototypes.

Keywords: Mixed Reality; Augmented Reality; Tangible Augmented Reality; Product Design

Introduction

In developing products and services, including wireless applications, it is common for designers to feel that they do not have enough information about users' needs (Bruseberg & McDonagh-Philip, 2002). This is especially true at the front end of a new product design process (Moultrie, Clarkson, & Probert, 2007) when many different concepts are considered. The ability to gather and incorporate needs information is strongly linked to product success (Creusen, 2011). Therefore, a user-centered approach to engage users is commonly used, particularly for assistive products and services.

Once engaged, a design team must be able to obtain valid information and feedback on an evolving design so that it can be iterated in a way that will result in improvements in the final product or service. There are two important components to this process. The first is soliciting information from users that is both comprehensive and accurate. The ability to do this relies on the second component, the presentation of the concept to a user in a complete and understandable way.

Usability testing is one of the most widely used and important methods for evaluating product design (Lewis, 2006). Usability is the effectiveness, efficiency, and satisfaction that users can achieve specific goals within a given environment (ISO, 1998). This means that a product/service concept must be of an appropriate level of fidelity so that a user can use and assess how well a task or objective can be achieved. Ideally, this is done in the context of a real usage environment (home, work, etc.).

To gather information via usability testing, generally, the more realistic the presented concept, the better the user evaluation. Detailed physical prototypes are often used, particularly for evaluating subjective attributes such as aesthetics and emotional appeal, ergonomics and usability, product integrity, or craftsmanship (Srinivasan, Lovejoy, & Beach, 1997). The main drawback with these types of prototypes is that they are both time-consuming and expensive to produce. The time and expense required to produce them mean that they are only available later in the process and after major design decisions have been made. At this late stage, the ability to make substantial changes is constrained by the product architecture already set in place from decisions and testing performed in earlier stages. Radical updates can impact all other parts of the design, essentially setting the design back to square one. Rapid prototyping techniques can speed up some aspects of constructing prototypes, but they do not solve the inability to make late-stage changes.

The dilemma for a product designer is that one of the most valuable times for input is during the early stages of concept development, but the highest fidelity representations that enable the best feedback are not available until later stages. This is a barrier to obtaining the kind of user-informed data that designers need and is important for a couple of reasons. First, the greatest innovations can happen in early design phases before interdependencies and requirements from previous design decisions limit options. The ideal goal is to explore many potentially very radical concepts to identify the most promising directions for further detailed development. The other reason is to identify problems. Design defects generally become more time-consuming and costly to fix the later they are identified (McGrath, Anthony, & Shapiro, 1992). This is for the same reason that major design changes late in the process are difficult to make. A change due to a defect can mean that most aspects of the product need change or re-design to work as intended. The sooner that a concept will likely meet a user's needs and that the design approach is unlikely to be a dead-end, the number of iterations needed to realize a final product and eliminate defects can be reduced.

Categories of Mixed-Reality Technologies

The realistic representation of a concept is the focus of this work. Mixed reality technologies such as augmented reality (AR) offer a way to potentially overcome many barriers to obtaining early feedback on design concepts. First, some definitions are helpful. AR refers to a view of the real or physical world in which certain environmental elements are computer-generated. This is generally referred to as mixed reality since it combines the view of a real-world environment (such as a room) with computer-generated elements added in and seamlessly mixed into the view. This contrasts with virtual reality (VR), where the full view and all elements are fully computer-generated and do not contain any real-world elements.

AR technologies come in several forms. One clear description of the various categories of AR comes from van Krevlan and Poleman (2010). They describe three main categories of AR: Handheld Displays (HHD), Head Mounted Displays (HMD), and Spatial Augmented Reality (SAR). The HHD is currently the most common and easily accessible method to implement AR. The augmented view in these types of applications is often achieved by using a marker, such as a QR code or some other unique marking. Software on the device is configured to detect the presence of the marker and, when identified, replaces the marker with some other 3D object. The effect is that the computer-generated 3D object appears within the environment instead of the marker. These types of applications work much like a camera application, such as on a smartphone. As long as the environment is viewed through the device, the digital object appears just as it would appear in reality (you can get a closer look by stepping closer, walk around it to view other angles, etc.). A drawback to this approach is that a user must continually hold up the device to maintain the view. HMDs can employ several different display technologies but integrate the device view into a headset. This frees the user's hands as the headset keeps the viewscreen in front of the eyes. An example of this kind of device would be Microsoft HoloLens or Google Glass. These devices are mostly seen through a display that sits in front of the eyes like glasses lenses. The devices also contain a camera to perform functions like marker tracking and depth finding, as well as some level of onboard computing power. A drawback to these types of devices is that currently, the resolution tends to be low (less than HD quality), and they have a narrow field of view, meaning that an augmented element can disappear unless looked at almost directly. Since AR headsets are specialized equipment, they are expensive and less common. SAR displays take a different approach by projecting a digital element into an environment. This is the kind of approach used to allow deceased musicians to be integrated into live performances (Peddie, 2017). The projection is made onto a semi-transparent medium. It is even more specialized than HMD technology and requires custom equipment and care in setup to be effective.

Another category is Tangible Augmented Reality (TAR). This can be thought of as an extension of AR but instead of flat markers utilizes a physical component that works in concert with the display technology. The physical part is generally a low fidelity representation of the product that is similar in shape, size, weight, and other attributes. Markers are used for tracking but are attached to components of the physical model as needed. The AR software detects the markers and overlays an augmented 3D view of the matching component directly onto the model. This provides a view of what the product would actually look like overlaid on the model wherever it is placed in an environment (Figure 1). Instead of simply holding a single marker card, a user can pick up the physical model and directly interact with it while looking at the augmented view.

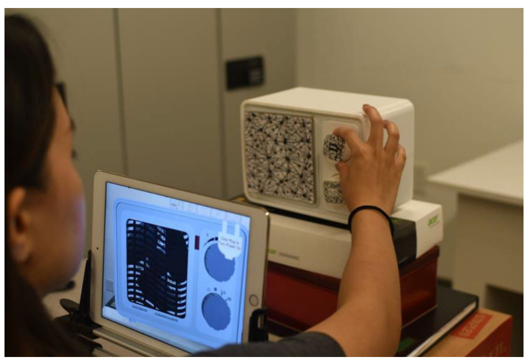

Figure 1. A space heater represented with TAR. Interaction is performed on physical model with results shown via the tablet that is providing the product view

Applications of Mixed-Reality Technologies

The work in this project focuses on HHD technology. The level of availability is one of the primary concerns. There are many common devices capable of supporting AR from smartphones, tablets, and laptops. The commercial availability and ubiquitous use of these devices mean that they are not only available but that users have a level of familiarity with how they are used that would not exist with other hardware. Most users these days will understand how to use and interpret the display of an HHD-based AR. The process and interface are the same as framing and taking a picture. This contrasts with a specialized device such as an HMD device that requires proper fitting and calibration that most users will have no experience with. The wide availability of technology is an important factor for designers. Users' level of familiarity with a technology reduces barriers to getting accurate feedback. It also means that leveraging AR to support design activities may not necessarily require acquiring (and training users how to use) specialized hardware. One big exception are users that are blind or visually impaired. Currently, AR and TAR are highly visually oriented. Additional research and likely technology development are needed to make mixed reality accessible to them.

An important question then would be: is it possible to get the same level of usability assessment and feedback from a product presented via AR with handheld displays as from the same concept presented via a high-fidelity prototype? This question so far has not been answered but could open many possible applications. AR has still begun to find a number of applications in various design tasks, even though there are gaps in the literature related to its use and validity.

There are a few examples of AR applications directly to support design, development, and user interaction. AR has been applied in product development as a tool to enable interactive modification of design concepts with users (Santos, Graf, Fleisch, & Stork, 2003). Using a tracking system, HMD, and a PC-based graphical station, designers can visually present design options using 3D models. The user can comment on elements as they look around, and the designer can immediately modify the design elements that are being viewed. Another common application is a TAR approach combining visualization with physical objects (Billinghurst, Kato, & Myojin, 2009), allowing users to experience an augmented view and manipulate the augmented view by manipulating physical elements (Lee & Kim, 2009). The physical elements are markers printed on cards and placed in front of a user. Users can place cards in specific locations in an environment to see how the product would look if it were physically there. The cards can also be held, turned, and rotated to view how a product would look from any angle. These AR systems can allow views of virtual interfaces, like a touch screen or keyboard, to be overlaid on physical surfaces and allow real-time interaction (Shen, Ong, & Nee, 2010). This can provide users with instant feedback and natural interaction with a virtual product/device (Lee, Nelles, Billinghurst, & Kim, 2004).

Most studies discuss techniques in which AR can be used in product development to visualize concepts, such as in an educational setting (Estrada, Urbina, & Ocaña, 2018). Others have evaluated the use of AR in conjunction with computer-aided design tools used to coordinate the mechanical design/architectural layout with tooling and production (Giunta et al., 2018). However, little study has evaluated the use of AR as a tool for assessing/testing a design (Faust et al., 2018).

Exploring the Effectiveness of AR and TAR in Evaluating Products

There has been some limited exploration of the effectiveness of AR and TAR in assessing products. One of these studies (Choi, Mittal, 2015) compared an AR and TAR representation of a portable, touchscreen mp3 player with the product. Another (Choi, 2019) study compared AR and TAR representations of a portable space heater with the product.

In each of the studies, digital mockups of existing products were created in AR and TAR. Existing products were used to isolate the presentation's impact by making the digital representations as faithfully representative as possible to the product. This was achieved through a validation process before the study began. The validation consisted of having five different people make a side-by-side comparison of the digital, augmented view of the product with the real thing to point out all possible differences in either appearance or functionality. The digital models were updated to eliminate any identified discrepancies, and five new people compared the updated model with the product. This process was repeated until all observed differences were eliminated. The same process was followed for both AR and TAR representations.

With the AR and TAR views of the products validated, independent subjects were recruited to perform a usability evaluation with either the product, the AR version of the product, or the TAR version. Each participant was given a defined set of tasks to perform, executed those tasks, and then completed a USE Questionnaire (Lund, 2001) to assess the product's usability.

The results demonstrated promise with both approaches. In the study involving the mp3 player, 60 students participated where groups of 20 independently evaluated the AR, TAR, and actual product. In this case, no significant differences were found between the usability assessments given based on the AR or TAR representations compared to those given based on the real thing.

In the study involving the space heater, 70 students participated. In this study, each participant did three evaluations based on each of the product representations (AR, TAR, and the product). The order of presentation was randomly assigned. The results, in this case, found something a little different. There was no significant difference in the usability evaluations between the TAR representation and the actual product. However, the usability scores of the AR representation of the product were significantly lower. This indicates that AR by itself is not always adequate and may depend on the product. In this case, the product was controlled by two front-facing physical knobs to adjust temperature and fan speed. The TAR model allowed for natural interaction because participants controlled the product by manipulating the physical model. This interaction did not translate well to a purely AR format with no physical elements to grasp. For example, the turning of a knob turned instead into swipes on a touchscreen. This dynamic was not an issue with a product like the mp3 player since all interactions were touchscreen-based. The implementation of the product in either an AR or TAR view did not change any of the fundamental interactions with the product. We can see through these and a handful of other studies (Faust et al. 2018; Barbieri et al. 2013; Santos et al. 2003; Billinghurst et al. 2009) that AR and TAR can be used to assess the usability of a product concept as accurately as a functional physical prototype, provided that the appropriate mixed reality technology to match the product is selected.

Applying AR to the Design of Wireless Assistive Products

AR would be a valuable tool in developing novel wireless devices and applications by supporting more efficient incremental innovation (improving access and functionality of existing wireless devices/applications). The ability to quickly iterate, test, and evaluate more radical applications of wireless devices and services that take forms that do not currently exist today will be especially important in developing acceptable (and successful) next-generation products.

Many of the same challenges commonly faced by assistive technology producers are likely to be factors that mixed reality approaches can tackle. Developing and testing a new product takes significant resources, which must be allocated effectively (Cooper, 2019). Smaller AT companies tend to devote a much higher percentage of resources to developing products (BIS, 2003). The high cost, especially for smaller companies, makes it important to extract the highest benefit from the investment since the products tend to occupy smaller, niche markets (Cowan and Turner-Smith, 1999). The products may be produced via a custom manufacturing process that may be higher cost than mass production but are flexible and more efficient for smaller quantities. This is important since assistive devices also often carry the need to be highly customized for the end-user.

There are still limitations and unanswered questions. The studies referenced earlier focused on students who are more likely to be familiar with using the newer technologies and have unique preferences and perspectives compared to other demographic groups. One of the objectives of this project was to focus on the use of augmented reality for usability testing among people with disabilities. The goals were to confirm that the technology application is as useful as with other user groups in previous studies and, if there are differences in effectiveness, to highlight them so that AR use can be made more accessible to users while being a helpful tool for designers.

The study also explored the effectiveness of AR and TAR in concept evaluation in relation to other types of representations that are commonly available during the design process, such as sketches, storyboards, or regular 3D renderings. This is needed to understand their relative benefit because there is still some level of effort involved in realizing a concept in AR/TAR (Samantak, Choi 2017). If other methods of presenting a concept are almost as good but take much less effort, then the extra work spent at the start of design to create realistic-looking, interactive augmented models may not be worth the effort.

In future studies, it will be important to understand how product-specific attributes can affect the accuracy of an evaluation based on AR or TAR. Likely, the presence or absence of certain elements on the product may not translate well into an augmented model. This may be because the method of interaction changes, the product type may have some impact, or there may be ways to overcome some limitations that haven't been identified.

New technologies can sometimes get ahead of themselves and get used in situations that they are not particularly well suited to. In the case of AR and TAR, there is encouraging initial evidence that using them during the product design process to evaluate the usability of a concept can be accurate and time efficient. These tools appear to be a possible solution to the chicken and egg problem with getting input for product development. Now it appears possible to be able to explore concepts at the front end of the design process. Time can be spent building concepts out digitally to be fully viewed and function as intended. AR or TAR can then provide a reasonable expectation of usability (efficiency, satisfaction, and effectiveness) without the need for advanced design and testing to create a functional prototype.

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Evolution of the Participatory Design Workshop Process for Reimagining Wireless Technologies

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Abstract

This paper describes the evolution of a series of half-day participatory design workshops intended to expose student designers to real-world problem-solving alongside experts in the fields of aging and disability services and end-users. The workshops were developed as part of the capacity building and training efforts of the Wireless RERC and explore approaches to ensure that upcoming designers of wireless technologies consider how their design helps or hinders their product's potential users. Attendees of the participatory workshops worked through an inclusive design process to identify and define problems, considering the design requirements necessary to meet the needs of target users, with the objective of designing and refining concepts to solve those problems. We describe the design of the workshops, iterations intended to improve on the experience, and our recommendations for conducting similar workshops

Keywords: inclusive research, usability, accessible design, inclusive wireless technologies, technology solutions, problem-solving, disability, design requirements.

Introduction

Wireless technologies are pervasive in our society today, enabling individuals to meet their everyday work, home, and mobile needs. When it comes to ensuring such products are designed to meet the differing abilities of individuals, we have seen significant progress over the years. Yet, people with disabilities and older adults often experience barriers when using wireless technology devices. Thus, it is important to educate those who will be responsible for the form and function of these devices, including existing and upcoming designers, engineers, and scientists, on the benefits of including individuals with varying disabilities in their design process (Moon, Baker, & Goughnour, 2019).

As part of the Wireless RERC Capacity Building and Training project, we have focused on making students and designers aware of the importance of inclusive design while also identifying and designing innovative wireless technology concepts that can enhance the quality of life of older adults and people with disabilities. We have developed a process for delivering a fast-paced, fun, and engaging half-day design workshop that ensures the core value of inclusion is at the forefront of design and effectively guides stakeholders and designers of differing skill levels through the key steps of the design process. This paper describes the inclusive design thinking workshop evolution, and the toolkit of elements developed based on workshop presentation and enhancement iterations.

Background

Design thinking workshops are often used to teach universal design and inclusive design in various industries and applications (Cassim, 2015). For example, design thinking has been used: to teach innovation in business product and service design (Liem, & Sanders, 2013), to encourage innovation in business management and operations (Wattanasupachoke, 2012), and to train healthcare professionals on problem-solving skills (McLaughlin, 2019). The design of wireless technologies presents a perfect case as they are rapidly evolving, found at the core of many products and services designed to address everyday needs. While there have been significant advances in designing wireless products to meet the needs and preferences of people with varying degrees of ability, there are still opportunities for industry to be more inclusive by involving people with disabilities and older adults in that design process to further remove barriers to use (Moon et al., 2019)

These hands-on workshops leverage different components to improve the experience for the participants. Barron (2015) discusses the importance of engaging participants by providing a variety of activities to help "participants think at different levels, which deepens connections between new skills and their existing experiences, making it more memorable" (p. 68). Carefully designing the materials to facilitate the workshop helps guide the participants and ensure the workshop runs efficiently (Koehle, 2000). Variation in the background of participants plays a key role in the success of the workshop. Subject matter experts bring in-depth knowledge of the problem areas and an understanding of the existing solutions. Including end-users with disabilities, who bring diversity to the process, helps designers develop empathy and ultimately results in more innovative solutions. Dym, Wesner, & Winner (2003) reflected on the value of diversity in design sessions that included different stakeholders in the overall design process. And Cassim (2015) described the value of differing perspectives provided by individuals with disabilities, as well as their technical understanding of assistive technology.

In practice, many workshops tend to focus on the *solutions*, with less emphasis on inclusive processes (Dym et al., 2003). It is important to incorporate aspects of the human-centered design process in design workshops, such as introducing empathy and personas to promote a deeper understanding of user needs. More importantly, design may improve if designers view the participants as experts and allow them to co-design. Thus, a participatory design process, where designers work with the individuals and consider them the experts in that domain, increases the student and industry designers' "respect and empathy for the end-user" (Liem, 2011, p.117). To be more inclusive in nature, workshops should attempt to include a range of end-users in the design process, especially older adults and people with disabilities, who are often overlooked in product design (Gandy, 2019).

We developed a participatory, inclusive design workshop process to address many of these overlooked considerations: targeting a diverse group of stakeholders, providing materials to facilitate and guide an efficient design process, as well as encouraging empathy and user-centered design thinking. A primary goal was to identify and define the problem space in-depth, including the key design requirements to provide students with a starting point for innovating new technology solutions. At the same time, the workshops provided attendees with a chance to design their own concept solution – a meaningful activity intended to help them understand the design process and the value they bring as co-designers.

Methods

From 2015 through 2020, a project team from the Wireless RERC hosted four participatory design workshops to refine the tools and methods used to guide the workshops. Over the years, materials were developed to help guide the process. (Wireless RERC, 2016).

The first three workshops (2015, 2016, 2017) were a central component of the single-track, LeadingAge of Georgia annual Technology and Aging Summits (Atlanta). The fourth workshop was organized as a pre-conference 4-hour workshop at the Assistive Technology Industry Association (ATIA) 2020 annual conference (Orlando). Participants in both conferences included: community organizations, service providers (practitioners), industry members, and academics. The LeadingAge of Georgia conferences also included government representatives. For all conferences, the professionals attending include older adults and individuals with disabilities. However, we invited more "community members" from these demographics to join as consumer experts to provide a broader end-user perspective.

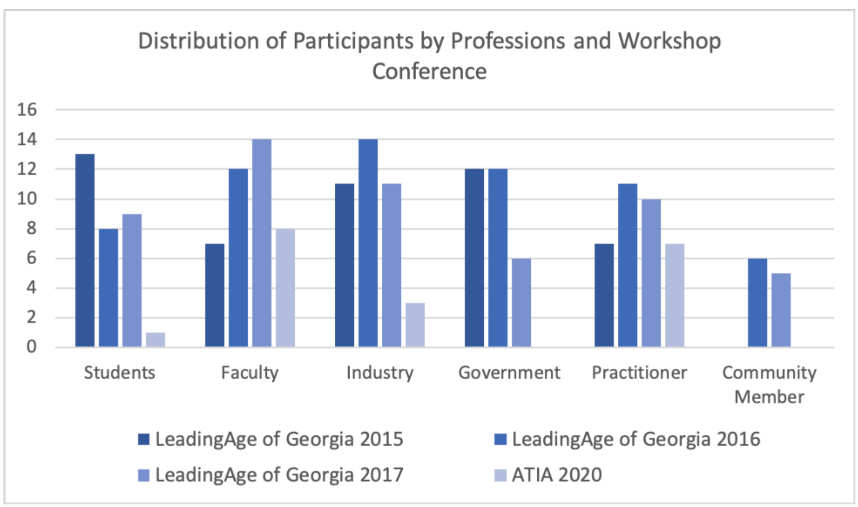

Figure 1: This chart compares the number of participants of different types in each of the four workshops.

For all workshops, we also invited students to add more diversity to the attendee group (Figure 1). We focused on recruiting students from disciplines like engineering, human-computer interaction, and industrial design to leverage their design interest, knowledge of technology, and sketching skills. The number of teams in each workshop depended on those attending, with some members pre-assigned to topics to ensure a balance between experts, students, and designers (See Figure 2).

Teams and Average Participants		
Conference Name	**Number of Teams**	**Average participants per team**
LeadingAge of Georgia 2015	9	5.56
LeadingAge of Georgia 2016	8	7.88
LeadingAge of Georgia 2017	7	7.85
ATIA 2020	3	6.33

Figure 2: This table provides the number of teams at each workshop and the average number of participants per team.

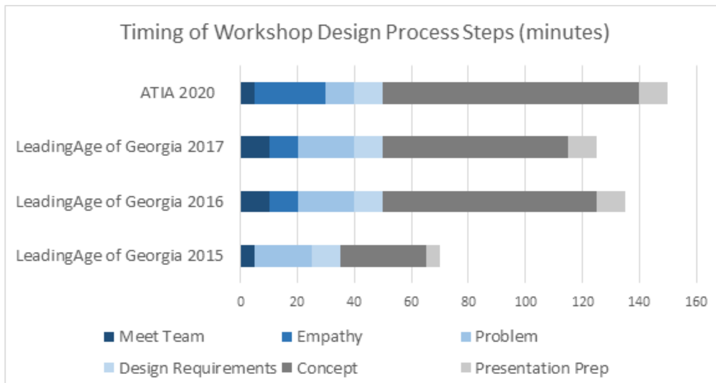

Figure 3: The figure shows the different times in minutes that were loosely adhered to for each step of the workshop design process. Team presentation times were left off this chart due to different numbers of teams with a 5-minute presentaiton time.

Each design workshop consisted of six core elements adapted from the engineering design and design thinking process: Empathy Training, Meet Your Team, Define Problems, Design Requirements, Design Concept, Prepare Presentations, and Presentations (typically five minutes per team). There were slight differences in the timing (see Figure 3) and approach of these sections based on experience from previous workshops and changes made to match our goals for each workshop.

With all the workshops, we provided either themes or specific challenges of interest to constrain the problem discussions. The 2017 workshop included an additional objective of continuing outputs beyond the workshops, so we chose three small businesses working on new concepts for their future product service offerings and three early-stage student projects, focused on different smart home-related solutions, to lead the team design efforts.

In 2015 and 2020, teams chose their theme for design from safety and independence, health and wellbeing, or social connectedness, then started defining the problem by first brainstorming challenges that individuals might face within the constraints of that theme. They then refined that list of problems quickly down to one problem and drafted their problem statement for which they would design. For the 2016 workshop, we solicited challenges from registered participants in advance of the workshop. At the workshop, "Challenge Champions" presented their challenge to their team. Then, team members discussed the challenge in-depth before redefining the challenge in a problem statement that would expand the scope to include other individuals with similar needs. Similarly, the industry members and students selected to lead the 2017 workshop topics introduced their problem space to the teams, who then helped fill in any gaps before drafting their problem statements.

We introduced the empathy training in 2016 and 2017 with presentations on person-first language, different types of disabilities, how these disabilities affect individuals, and disability etiquette. For the ATIA workshop, we expanded the empathy training to include a team exercise on empathy building, both as an ice breaker and to inspire the participants to embrace empathy in their design process.

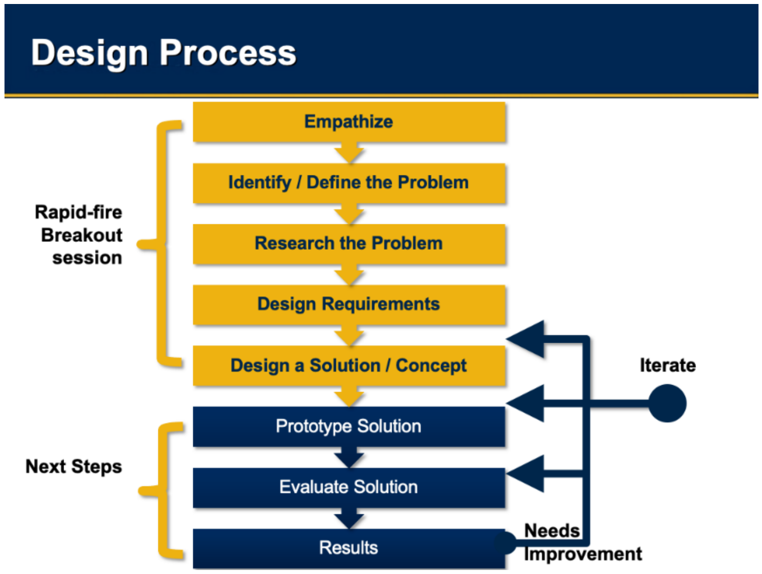

Figure 4: Engineering / Design Thinking process adapted for shortened workshop

While the 2015 and 2016 workshops relied on the team members to consider the abilities and varying needs of the target users, in 2017, we added more formal user-centered design methods, using persona development and empathy mapping. In advance of the workshop, student team leads developed personas based on general user research into older adult users and people with disabilities, including common functional and perceptual challenges. During the design requirements portion of the workshop, the team leads guided the teams through modifying these personas or creating their own based on the user characteristics they deemed most important to consider. Empathy mapping with these personas helps the team define important aspects of those they are considering in the design, including beliefs, attitudes, motivations, pain points, and similar before defining the design requirements. For the 2020 workshop, we modified that approach slightly to focus more on the characteristics of the users.

In all workshops, we encouraged teams to fully consider the design requirements or design elements required for any possible solution and use those requirements at a minimum, as they quickly drafted their concept ideas. Those concepts were then rapidly reduced to a single candidate concept, on which they iterated into their final solution. We encouraged teams to use technology in their concepts but did not instruct them explicitly to consider wireless technology in their designs. This was an intentional omission to ensure the teams would think beyond just an app.

In preparation for the first workshop, we developed a workbook (Wireless RERC, 2015) to guide teams through the design process steps, including timing and suggestions on what information to prepare during their presentations at the end. Instructions in the workbook were modified to match the workshop changes. The latest workbook (Wireless RERC 2020), developed for the ATIA workshop (see Figure 5), was designed to be more generic so that it can serve in the future.

Figure 5: Workshop workbook pages that step the team through the design process.

With the goal of generating new concepts leveraging wireless technology products, we reviewed the team concepts, searching for keywords specific to wireless technologies. Smartphone apps, embedded technologies, wearables, smart home, and voice assistants were common. Of the 26 teams that participated in the workshop and provided their work, some form of wireless technology was explicitly mentioned in 24 concepts (Figure 5).

The remaining two concepts focused on a tech-enabled prosthetic and smart stove/oven safety, both of which could easily be wirelessly connected to deliver alerts or updates to the user or a caregiver. Examples of a wireless technology-enabled concept from each workshop are provided in Figures 7-10.

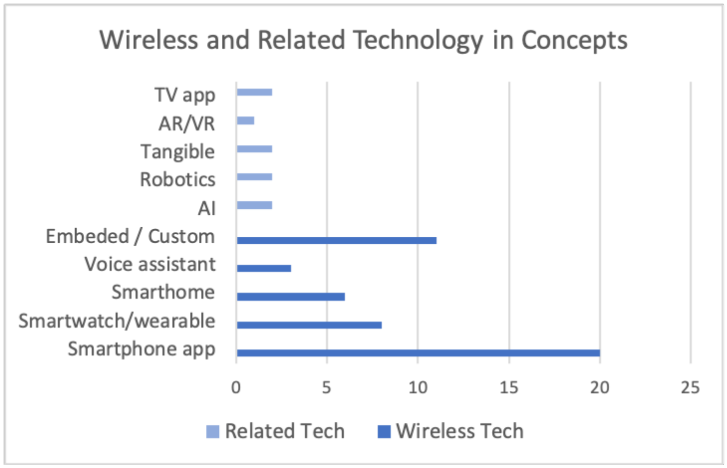

Figure 6: Wireless and Related Technology Concepts.

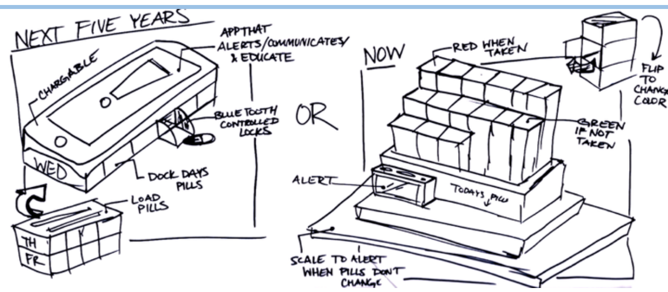

Figure 7: 2015 DESIGN CONCEPT: A product to support medication adherence in an individual living in their own home or on the go. The mobile solution includes a pillbox that snaps onto your phone and uses an app to remind and Bluetooth to unlock the pill container.

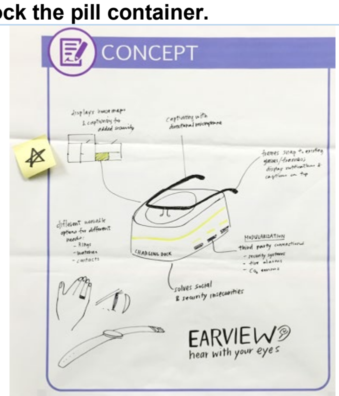

Figure 8: 2016: Earview Concept showing eyeglasses that display notifications and automated captions for individuals who are deaf or hard of hearing; includes charging station with accessory connections. Also imagined as available through other wearable devices such as rings, contacts, and watches.

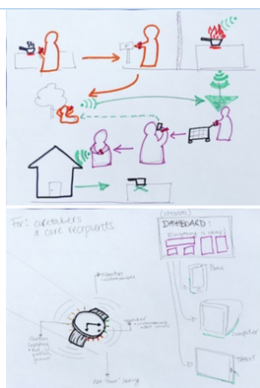

Figure 9: 2017: Ambient Alerting concept drawings showing user leaving home with the stove on and smart home sensing and alerts provided through in-home dashboard display and apps on wearable, mobile, computer devices.

Figure 10: 2020: RideShare concept sketch with mobile and wearable apps supporting a user with intellectual or developmental disability throughout the ride while also updating the remote caregiver

Results

Over the years, we have been able to test different approaches to better understand the critical components necessary to deliver a half-day workshop experience that provides meaningful, educational activity for conference attendees while introducing participants to the application of inclusive design thinking. Specifically, we were interested in problem-solving and considering how wireless technologies can more effectively meet target audiences' needs. Here, we are focused on older adults and people with disabilities. In terms of Capacity Building, we included students as designers in the workshops to help them appreciate the value of the different stakeholders in the process and the value of designing with others rather than just for others. Students were also engaged in planning the workshops, leading/facilitating the teams, and facilitating the workshop in the case of ATIA. Capacity building can continue beyond the workshops, building on the problems identified and design requirements as a starting point for student projects.

The requirement that technology is considered in the concept development phase generally led to incorporating some form of wireless technology in the final concept (figure 5). Certainly, groups had to find a balance between simple, familiar, and connected when considering what would work best for the target users. The Pill Pusher concept from 2015 (figure 7) provides an example of how groups considered what could work at that time versus what might be acceptable or possible in the future. While the original system was more about reminders and tracking medication taking, the future system imagined a dispensing system that could be attached to the phone for dispensing on the go and controlled through the app with Bluetooth.

Recommendations

To ensure the success of a workshop using the participatory process, there are several components to consider based on our experience. These include the following.

<u>Timeline</u>: If your workshop is self-contained or part of a larger conference track, plan your timeline appropriately based on the available time. The sweet spot for the design portion of the workshop is around 90 to 120 minutes, with an additional 5 minutes for each team to present. We would also recommend a speaker relevant to your topic area to attract interest, followed by a presentation on empathy to set the stage and a brief overview of the steps and what you expect from each step.

<u>Facilitators</u>: Having facilitators for each table or up to three tables can help move the teams along. These facilitators should be trained on empathy, have a strong understanding of the process steps, and how to guide teams if they get stuck.

<u>Diverse teams</u>: Since the success of teams at the workshop is dependent on the attendees, and we recommend having at least one practitioner or expert in the domain, a researcher or student designer, an industry member, and at least one person in your target demographic (e.g., older adult/person with a disability). Identifying a conference where practitioners or experts in the domain will be present and ensuring a group of

student designers can participate is key. Market your event to the target attendees well in advance and stay in touch with those interested. We found it helpful to survey attendees during or after registering to gain an understanding of the participants, accommodations, and needs and to help form teams. Assume you will have to help form diverse teams during the workshop due to last-minute cancellations and additions. If you want to include students, know their scheduled semester breaks and other major conflicts, partner with instructors of local design courses to attract students, and offer to pay their admission or provide a significant discount.

Challenge/Problem Descriptions: For workshops where you have less control over who will actually attend, providing a few themes to constrain the problem space, then having teams choose a theme for their group and start the problem discussion with brainstorming within that theme works best. For workshops where the possible attendees are known, soliciting and defining challenges in advance, then asking an expert to explain each team's challenge is extremely effective at focusing teams quickly. It often provides a real person as a starting point for developing a persona, which greatly helps in the design process.

Time management of the overall session can be a difficult balance, as some groups spend longer on the problem identification and definition part of the process. In contrast, others want more time to work on polishing their concept. Facilitators should allow some flexibility in the timeline and help teams choose a solvable problem, where they can understand the problem well enough to define it concisely then develop the design requirements before concept generation. Managing team dynamics can be difficult as well. Some attendees may get caught up in the social interaction of working through the process and thus fall behind with the overall agenda of the workshop. That interaction is an enjoyable part of the process, but facilitators should help get teams back on track.

Workbook/materials: We recommend a workbook to guide the process and time recommendations for each step of the process. Workshop attendees have praised the workbook as helpful for guiding teams without any experience through the design process. In cases where team members are familiar with the process, the workbook may serve as a loose guide as they leverage other expertise to move through the process. Personas or user-characteristics worksheets have proven helpful for groups to ensure design spans different user needs, while empathy mapping worksheets may help teams consider how users experience the problem.

Outputs: It is valuable to consider what a successful workshop means to the team during planning. What are some metrics that your team would use to evaluate the success of the workshop? We used outputs from the workshops such as sketches, design ideas, and contacts from practitioners. These metrics would be used to indicted user engagement throughout the workshop. The number of attendees would additionally provide a metric to measure reachability, recruiting, and marketing strategy.

Conclusion

As has been the case with much of the research and development projects conducted by the Wireless RERC, the COVID-19 pandemic created a challenge for conducting these in-person workshops and offered the opportunity to rethink how this experience could work remotely and thus engage a broader audience. Of course, this would have its own set of challenges, but the considerations from these past workshops provide a great starting point.

The inclusive design workshop process detailed above can serve as a useful capacity-building tool, engaging students in meaningful design activities while providing a unique experience for other stakeholders and conference-goers. The workshops outlined above have also produced starting points for students to explore the problems in class projects and research. To date, selected problems have been shared with specific design courses as a starting point for students to define the problem through user research further and design their own concepts. Some courses focus more on the user research methods, while others focus more on developing the solutions. By providing the same problem to groups in different courses over time and sharing previous work, we expand our understanding of various stakeholders' needs and generate a collection of possible prototype solutions. Going forward, we expect to expand on these efforts, making the problems more accessible to students by adding them to the "Problems worth Solving" website (currently in beta) developed by our colleagues to meet this need.

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Inclusivity, Usability, & the Application of Personas for Technology Policy Design

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Abstract

People with disabilities and the increasingly aging populations characteristic of developed economies represent under-served populations with respective challenges and opportunities for policymakers as well as for industry and the third sector. The ability to maintain independence, quality of life, and social engagement can be facilitated by a number of technological possibilities. Policy is often developed in response to social conditions and to address consequences related to technical developments. Effectively addressing these underlying problems requires designers to have a sense of the populations and contexts they are designing for. Given the nature of social systems, this applies to designing solutions for policy problems and physical design. The inclusion of target populations in persona development and application helps designers, researchers, engineers, and industry collectively innovate solutions to the challenges faced by the aging population and people with disabilities and the society they exist within. More broadly, it can impact and inform the development of policy. In this article, we explore how the concept of design personas could be applied in policy development that could impact the design, development, and adoption of useable, inclusive connected technologies.

Keywords: Policy and Legislation, Information Technology and Telecommunications, Universal Design, Emerging trends

Introduction: Disability and the context of technology design and development

In many societies globally, people with disabilities and the increasingly aging populations characteristic of developed economies represent under-served populations with respective challenges and opportunities for policymakers as well as for industry and the third sector. From the individual's perspective, the ability to maintain independence, quality of life, and social engagement can be facilitated by a number of technological possibilities. Conversely, technologies are often designed and developed in response to user needs, innovations, or dynamic environmental considerations such as regulatory change. Similarly, policy is often developed in response to social conditions and to address consequences related to technical developments. In any case, effectively addressing these underlying problems requires the designer to have a sense of the populations and contexts they are designing for. It is a truism in design that “it is difficult to design for that which you have no experience of.” Given the nature of social systems, this applies to the design of solutions for policy problems as well as physical design. In this article, we explore how the concept of design personas could be applied in the development of policy that could impact the design, development, and adoption of useable, inclusive connected technologies.

Internet of Things (IoT) related technologies, such as wearable devices, voice assistants, and sensor-based applications, can be used to help a person increase their personal independence by reducing inaccessibility. However, confounding considerations include the characteristics of the end-user, as well as the environmental context of use. A useful tool in design, be it technology, services, or policy, is the use of personas. Design tools such as *personas* allow reliable and realistic representations of key user segments for reference (usability.gov). The development of personas can help inform designers, researchers, and engineers on the unique challenges faced by vulnerable populations (e.g., people with disabilities and aging populations) so that they may be able to develop technological, social, and policy approaches to mitigate those challenges.

Iteratively, the inclusion of target populations in persona development and application helps designers, researchers, engineers, and industry collectively innovate solutions to the challenges faced by the aging population and people with disabilities and the society they exist within. In doing so, the development and use of personas that reflect target populations can further increase independence and social participation by incorporating innovative solutions with inclusive policy and accessible technology. More broadly, it can impact and inform the development of policy. “Policies and healthcare systems should rely on quantitative data to ensure the best impact on society, but no database exists that represents the aging population in a holistic and deep way, making it difficult to create effective personas” (Gonzalez de Heredia et al., 2018, p. 2645).

Wireless and Information Technologies: Accessibility, Usability, and Inclusion

Full social engagement, active participation, and maintaining independence are critical social objectives for all individuals but can be especially challenging for people with disabilities and the aging. Recent digital and information-based (ICT) advances such as wearable devices, voice assistants, Internet of Things (IoT) applications, and intelligent agents, made possible by the implementation of faster wireless networks (e.g., 5G), provide new technologically mediated avenues that can help maintain independence for people with disabilities and individuals as they age. A key concern of disability research relates to technologies (e.g., design, accessibility, usability, etc.) and how they function in an assistive manner. Digital and communication technologies can enhance inclusion and increase engagement for the aging. For instance, IoT and 5G networks, applied in healthcare settings, necessitate integrating relevant policies surrounding these technologies with health information and design policies. Designers, developers, and policymakers often operate independently of each other, resulting in products, services, and even policy, that do not meet the needs of the users, lack interoperability, or are hindered by obstructive implementation (Gandy, Baker, & Zeagler, 2017). By incorporating inclusive policy design, digital technologies are more likely to align with the target audience's needs (Ratwani et al. 743). Such systematic change will also result in future applications of these technologies facing fewer challenges moving forward. But the success of these technologies depends on the effectiveness of their design and modes of adoption (Denker and Baker, 2020).

In terms of technologies, while many entities—including device manufacturers, application developers, network carriers, and other organizations recognize the importance of technology usability, considerably fewer make an inclusive design process central to component development (Moon, Baker, and Goughnour, 2019). To create digital technologies that truly meet the needs of all users, accessibility and, more broadly, usability, need to be considered during each stage in the development process. Active end-user involvement becomes particularly important when designing applications to be used by people with disabilities due to their specialized user requirements and applicable regulations, standards, and guidelines. If the technology development process incorporated UD and inclusive design thinking as well as the active participation of people with disabilities, the end result would be greater independent living, more personalized care, more flexibility and mobility, and better employment and education outcomes through next-generation wireless technologies.

Finally, we propose that given the nature of policy as a constructed “object,” many of the objectives that apply to technology development can likewise apply to the inclusive design of public policy (Gandy, Baker, and Zeagler, 2017). Specifically, we explore using a design process tool – personas, to inform the formulation and implementation of policy development.

The Design of Artifacts

In design thinking, early and recurrent incorporation of representation of stakeholders offsets these flaws. The approach used in this paper is to incorporate a stakeholder perspective early and often through the development of and framing from personas. The persona is uniquely qualified in facilitating policy development because it can represent critical characteristics of a stakeholder. Basic demographic information, relevant psychological profiles, material descriptions, social circumstances, pertinent personal connections, and other significant information personalized to both the stakeholder and the policy development process can be articulated. This helps both ground the quantified and qualified aspects of the policy and its design. It also provides helpful clusters of interlocking information that help describe a narrative of the stakeholder.

For instance, consider the broad category of people with disabilities. Normative age-related declines on top of a pre-existing mobility disability can create new barriers to everyday activities and interrupt adaptive strategies previously employed to bridge functional limitations. This gap represents a prime area for innovation, both in terms of technological solutions as well as in terms of public policy that can facilitate greater social participation and inclusion. Research conducted by Georgia Tech researchers has explored the use of data-driven personas to provide information about the needs of this population and inform the design of support services, tools, and technologies. Based on end-user data collection, observations, imagery, and anecdotal data were entered into a database by activity with the following categories: assistance from others, devices used, mobility aids used, home modifications, physical environment accommodations, damages to the home, barriers to mobility, changes over time, and ideal solutions. Personas were created by selecting a major issue or challenge identified during data collection and then adding details derived from study data but assembled in ways that protected the identities of the research participants.

Personas were developed to reflect the challenges identified in the aforementioned domains. Some 30 challenges and associated adaptations were identified during the study, from which ten major issues were extracted associated with mobility challenges in and around the home, in this case, due to age-related declines. Each of the ten major issues was supplemented by photographs and other data to provide context. Data and observations from multiple participants were often combined into one persona to protect participants' privacy and better represent general trends seen across participants. Components included in the persona development were insight into the individual's environment, the remaining abilities and functional limitations experienced by the individual, goals and key motivators, and biographic information. In this way, the persona could be described from three different perspectives. First described was the health and wellbeing of the individual, incorporating the particular diseases, conditions, or circumstances that contributed to functional limitations experienced by the user. Second, insights were included about the home environment that interacted with the user's abilities, producing some challenges from the user's perspective. Details and imagery of the home provided crucial input for this section, highlighting the importance of in-home data collection. Third was insights on the user's goals, aspirations, and unmet needs. This data provided a framework for envisioning a design solution to a particular problem faced by the user that might be addressed through a given intervention (see Figures 1 and 2). Providing more information about the individual and the environment helped delineate internal issues, external issues, capacities, and social challenges to clarify the presented design challenge.

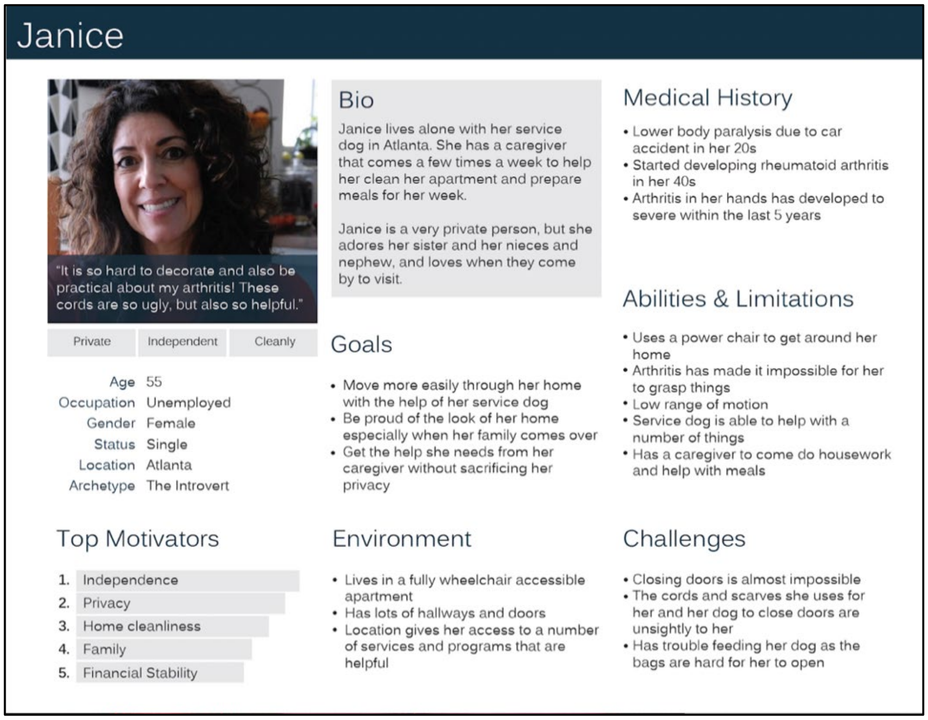

Figure 1. Example Persona Background Information

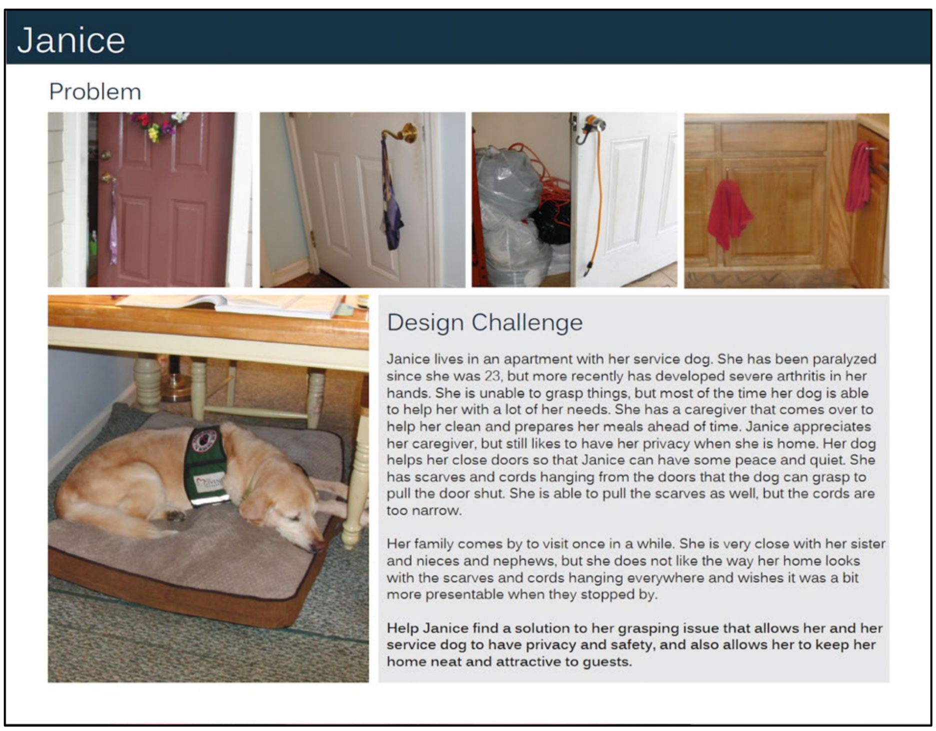

Figure 2. Example Persona Design Challenge.

The Role and Design of Policy

Policy does not emerge in a vacuum. It is an iterative process by which the convergence of actions yields a change in societal structure and interactions. It can be thought of as:

> A set of interrelated decisions taken by a political actor or group of actors concerning the selection of goals and the means of achieving them within a specified situation where those decisions should, in principle, be within the power of those actors to achieve. (Jenkins, 1978, p.15)

Typically, this formulation follows a loose hierarchy where high-level abstract ideas set the framework from which mid-level granular concepts emerge, which in turn provides the environment that low-level fine-tuning ideas are experimented with (Haelg, Sewerin, & Schmidt, 2020). An alternative, somewhat inductive approach considers a design-oriented process, whether it is intentionally inclusive of end-users or even if that design is the unintentional consequence of political, economic, or social objectives. Suppose the objective of policy development is to generate an inclusive, usable, and effective policy. In that case, a key consideration is mitigating undesirable constraints, whether those elements are theoretical or result from the policy's implementation.

This relatively new approach to the development of policy, the application of design thinking processes (Lewis, McGann, & Blomkamp, 2020), can be loosely understood as a 'human-centric' approach to policy development that draws from the techniques used by industrial designers. In terms of designers, it is: "Performing the complex creative feat of the parallel creation of a thing (object, service, system) and its way of working" (Dorst, 2011, p. 525). Design thinking is an approach that may help mitigate undesirable problem elements. Design thinking "encourages end-users, policy designers, central departments, and line agencies to work in a collaborative and iterative manner. The most important skill for a design thinker is to "imagine the world from multiple perspectives – those of colleagues, clients, end-users, and customers (current and prospective)" (Brown, 2008, p. 87). One helpful categorization of stakeholders is the following framework: citizens, members of industry, members of a community, not-for-profit groups, and government entities.

A further categorization series of stakeholders include informants, testers, contributors, and co-creators (Lupton, 2017). By gathering and consolidating a varied and healthy representation of different stakeholders who both are affected and would affect the policy in the policy formulation process, from the beginning, that policy can more closely approach an inclusive outcome. Traditionally, and too frequently, there is a delay in gathering these stakeholders until late in the development process. Specifically, according to Mintrom and Luetjens (2016, p. 393):

> After problem definition has occurred, options have been analyzed, and broadly acceptable ways forward have been explored. Consulting at this later stage

reduces the risk of policy work being subjected to major challenge and being sent back to the drawing board.

Another potential flaw in constructing a policy without suitable inclusion of all accurately represented parties exists (Lupton, 2017). Policymakers could focus narrowly on constructing their policy solely within the assumption that the policy will be followed as planned – which is not always the case. Only when the policy is implemented can policymakers see how the stakeholders are affected. At best, this means the final policy may be used in an unexpected way. At worst, it may mean that the design of the policy receives or causes negative consequences. Either way, policymakers may fail to account for what the policy would achieve with the target populations, which could have been avoided by emphasizing more inclusiveness in the design stages of the invention.

Some policymakers and innovators use prototypes (or, in this case, personas) for this very reason. A policymaker will authorize the development and deployment of prototypes to provide a tactile object the stakeholders can use to provide feedback on how they can and are likely to interact with a policy implemented similarly to the prototype. This use of prototypes in the design process is strategically circumstantial. Two uses include the design science perspective and the exploratory perspective. The former is helpful for "validating a set of requirements within a systematic process, helping evaluate and eliminate options;" the latter is better for "a design process which [re]-assembles current and future actors, artifacts, practices, identities and outcomes" (Kimbell and Bailey, 2017, p. 219). The earlier a prototype is introduced, the more information can be gleaned from stakeholders as to what the effect of the policy may look like in practice.

A holistic way of viewing these practices of collaborative design for policymakers uses an inclusive policy design approach, where policymakers take into account as fully as is possible of the impact the policy will have on different groups—families, businesses, ethnic minorities, older people, the disabled, women—who are affected by the policy (Gandy, Baker, Zeagler, 2017). A frequently touted strategy in the inclusive policy approach is the Diverse Voices method, which is intended to strengthen "pre-publication technology policy documents from the perspective of underrepresented groups" (Young, Magassa, & Friedman, 2019, p. 89). The Diverse Voices method requires developing and using an environment where a diverse and representative body of perspectives may freely comment on and critique design elements. Upon receiving this feedback, the method involves a follow up where the contents of the feedback are used to improve the policy in question and then must be presented in a way that is "compelling and actionable to authors" (Young, Magassa, & Friedman, 2019, p. 100). A way to frame this method is to envision policy designers as composed of three primary sets of interpreters or designers. The interpreter's technology (engineers, coders, developers, etc.), the interpreters of process (legal policy, regulation, standards), and the interpreters of change (social-economic technological, etc.) who have either a direct or near-direct interest in not just the outputs, but also the outcomes of the proposed policy. This third listed group of stakeholders are those who will be affected in some way by the policy and should be viewed as interpreters of "what a policy does" to add to the other two primary designers of "what a policy should do."

Stakeholders included early in the design process help define the early frameworks of policy design. Then with each question, decision, and inclusion involving those stakeholders, their influence in the design process becomes more solidified, trust between stakeholders and policymakers is enhanced, and there is potential for more agentic participants (Blomkamp, 2018). The framework involving their input and consideration becomes further enmeshed in the designer's decision-making. It can be viewed as a compounding effect where the earlier a stakeholder is included, the more ingrained they become in the design. Alternatively, incorporating a stakeholder late may be construed or even conceptualized as rendering them a smaller role in the growing design or resulting in policy that needs to be altered later at greater costs or reduced efficacy.

Towards a More Nuanced and Inclusive Policy Design. How then might design tools such as personas be used in an inclusive policy design approach? When incorporating personas, which can be thought of as a type of policy input, a policymaker informs the policy's framing. All data considered relevant reflects on the objectives of the policymakers. Consider the collection and use of user data. Personas derived from extensive interviews and open-ended questions provide a large basis of subjective information that can advise the narrative structure of policy. Consider the case of internet of things (IoT) technologies designed to be worked on or adjacent to the body – wearables, for instance. The same basic set of technologies – sensors, data collection and manipulation, processing (e.g., software application), wireless connectivity, and display can have very different uses and contexts. A health or fitness app or device collects essentially the same data as a medical device but is treated and regulated quite differently. The Food and Drug Administration (FDA) has stated their intention to observe high-risk products (e.g., medical technologies) that facilitate the treatment of patients by clinicians; they also stated: "lower-risk products, such as fitness tracker apps and other software not considered a medical device, will not be subject to FDA oversight" (Advisory Board, 2019, para. 7). The reasoning provided is that:

> Certain digital health technologies – such as mobile apps that are intended only for maintaining or encouraging a healthy lifestyle – generally fall outside the scope of the FDA's regulation. Such technologies tend to pose a low risk to patients but can provide great value to consumers and the healthcare system. (Office of the Commissioner, 2019, para. 11)

Unregulated wellness products branded as having positive health consequences can be sold with significantly fewer restrictions and under simpler criteria than medical technology if the technology is not branded as medical in nature. Policymakers, when generating a persona, may instead prefer qualitative study over quantitative. Instead of inquiring as to regular numerical data from a lengthy and expensive clinical trial, the policymaker may instead authorize questions such as "how do you feel using our application?" A cell phone with an application that gauges heart rates during a morning jog may facilitate positive health behaviors and feedback for the stakeholder. If it does, a series of qualitative questions for stakeholders of a potential product could be used to discern design elements such as value, marketability, reliability, and ease of use of the application. Therefore, the stakeholder's values, beliefs, and perceived value proposition can be incorporated as design elements (Wilson et al., 2018). These elements can then be included in the adoption of user personas into the policymaking process.

That said, the application of personas in policy formulation requires reliability and sophistication to be useful. Specifically, "to be useful, they also need to convey the multiple types of information that affect aging and impact policy and healthcare. These include not only medical information but also social, psychological and functional data" (Heredia et al., 2018, p. 2646). In practice, it is desirable to capture the converging lived experiences of stakeholders with disabilities and aging stakeholders (Loitsch et al., 2016; Schulz & Fuglerud, 2020). As this can be complicated due to various constraints, as an alternative, a narrative can be developed around additional personas, here representing a wider range of stakeholders. As more personas are developed, connections between the personas can allow the narrative to continue developing in complexity and even reliability. This narrative can be a driving framework not merely for policymakers involved in developing these personas but also for other policymakers who have been informed in part by the spread of these narratives. Moreover, personas can bridge gaps between policymakers and stakeholders, enhancing the latter's capacity to act and be agentic (Wilson et al., 2018). Recalling the Jenkins (1978) definition of policy, these narratives can help provide an upper-level understanding of representative goals and situations to more accurately, reliably, and effectively tackle policy not merely as a measure of what is theoretically desirable, but as a measure of what can practically be accomplished given a set of factors and how.

The persona design as introduced in this paper represents a jumping-off point for applying the personas to various categories of disability, or more broadly, other target groups. In the Policy Design Process model (Gandy, Baker and Zeagler, 2017), used in this paper, the final policy output – the "product" – comes from a set of input factors, evidence-based input of applied research, project design components, policy considerations, clear identification and articulation policy of outcomes, and ideation by stakeholders and end-users. This model deviates from the traditional linear policy formulation process, as it is iterative, where each stage can simultaneously impact and be impacted by other stages in an intentional cycle. Representation within the design process involves a series of decisions based on consultation with a wide range of stakeholders and users. In the negotiation and development of policy, it is not uncommon for policymakers to rely on established thinking within certain frameworks if those frameworks have helped them with their policy design previously. This, of course, runs the risk of reinforcing social inequity or maintaining existing economic or technological barriers.

Conclusions – What Can Be Done/Next Steps

While personas are well established for design and technology development purposes, personas offer a valuable tool to enhance the inclusive research of individuals with disabilities and aging populations more broadly in a range of policy settings. Rather than erasing or minimizing the experiences of underrepresented demographics, the resulting research can then be used to position these experiences in the early developmental stages of policy and policymaking. The use of the term “policy” in this paper has been applied broadly to refer to a number of different realms, one of which is technology. We argue that these perspectives are relevant and support stakeholder and user-related research in support of policy development.

A truism in using personas for research is that the depth of research is often considered more useful than the breadth. In other words, scarce resources and time may force a research group to decide how detailed their examinations and individual persona creations are. A significant aspect in developing personas is maintaining a strategy to gather as much reliable depth of each persona as is feasible. The process of writing the story and getting it validated, either by experts or by users, helps to reveal potentially wrong assumptions among the project participants. For example, applying personas inclusive of minorities can educate other population entities to spread awareness, increase the inertia for policy reforms, reduce stigma, increase empathy, and challenge narratives sustained by majority groups. Thus, personas can act as a nexus for education (Loitsch et al., 2016), one being a policy intervention instrument.

In furthering research based upon the inclusion of different groups and perspectives, personas are one of several frameworks that can be used. Furthermore, discussions for enhancing the democratization of research to more actively engage the “hard to reach” can happen within the wider scope of a research framework (such as co-design) that engages concurrent themes with that of the personas framework (Blomkamp, 2018). Beyond the engagement and participation of actual different groups, the use of personas to enhance public policy perspectives can more effectively generate “innovative ideas, ensure policies and services match the needs of citizens, achieve economic efficiencies by improving responsiveness, foster cooperation and trust between different groups, … and achieve support for change” (Blomkamp, 2018, p. 729). Discussions between those invested in these frameworks could help foster more creativity in research development, narrative framing, and the construction and implementation of policy.

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CHAPTER 3: ACCESS & USABILITY

Next Generation Wireless Device Adoption and Use among Individuals with Disabilities: Findings from a National Survey of User Needs, 2019-2020

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Abstract

We present findings from the Rehabilitation Engineering Research Center for Wireless Inclusive Technologies (Wireless RERC) Survey of User Needs (SUN) 2019-2020. The Wireless RERC has surveyed wireless technology adoption and use among individuals with disabilities since 2002, and this article presents findings from the sixth iteration of the SUN. Broadly, it finds growing adoption rates of smartphone technologies among people with disabilities relative to the general population. With an increase of smartphone use among individuals with disabilities from 54% in 2012-2013 and 71% in 2015-2016, to 88% in 2017-2018, and remaining at 88% in 2019-2020, our findings suggest a further narrowing of the digital “disability divide.” SUN respondents generally indicated that their devices were easy to use. Regarding device satisfaction, over three-fourths of smartphone users indicated that they were satisfied or very satisfied with their smartphones. Relatively less established, newer features such as real-time-text and intelligent personal assistants have yet to be widely adopted. However, the higher-than-average use of real-time-text among individuals who reported deafness or difficulty hearing suggests this feature’s potential for increasing usability and accessibility of these devices, specifically and communications, in general. For this version, we added new questions on the adoption and use of next-generation wireless devices as part of a growing trend toward Internet of Things (IoT)-based “smart homes.”

Keywords: Smartphones, wireless devices, intelligent personal assistants, emerging assistive technologies, information and communications technology (ICT), and software

Introduction

Smartphones have transformed mobile phones from merely telecommunications devices to multifunction computing devices. They serve as a news and information source, enable communications for people with hearing disabilities without an intermediary, are of assistance during and in the wake of emergencies, facilitate telehealth, and can be a key route to employment through job searches and the online application process. We present findings from the Rehabilitation Engineering Research Center for Wireless Inclusive Technologies (Wireless RERC) Survey of User Needs (SUN) 2019-2020. Wireless RERC's ongoing SUN data collection and analysis identifies trends in access to wireless technologies by people with disabilities. Now in its fourth cycle of funding by the National Institute on Disability, Independent Living and Rehabilitation Research (NIDILRR), the Wireless RERC has surveyed wireless technology adoption and use among individuals with disabilities since 2002.

This survey, now in its seventh iteration, builds on prior versions of the survey (Morris, Jones, and Sweatman; Morris et al.; Moon et al.) through the inclusion of next-generation wireless technologies, such as wearables and the Internet of Things (IoT), and their prospective applications for monitoring, sensing, assistance, guidance, and navigation. Our final validated sample size was N=231. Of this sample, **98.3% (N=227)** reported using or owning a wireless device, while 1.7% of respondents (N=4) reported that they did not use or own a wireless device. Below, we provide data based on the sample of users who indicated owning or using a wireless device such as a traditional cell phone, smartphone, tablet, or wearable device. This article comprises three main areas of analysis: 1) overall adoption and use of wireless devices among users with disabilities, with comparison to prior iterations of the SUN and against the general population as surveyed by the Pew Research Center, 2) use of specific wireless device features generally associated with greater accessibility or usability for specific disability categories, and 3) activity-based use of wireless devices by individuals with disabilities, which is new to this version of the SUN.

Materials and Methods

Originally launched in 2002, the SUN is updated periodically to be responsive to the rapid pace of technological change. For this version, we added new questions based on Wireless RERC focus group research on adopting and using next-generation wireless devices, including "smart speakers" such as Amazon Echo with Alexa or Google Home with Google Assistant (Wireless RERC). As part of a growing trend toward Internet of Things (IoT)-based "smart homes," these technologies represent, in essence, the next generation of home automation and accessibility solutions (Atzori, Iera, and Moribito; Domingo; Moon, Baker, and Goughnour). It is worth noting that devices such as smart lights and thermostats can be controlled through smartphone apps, further reflecting the continued integration of wireless technologies. We also refined disability categories in response to prior findings to capture this demographic information more accurately and revised the wording for items to reduce ambiguity and erroneous responses.

The SUN is a national survey administered online, as well as by telephone. Recruitment relies upon convenience sampling, drawing upon the Wireless RERC's Consumer Advisory Network (CAN), which totals about 2,100 individuals with disabilities, as well as web-based recruitment through partnering universities and organizations. Disability demographics were based upon categories used by the American Community Survey (ACS), augmented with categories adapted from the National Health Interview Survey (NHIS) for a more robust listing of functional limitations (Lauer and Houtenville; McGuire et al.). However, the categories allowed for finer segmentation of respondents by disability sub-type, such as distinctions between individuals who are blind and who have low vision.

Results

Device Ownership and Use. A total of **10.1% (N=22)** of wireless device users indicated ownership of a ***basic cell phone*** (sometimes referred to as a feature phone), described as having the form factor of earlier-generation phones, with button-based input and a small display. This proportion continues to decline, downward from 13.4% in 2017-2018 and a similar level in 2015-2016 and 31% in 2012-2013 (Moon et al., 2020). This decline may be attributed to increasing ownership of smartphones among users with disabilities, owing in part to greater affordability, accessibility, and user preference. It also may be due largely to decreasing availability of, and support for, feature phones on the market. These rates of use and ownership are slightly lower than for the general population, with the latest Pew survey reporting 15% of U.S. adults who own cell phones but not smartphones (Pew Research Center).

Regarding users of basic cell phones in the current survey, a majority of these users are over 50 years of age, male, Caucasian, and have an income of less than $35,000 per year. Over three-quarters (3/4) of basic cell phone owners (76%) reported owning their devices for more than four years, up from 52% in 2017-2018. Only two people reported owning their devices for less than one year. Interestingly, 18% of basic cell phone users also reported owning smartphones, tablets (32%), and wearable devices (9%), such as an activity tracker.

To maintain consistency with previous surveys, respondents were asked to self-identify and select all categories of disability that applied to them. In doing so, some respondents indicated more than one disability. Additionally, the survey instrument operationalizes disability as “difficulty” in a manner similar to that used by other national surveys on disability, such as the American Community Survey (ACS), Survey of Income and Program Participation (SIPP), and the Current Population Survey (CPS). For finer segmentation of disability, six disability types: hearing difficulty, vision difficulty, cognitive difficulty, ambulatory difficulty, self-care difficulty, and independent living difficulty. Respondents who report any one of the six disability types are considered to have a disability.

With a range of 0 to 5 and a standard deviation of 1.3 reported disabilities, the average number of disabilities reported by users of basic cell phones is 2.2 disabilities. In rank order, these disabilities include lower-body physical limitation (59%), upper-body physical limitation (50%), speech or communication limitation (27%), cognitive or learning disability (23%), emotional, psychiatric, or behavioral disability (18%), and vision limitation other than blindness (14%).

Among individuals who indicated using a wireless device, **88.5% (N=192)** reported owning a ***smartphone***. The proportion of respondents with a disability who indicated use of a smartphone continues to increase, as compared to 54% in 2012-2013, 71% in 2015-2016, and 88% in 2017-2018 (Moon et al., 2020). Interestingly, SUN respondents continued to report higher smartphone adoption rates than the Pew national sample of the general population (81%) in its most recent survey (Pew Research Center). This continues a trend also seen in the early versions of the SUN, in which people with disabilities similarly reported slightly higher smartphone use.

Regarding current SUN users of smartphones, a majority of these users are under 60 years of age, female, Caucasian, and have an income of over $25,000 per year. Some smartphone users indicated more than one disability. With a range of 0 to 6 and a standard deviation of 1.1 disabilities, the average number of disabilities reported by users of smartphones is 1.7. In rank order, these disabilities include lower-body limitation (34.9%), upper body limitation (22.4%), Deafness (18.8%), hearing difficulties other than Deafness (18.8%), blindness (18.2%), and vision limitations other than blindness (17.7%).

Regarding *smartphone type by operating system*, more Apple iPhones (68%) were reported than Android-powered smartphones (35%), such as the Samsung Galaxy and Google Pixel, continuing a trend of more reported iPhone ownership and use from 2017-2018 (54% vs. 46% Android ownership/use). One respondent indicated using a Windows-powered smartphone, and one individual indicated the use of a BlackBerry phone. Interestingly, a small proportion of smartphone owners (4%) reported ownership of two smartphones.

Regarding the *duration of ownership*, 57% of smartphone owners have owned their devices for more than four years, while 10% reported owning their phones for 3-4 years, and 9%, for 2- 3 years. Of the remaining users, 16% have owned their devices for at least one year, while only 9% have owned their devices for less than one year. The following chart shows the duration of device ownership for smart and basic cell phones compared to other wireless devices queried by the SUN.

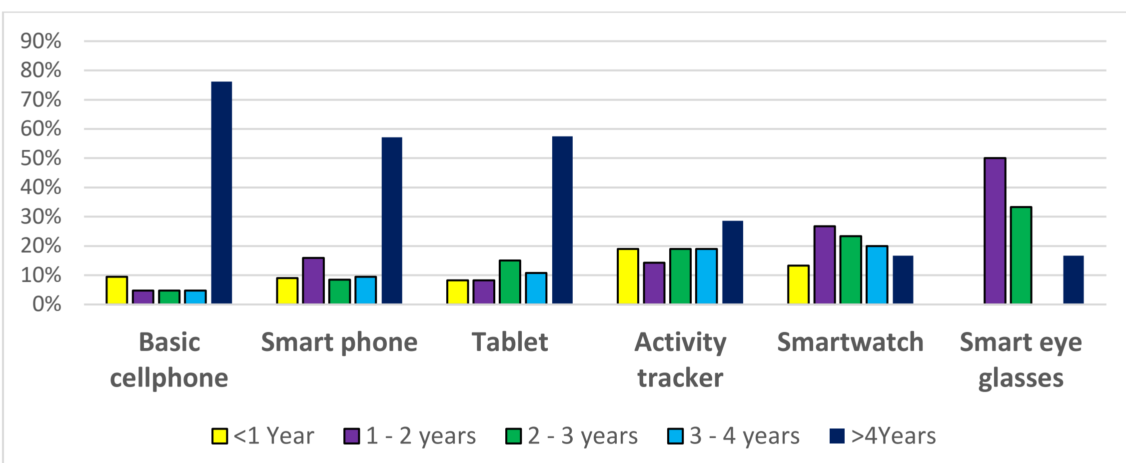

Figure 1. "How Long Have You Had Your Device?"

This continues a trend from the previous SUN of long-term ownership and use. By comparison, in 2017-2018, 43% of smartphone owners had owned their devices for more than four years, while an additional 8% reported owning their phones for 3-4 years, and 16% reported owning their devices for 2-3 years.

Ease of Use and Device Satisfaction

Regarding *overall ease of use* for wireless devices, a majority of users of smartphones indicated that their devices were easy to use. In contrast, a majority of basic phone users did not. Regarding ***basic cell phones***, 24% indicated that they were very easy to use, and 14% indicated they were easy to use, for a total of **38%** (rounded up). Of remaining basic cell phone users, 43% indicated they were somewhat hard to use, 14% indicated they were hard to use, and 5% indicated they could not use them without help.

Regarding ***smartphones***, 42% indicated them as very easy to use, and 36% indicated them as easy to use, for a total of **78%**. Of the remaining users, 18% indicated they were somewhat hard to use, 2% indicated they were hard to use, and only five users (3%) indicated not being able to use it without help. Figure 2 provides a complete breakdown of responses to the question, “How easy is it to use your device?” with comparisons to other wireless devices surveyed by the SUN.

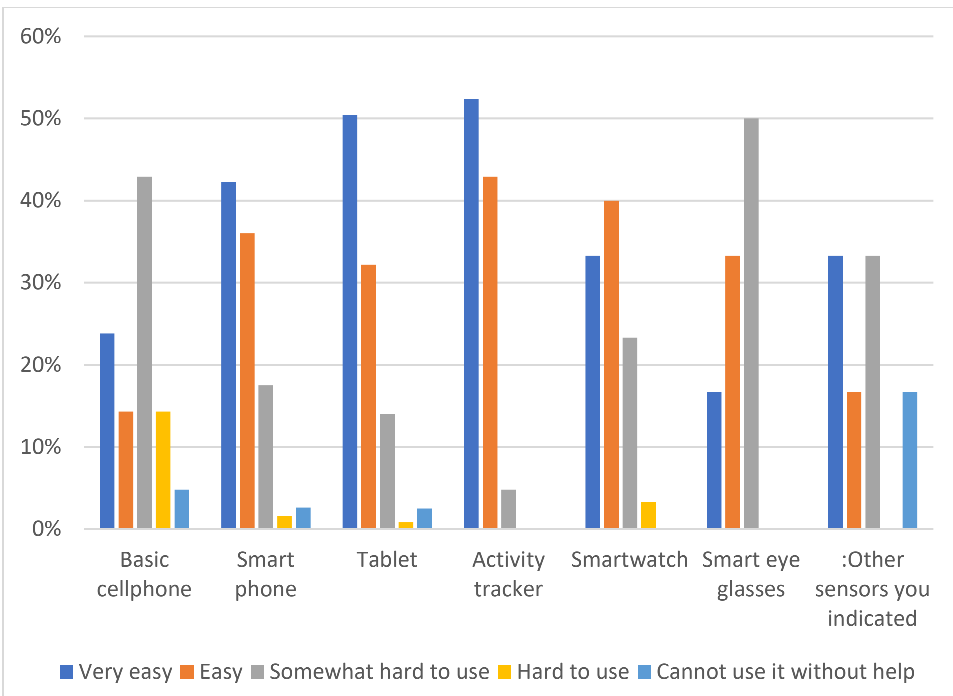

Figure 2. “How easy is it to use your device?”

Regarding *device satisfaction*, **over three-fourths (77%) of smartphone users indicated that they were satisfied or very satisfied** with their smartphones (Figure 4), continuing a trend from the 2017-2018 SUN in which 75% of users expressed satisfaction with their smartphones. By contrast, a decrease was noted in the satisfaction of **basic phone users**, with just **35% reporting that they were satisfied or very satisfied** with their devices and the same proportion reporting that they were dissatisfied or very dissatisfied.

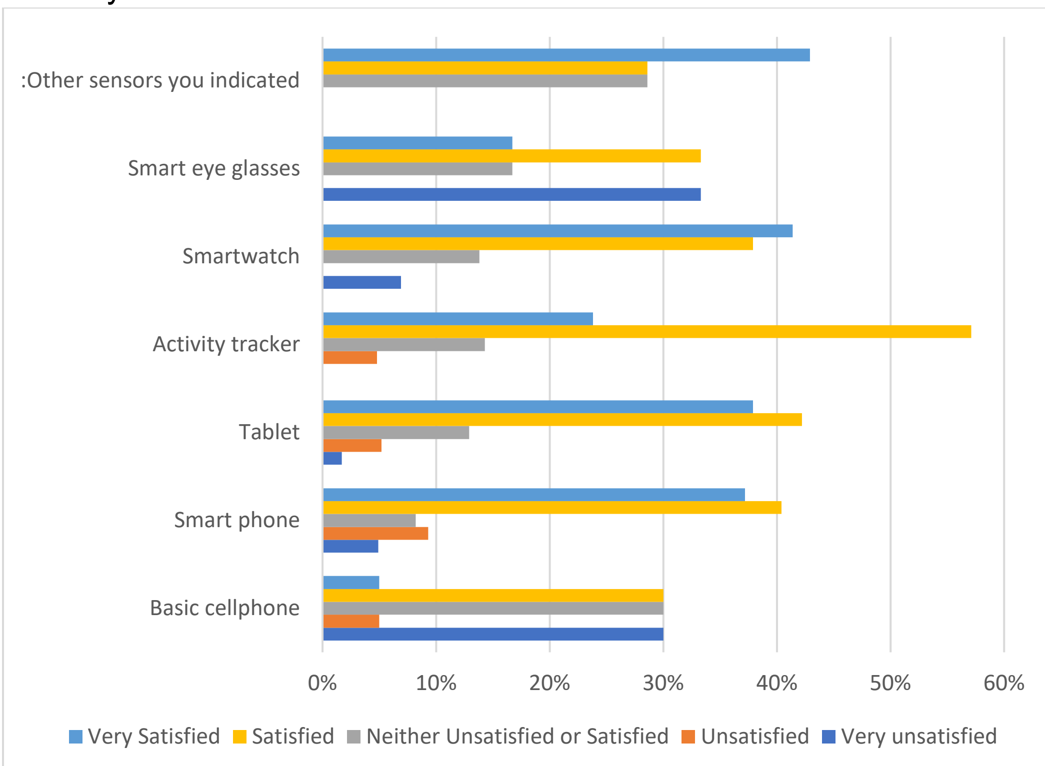

Figure 3. User Satisfaction with Wireless Devices

Regarding *the selection and purchase of devices*, personal recommendations were the most important source of information, with 57% of respondents indicating very important and important, followed by online consumer sources (51%), consumer reviews (51%), and package labels (47%) comprising either important or very important sources of information (See Figure 4).

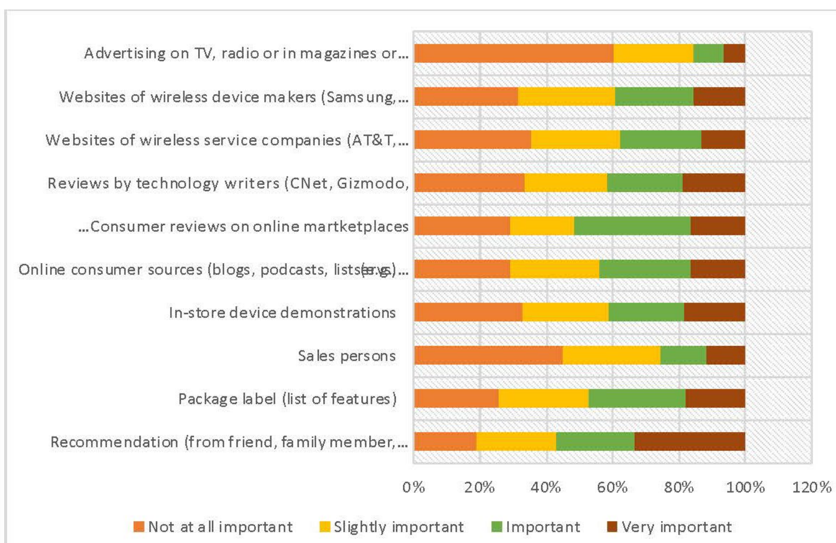

Figure 4. Factors in Selection and Purchase of Wireless Devices

Visual and Audio Display Technologies: Screen Reader and Screen Magnifier Technologies

The SUN probed on using technologies to present textual or graphical content in alternate formats to make this content accessible for users, including for individuals who are blind, individuals with low vision, or individuals with other vision-related disabilities. Of our total valid sample (N=223), a total of 115 indicated one of the vision impairments listed. Of the valid Vision sample, 32 respondents, or 37%, indicated their use of ***screen-reader*** technology. Of this group, 33 individuals, or 79%, reported blindness, 7 (17%) reported having a vision difficulty, and two respondents indicated (5%) indicated either a cognitive (1) or speech (1) impairment. *Respondents were allowed to indicate multiple disabilities, so percentages may exceed 100% due to reported co-occurring disabilities*. However, over 20% of screen-reader users report cognition, anxiety, hands and fingers, or mobility difficulties.

Screen-reader technology users reported 1.7 ± 1 disabilities on average. Of this group, 62% of the sample reported only one disability, 33% reported 2 or 3 disabilities, and 5% reported four or more. Sixty-two percent (62%) of screen-reader users in the SUN sample were female; 86% identify as white or Caucasian; 62% had a bachelor's degree or higher; and 48% are currently employed either full or part-time. The average age of screen reader users was 53 years of age.

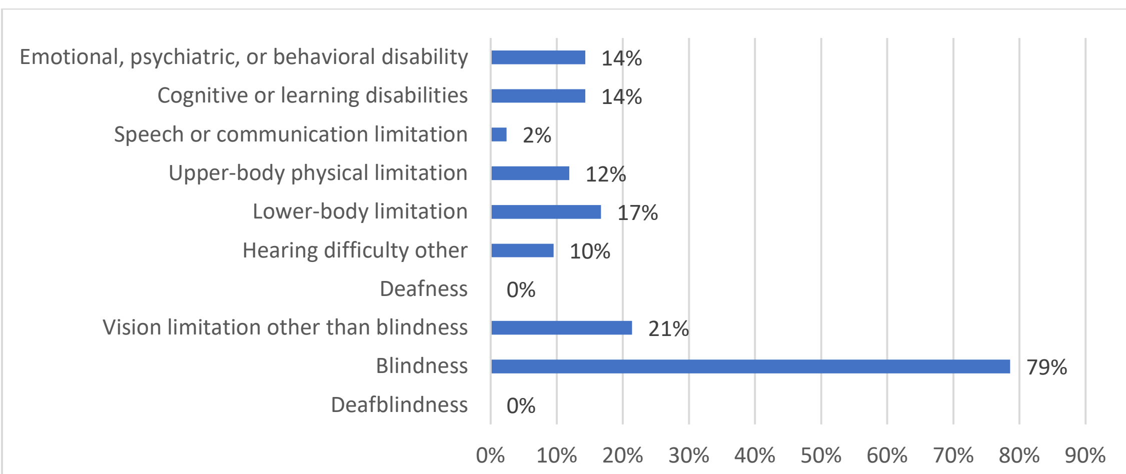

Figure 5. Use of Screen-Reader Technologies, by Reported Disability

A total of 32 respondents, or 15% of the SUN sample, reported using ***screen magnifier*** technologies for their wireless devices. Of this group, 21 individuals, or 66% of these users, reported a vision disability, while 25% reporting being functionally blind. Considering the application of this technology and its reliance on vision, these findings may be as expected. *Because the questionnaire does not specify the nature of blindness in diagnostic terms, it is possible that respondents that indicated as "blind" may have some usable vision*. Interestingly, over 31% of screen magnifier users reported disabilities with mobility, and 56% reported difficulties with cognition or emotional, psychiatric, or behavior, as shown in the following graph.

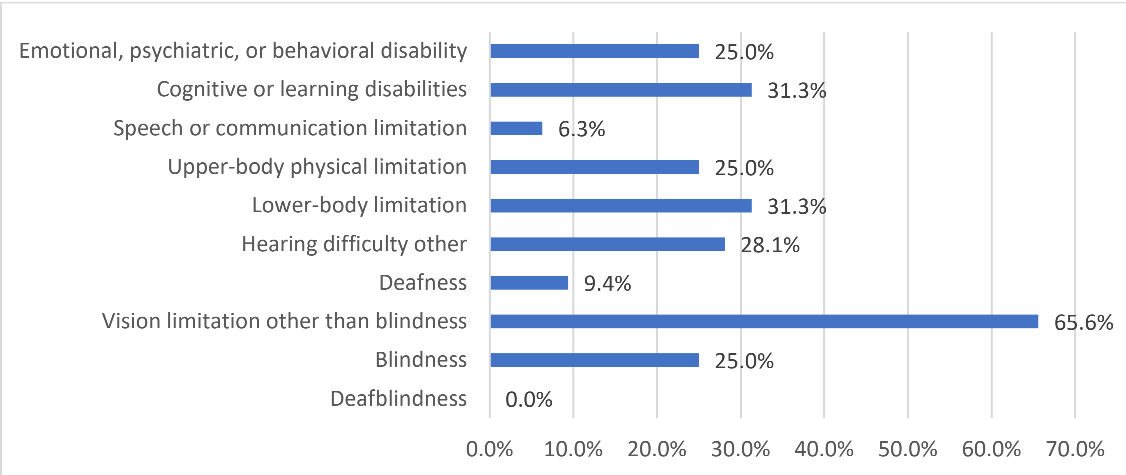

Figure 6. Use of Screen Magnifier Technologies, by Reported Disability

Screen magnifier technology users, on average, reported 2.5 ± 2 disabilities. The median number of disabilities was 2. Sixty-nine (69%) of screen magnifier technology users in the SUN sample were female; 81% identified as white or Caucasian; 53% had a bachelor's degree or higher; and 41% were employed full or part-time. The average age of these users was 52 ± 15 years old, with 41% of users being 50 years of age or older. While these findings strongly suggest a relationship between vision-related disability and the use of this technology, it also implies a possible relationship between age and screen magnifier use.

Wireless Device Features: Real-time Text and Intelligent Personal Assistants

The SUN also probed on features and applications generally not considered assistive technologies but may support accessibility and usability within specific contexts. Two of these features, real-time-text (RTT) and intelligent personal assistants, are presented here.

A total of 78 respondents indicated the use of ***real-time text (RTT),*** which may be defined simply as text messaging that is transmitted instantly as it is typed or created. Of these users, 18 individuals, or 23% RTT users, reported difficulty with hearing. An additional 22% of respondents reported functional deafness. Also, over 32% of RTT users reported upper or lower body limitations.

The total number of disabilities reported by RTT users ranged from 0-6, with 1.9 disabilities reported on average. Forty-one percent (41%) of the sample reported only one disability; 45% reported 2 or 3 disabilities; and 9% reported four or more. Sixty-three (63%) percent of RTT users in the SUN sample were female; 77% identified as Caucasian; 64% reported earning a bachelor's degree or higher; and 31% reported annual incomes of $50,000 or greater. Thirty-four percent (49%) were currently working either full or part-time. The average age of RTT users was 52 ± 15, and 37% of users were over age 60.

In asking respondents about their use of RTT, the survey defined it as "text messaging that is transmitted instantly as it is typed or created." This generally coincides with the Federal Communications Commission's (FCC) description of RTT as "a mode of communication that permits text to be sent immediately as it is being created," which has been offered as an accessibility solution for use with IP-based voice communications networks and services and as a possible replacement or substitute for legacy teletypewriter (TTY) communications. However, it is possible that some respondents conflated RTT with texting or SMS technologies, especially considering that RTT has yet to enter the mainstream of wireless use yet.

The SUN also queried on ***intelligent personal assistants*** for wireless devices, such as Apple Siri, Google Now, Microsoft Cortana, and Amazon Alexa. A total of 112 respondents, or 50% of the SUN sample, indicated their use of intelligent personal assistants. Users indicated a diverse range of functional abilities, with lower and upper body limitations tied as the top two disabilities (N=50 (45%) upper and 40 (36%, respectively.) Vision-related disabilities, including blindness, were reported by 43% of users (N=48). The following chart presents a breakdown of intelligent personal assistant use by disability.

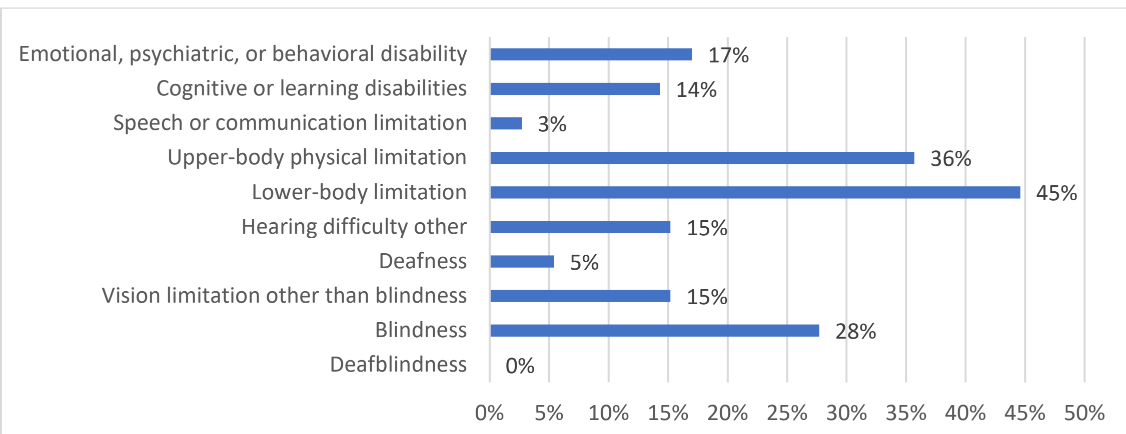

Figure 7. Use of Intelligent Personal Assistants, by Reported Disability

Forty percent (40%) of the sample reported only one disability; 43% reported two or three limitations; and 9% reported four or more. Sixty-one percent of intelligent personal assistant users in the SUN sample were female, and 78% identified as Caucasian. Fifty-three percent (53%) reported obtaining a bachelor's degree or higher, and 37% reported annual incomes of over $50,000. Fifty-four (54%) were currently working full or part-time. The average age of users of intelligent personal agents was 51 ± 14 years of age. Fifty-five percent (55%) of this group were 50 years of age or older.

Device Use by Activity and Disability

The SUN also queried respondents with disabilities regarding the activities for which they used their wireless devices beyond "core" communication functions. We present the findings for six categories, based upon the key functions associated with many frequently used applications for smartphones, tablets, and other wireless devices. These may include address books, electronic calendars, notepads, and voice recorders for organization. They also may include GPS and map-based apps such as Google Maps, Waze, or Apple Maps for navigation and directions. A variety of apps exist to assist individuals with saving or managing money, as well as the apps provided by banks for online banking and bill-pay apps provided by many utilities and service providers. Rather than consider specific apps, this version of the SUN took a functional approach.

Organizational Activities. SUN participants were queried about the use of their wireless devices for organizational activities for everyday activities, such as time management or keeping up with contacts. At least 76 percent of respondents in all disability categories indicated using their devices for organizational activities. The most commonly indicated uses included keeping a directory of contacts (87%), keeping a calendar of appointments (72%), and recording notes or reminders (60%). A minority of respondents, only 42%, indicated using their devices for completing work activities, such as word processing or creating and showing presentations. From the four options provided, respondents indicated an average of 2.5 $\pm$ 1.4 activities reported in this category. Respondents who identified as having a hearing disability, being functionally deaf, blind, or having a vision disability used their devices' organizational activities most frequently.

Community Mobility Activities. Next, the SUN queried on the use of wireless devices for assisting individuals with navigation and wayfinding, which are commonly associated with apps such as Google Maps or Apple Maps. A sizable majority of respondents used their devices for two of these uses, particularly navigating and wayfinding through GPS and map-based apps (89%) and locating places of interest such as restaurants and stores (85%). Wireless devices were used for an average of 1.5 $\pm$ .77 for community mobility activities. In particular, respondents who identified as having a vision limitation used their devices for community mobility at 86%, far more than any other group, closely followed by individuals who had a hearing-related disability. However, at least 74% of all SUN participants indicated using their devices for community mobility, regardless of disability or functional limitation.

Finances. SUN participants were asked about the use of their wireless devices for managing money and finances. The most commonly indicated uses included shopping online either to compare prices or make purchases (74%), banking online (63%), or paying bills (54%). Only 34% of respondents indicated their use of instant payment applications such as Apple Pay or Google Pay. Use of wireless devices for the five finance activities listed had an average of 2.2 $\pm$ 1.5 activities, which suggests that while no one activity was performed by a majority of respondents, over sixty-four percent of SUN participants used their devices for at least one of the possible options. Users who identified as having a hearing disability (77%), being deaf (74%), having a vision disability (64%), being blind (74%), or having a speech disability (70%) were the most frequent users of devices for managing money or finances.

Health, Wellness, and Home Environment. SUN participants were asked about the use of their wireless devices separately for health and wellness, as well as control of their home environment. Taken together, however, these activities were the least commonly indicated uses for wireless devices. In no instance did any activity receive a response of greater than 40%. In order, use of the wireless devices for these activities included tracking personal fitness such as steps taken, calories burned, or nutrition (40%), monitoring personal health such as weight, blood sugar, blood pressure, or heart rate (37%), using wireless devices for home automation such as control of lights, thermostats, or other environmental devices (27%), and using wireless devices to control home security systems (21%). Only 21 SUN participants (13%) indicated using their devices for personal medical alerts, such as Alert1 or LifeAlert. The use of wireless devices for the health, wellness, and home environment activities listed had an average of 1.3 ± 1.3 activities.

Leisure and Social Activities. Finally, SUN participants were queried regarding the use of their wireless devices for leisure and social activities, ranging from social media to entertainment to gaming. Use of wireless devices for watching videos and movies or videos on sites such as YouTube were the most commonly indicated recreation and leisure activity (76%), followed closely by social networking on such sites like Facebook, LinkedIn, Twitter, and Instagram, and sharing photos (both at 75% each.) Use of wireless devices for other related activities included, in order, listening to audio content such as music, podcasts, radio, or audiobooks (71%), reading or studying (59%), and playing games (56%). The use of wireless devices for the six recreation and leisure activities listed had an average of 3.9 ± 2.1 activities reported.

Discussion

Based upon responses to the Wireless RERC's SUN for 2019-2020, consumers with disabilities generally report high usability and satisfaction with their mobile phones. Demographics suggest that basic cell phones tend to be owned more frequently by individuals who are older or who report lower incomes, while higher incomes tend to characterize users of smartphones, which aligns with prior Wireless RERC SUN analyses, as well as other national surveys of mobile phone usage among individuals with disabilities. No single indicated disability seems to explain ownership preferences between basic cell phones and smartphones. In either case, however, owners of these devices tend to use them for a relatively long duration. One likely explanation may be due to the rising costs of smartphones. However, Wireless RERC focus group research has suggested that the long duration of ownership may be the result of users becoming accustomed to the features on their phones and not wanting to have to learn a whole new set of interfaces and user controls on an upgraded model – especially if one gets accustomed to the accessibility features. In all cases, owners of these devices report high levels of ease of use and satisfaction, which suggests increasing levels of usability.

Drawing upon the SUN's sample of users with disabilities, it remains clear that certain wireless technology features for accessibility continue to experience high use levels based on their utility to certain groups. The use of screen readers and screen magnifiers at high levels by individuals who reported blindness or vision-related disabilities provide but one example of how built-in accessibility features remain vital to technology access. By contrast, relatively less established, newer features such as real-time-text and intelligent personal assistants have yet to be widely adopted. However, the higher-than-average use of real-time-text among individuals who reported deafness or difficulty hearing suggests this feature's potential for increasing usability and accessibility of these devices, specifically and communications, in general. Meanwhile, the use of intelligent personal assistants, while rather lower than average overall, has a more diffuse group of users, suggesting these features' usefulness across multiple disability categories. The voice control associated with intelligent personal assistants may benefit people with vision-related disabilities and individuals who have difficulty using their hands or fingers.

Regarding the use of devices for more general activities, it is clear that some uses are more established than others. The relative novelty of "smart home" technologies that rely upon wireless devices for controlling the home environment or specific devices for health probably explains their lagging adoption by individuals with disabilities. On the other hand, activities that are enabled by applications intrinsic to the devices themselves, such as those for organization, enjoy wider use among individuals with disabilities.

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The Impact of Wireless Technologies on the Social and Vocational Outcomes of Individuals with Intellectual and Developmental Disabilities

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Abstract

As society increases its dependence and integration of wireless, mobile, and wearable technologies into everyday life, there are populations of people, namely those with disabilities, who are excluded. This paper examines the technologies individuals with intellectual and developmental disabilities (IDD) use in various settings. This paper's secondary line of inquiry aims to identify how these individuals used these technologies to improve their access to meaningful social and vocational experiences. The study employed a focus group methodology to gather rich experiential data. The participant group consisted of 13 youth and adults with IDD, parents of individuals with IDD, and professionals working with people with IDD (e.g., rehabilitation counselors). This study's findings align with previous research, which suggests that people with disabilities who are digitally connected express a better sense of well-being and quality of life.

Keywords: Individuals with intellectual and developmental disabilities (IDD), connectivity, wireless devices, wearable technologies, accessibility

Introduction

In the last decade, wireless technology has become an integral part of our daily lives. Despite the pervasive use of technology in today's society, evidence suggests that, in general, people with intellectual and developmental disabilities (IDD) have limited access to technology and that technology is underutilized by this population for a variety of reasons, including cost-related challenges and issues with devices being cognitively accessible. The lack of accessibility of some technologies for people with disabilities is concerning as this population stands to benefit the most from new technologies. They can serve as important tools for gaining greater independence and social integration. Improved independence and connectedness can ultimately lead to an improved sense of well-being and quality of life.

While mobile, wireless, and wearable technologies are becoming more widely used and the dependence upon such technologies is increasing, it is evident people with all types of disabilities have the lowest rates of usage (Kaye, 2000). Numerous barriers are associated with their non-participation, including (a) lack of basic computer and Internet skills (Moisey & van de Keere, 2007); (b) financial barriers, as many people with IDD cannot afford the cost of devices and their associated services (Moisey & van de Keere, 2007); and (c) limited cognitive accessibility, which is exacerbated by the decreasing size of the interface and the increasing number of features which can be confusing and overwhelming for individuals with IDD (Stock, Davies, Wehmeyer, & Palmer, 2008).

Technology Use in Social Settings by Individuals with IDD

For individuals with IDD, access to cellphones and other mobile technologies means more than being able to text message friends conveniently or pass the time playing video games; it is a matter of security and safety and, potentially, greater independence vs. increased isolation (Stock, Davies, Wehmeyer, & Palmer, 2008). Interacting with others increases learning and helps individuals with IDD build relationships, thereby improving their quality of life (Carter et al., 2010). Efforts to increase social skills and support social connectedness for individuals with IDD may also improve educational and employment outcomes for individuals with IDD (Test, Fowler, White, Richter, & Walker, 2009).

Clement and Bigby (2009) noted that ‘‘typically, people with intellectual disability have small, highly restricted social networks characterized by interactions with other people with intellectual [disability], family members, and paid workers’’ (p. 264). This limited social network ultimately results in the individual having more difficulty building social capital (Davies et al., 2015). Social capital can be defined as ‘‘features of social organizations such as networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit’’ (Putnam, 1995, p. 67). Social capital is generated when individuals use their social networks to connect with others and access information and resources that enable them to gain economic, educational, and vocational advantages and to gain emotional and physical support. Lack of social capital results in less access to the economic, educational, and vocational advantages as well as emotional and physical support that this population may benefit from. The inability to generate social capital has long-term impacts for individuals with IDD, including reduced access to educational opportunities, employment opportunities, and feelings of isolation (Davies et al.).

Researchers have found that social media apps like Facebook can impact social capital by facilitating direct communication through posting comments and messaging, typically with individuals the users also know offline, and through browsing profiles and liking photos and posts (Wilson, Gosling, & Graham, 2012). The use of social networking sites, such as Facebook, is rapidly expanding. Still, people with IDD are at risk for exclusion because sites like Facebook are not designed for cognitive access (Davies et al., 2015). Cognitive accessibility issues include but are not limited to processing speed, deficits in understanding letters, number symbols, and language, and challenges with comprehension and decision making.

Technology Use in Vocational Settings by Individuals with IDD

The rate of integrated employment of people with IDD is low and has remained unchanged for the past ten years (Butterworth et al., 2014). According to the National

Longitudinal Transition Study (NLTS-2), approximately half (52%-54%) of young adults with disabilities are employed after exiting school. However, there is a trend towards removing systemic barriers to employment in the community and increasing effective job support for people in individual jobs (Association of People Supporting Employment First, 2017). In fact, policies are being implemented nationwide to improve the employment prospects and outcomes of people with IDD, a population known to have one of the highest unemployment rates (Rusch & Dattilo, 2012). Despite progress being made, there are still major barriers in the planning and provision of employment services and supports for people with IDD (Butterworth et al., 2016). Hence, even though many young adults with IDD want to enter the workforce and maintain gainful employment, they frequently require extra assistance that employers are unable and/or unwilling to provide at this time due to cost, perceived lack of skills, and potential legal issues (Kocman, Fischer, & Weber, 2018).

Access to technology to support people with IDD in the workplace is vital. Notably, hand-held prompting systems have shown to be effective in aiding students with IDD transition through vocational tasks (Cihak, Kessler, & Alberto, 2007; Cihak et al., 2008). Assistive technology for people with IDD can range from personal hand-held devices to communication supportive devices to wheelchair physical support. For example, Green, Hughes, and Ryan (2011) indicated that using a vibrating watch was an effective technology in the workplace setting for improving time management skills. In addition to held-held devices and vibrating watches, other devices such as iPhones (Randall et al., 2020), audio-visual technologies (Cavkaytar, 2017), computer-based interactive games with Augmented Reality (Chang et al., 2014), and iPods as video prompting devices (Van Laarhoven et al., 2009) have also been effective in supporting individuals with IDD in the workplace.

Method

A series of focus groups were conducted to determine what technologies individuals with IDD were using to navigate social and vocational settings and how they were using these technologies to improve their access to meaningful social and vocational experiences.

Participants. To increase the study's rigor, focus groups involved participants with IDD, professionals, and parents, allowing the research team to triangulate multiple data sources (Lincoln & Guba, 1985). Individuals invited to participate in the study included youth and adults with IDD, parents of individuals with IDD, and professionals working with IDD (e.g., rehabilitation counselors). Individuals were excluded from the study if they (a) were 20 years of age or younger and (b) did not identify as a stakeholder in one of the following categories: rehabilitation counselors, K-12 educators involved in career transition, certified job coaches, individuals with intellectual and developmental disabilities and/or their families, or employers.

The vocational focus groups had 13 participants across three focus groups, including adults with IDD (*n* = 10) and parents of individuals with IDD (*n* = 3). The ages of participants ranged from 18 to 61 years, with a mean age of 33.9. The participants varied in age, race, gender, occupation, employment status, and level of education (see Table 1 for complete participant demographic information). The social connectedness focus groups had a total of 27 individuals, including individuals with IDD (*n* = 10), parents of individuals with IDD (*n* = 7), and professionals (*n* = 10). The ages of participants ranged from 22 to 63 years (*M* = 43.4; *SD* = 15.0). The participants varied in age, sex, occupation, employment status, and highest level of education.

Procedures. Each focus group began with a participant priming session during which the participants were provided specific examples of wireless technologies such as a smartphone, a tablet, or a Fitbit. The interviewer also reviewed definitions of the terms *wireless technology, wearable technology*, and *wearables* and asked if participants had questions or required clarification about these terms. After defining the terminology, videos were presented showing various forms of wireless technologies and wearables. Following the video presentation, the researcher conducted the semi-structured focus group interviews using the established interview guide.

Focus group recordings were transcribed verbatim and then coded in two phases. First, two independent coders, including a faculty member and a research staff member, first engaged in an inductive open coding process to generate initial codes, group initial codes into categories, and generate themes. Each coder was provided focus group transcripts and a semi-structured guide to inform their initial coding. Initial coding followed three distinct and iterative stages characterizing a highly modified constant comparative approach (Glaser & Strauss, 1967). Next, once the codebook was established, data were independently deductively coded.

After completing coding and analysis, a faculty member with extensive training in qualitative methods conducted a final round of coding review and data interpretation. The purpose of this final round of interpretation was to enhance the study's credibility by using multiple coders with various levels of training and diverse disciplinary perspectives (Maher, Hadfield, Hutchings, & de Eyto, 2018).

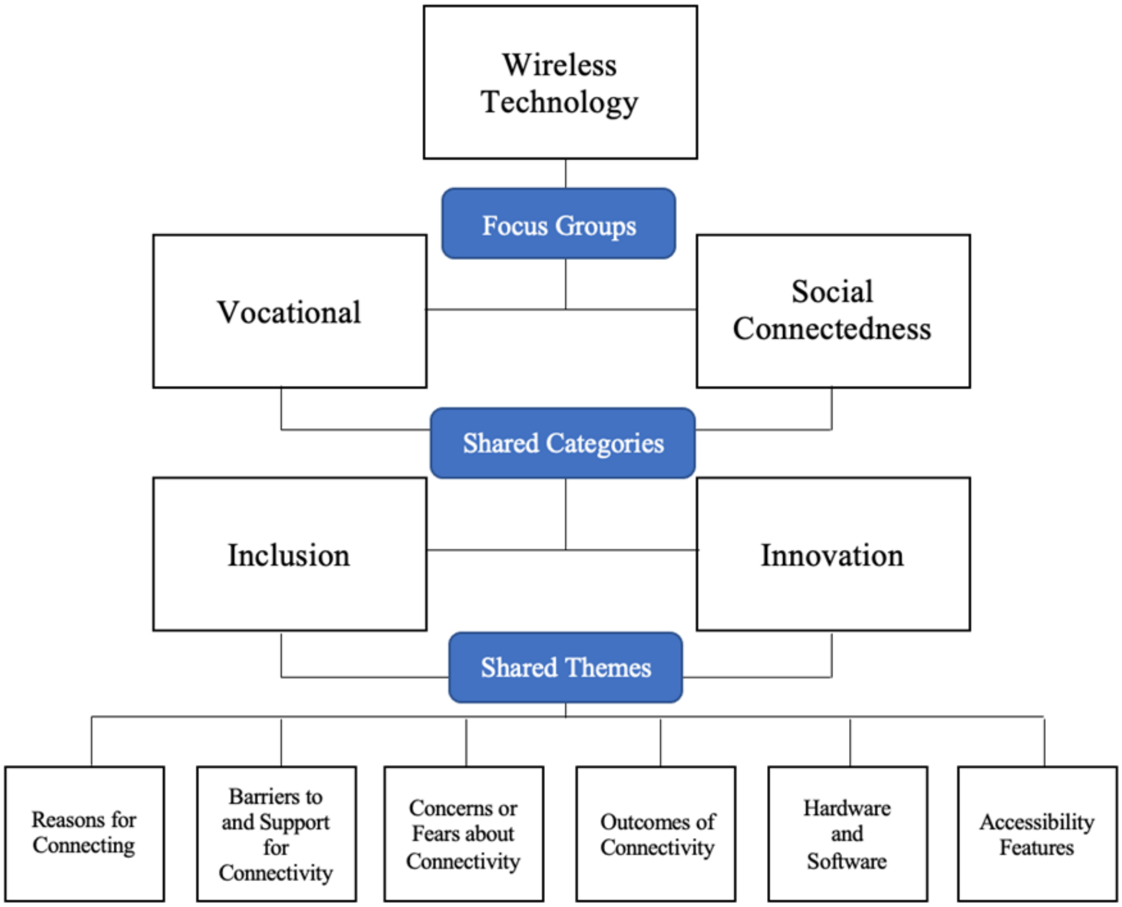
Results

Six major themes emerged from the data across both sets of focus groups, including Reasons for Connecting, Barriers to and Supports for Connectivity, Concerns or Fears about Connectivity, Outcomes of Connectivity, Hardware and Software, and Accessibility Features (see figure 1). These themes are situated within two broader categories: Inclusion and Innovation.

According to the CDC, the inclusion of people with disabilities into everyday activities involves practices and policies designed to identify and remove barriers such as physical, communication, and attitudinal, that hamper individuals' ability to have full participation in society, the same as people without disabilities. Innovation, or the process of "creating value by applying novel solutions to meaningful problems"

(Digintent, 2020), can be used to support inclusion for individuals with disabilities. However, these efforts should be shaped by a clear understanding of the experiences (i.e., successes and challenges) of technology users with IDD.

Figure 1: Flowchart for Wireless Technology Focus Groups



Inclusion. Focus group participants provided many reasons for why they connect socially and vocationally, which commonly included the following: *keeping up with family and friends, fitness/competition, safety,* and *networking*. Across the focus groups, several categories were identified as areas where barriers existed, and supports were needed when using wireless devices: *compatibility, knowledge and training, software*, and *financial*. Many participants with IDD expressed frustration with not knowing how to use technology and the software issues that occur when using technology. Software issues, such as applications not updating, lack of or disruptions in Bluetooth and WiFi connectivity, and limited data, were another frequently mentioned barrier. Supports for knowledge and training and software issues were also described; one parent mentioned seeking and receiving professional support for troubleshooting. Finances were identified often as a difficulty people with IDD face in connecting socially using wireless technology. Technologies, especially wireless, are expensive and often present as the first barrier an individual will experience in connecting via technology. The participants ' responses identified five subthemes related to fears and concerns about connectivity, including *device breaking, inappropriate interactions,* and *safety and privacy*. Five subthemes emerged from participants' discussions about the outcomes resulting from the use of wireless technologies for social connectivity: *independence, friendships, and support networks,* and *missing out on real, human connection.*

Innovation. Participants described using various kinds of devices frequently to enhance their social connectedness, including hardware such as phones, laptops, and Bluetooth headphones, as well as software and applications such as text messaging, Skype, email, games, and more. Somewhat surprisingly, differences were not divided clearly across the different groups of participants; individuals, parents, and professionals mentioned accessing the same devices and applications, emphasizing social media platforms like Facebook, Instagram, and Snapchat. Participants expressed that digital assistants (i.e., Siri, Alexa, Google Assistant) were beneficial in accessing technology to assist in connecting for social and vocational purposes. Professionals and individuals with IDD agreed that the speech-to-text function on phones is one of the best supports in participating socially online.

Discussion - Transformation: Implications for Research and Practice

As the digital technology landscape continues to expand, it will be important to explore if and how students with IDD at primary, secondary, and post-secondary education levels are exposed to digital literacy training (Alsalem, 2016) to help them to overcome barriers to access, to quell parents' and professionals' concerns and fears about students with IDD connecting online, and to maximize their outcomes. Digital literacy encompasses all of the ways individuals use information communication technologies to evaluate and communicate information; it extends beyond the ability to use software or operate digital devices to include a range of cognitive, social, and emotional skills needed to consume and produce information (Eshet, 2004) effectively. Furthermore, research should be conducted on the similarities and differences in digital use and exposure between individuals with IDD and typically developing peers. By doing so, researchers could examine the root causes (e.g., observational learning, group-maintained behavior) of engaging in risky digital behavior (e.g., sharing too much personal information) to tailor digital literacy training to decrease online risk.

As inclusive post-secondary education (IPSE) programs for students with IDD flourish at colleges and universities across the country, researchers, advocates, and educators might consider standardizing a digital literacy curriculum to ensure students have the training and support to access all the wireless tools and platforms they need to be successful in their education, employment, and social life (Lombardi et al., 2017). One promising program, E-mentoring, has been shown to be an effective method for mentoring individuals with IDD by promoting a peer support system to include peers and near-peers (Burgstahler & Crawford, 2007). This method focuses on utilizing individuals with disabilities of the same age to share their personal experiences and approaches to digital literacy to prevent their peers from making similar mistakes online. Additionally, near-peers are individuals who are close in age but can make connections different from adult mentors. As individuals move through the program, they themselves can become mentors while gaining valuable connections along with leadership skills.

When people with disabilities become electronically connected, their sense of well-being and quality of life may improve in many ways (Moisey & van de Keere, 2007). For this reason, it is important that the field of special education attend to the voices of individuals with IDD, their parents, and other stakeholders as represented in the present study and related research.

Next Steps

The findings of the present study were generally consistent with previous research in this area and therefore support the following recommendations for practicing educators, transition specialists, parents, and other stakeholders: (1) teach technology skills while children with disabilities are in school; (2) encourage and support technology developers in making accessibility features and modifications rather than specialized devices; (3) advocate for web accessibility (e.g., screen readers and assistive software) across devices and operating systems; (4) actively promote online inclusion and (5) provide explicit instruction on the value of social capital and methods for generating social capital for individuals with IDD.

Future research should consider exploring which types of wireless devices are most intuitive for people with IDD to use and most financially accessible. It may also be fruitful to explore if and how students with IDD at primary, secondary, and post-secondary education levels are exposed to digital literacy training (Alsalem, 2016) to help them to overcome barriers to access, to quell parents' and professionals' concerns, and fears about students with IDD connecting online, and to maximize their outcomes. Additionally, while some of the available research on technology and social connectedness for individuals with disabilities includes individuals with IDD as participants or informants, this trend must continue.

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IoT and Covid19: Opportunities for Inclusive Technology Adoption

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Abstract

The Internet of Things (IoT) has been part of a series of digital and wirelessly connected technology-based innovations affecting the function of industry and government as well as daily living activities at an individual level. With the occurrence of the Covid-19 pandemic, a number of institutions, including industries and their markets, underwent disruption, generating a research opportunity to explore 1) IoT development and adoption, broadly, 2) specific use cases such as health and well-being, and lastly, 3) the impact of these adoptions on accessibility and social inclusivity. This paper draws on an analysis of industry and academic publications to examine economic and technological changes that affect the design and development of IoT technology and the consequential accessibility and assistive technology impacts. Conditions arising from the pandemic are examined, emphasizing opportunities for health and well-being, enhanced social participation, and potential responses to advances in these changes. This paper concludes with an assessment of pandemic-related conditions and opportunities driving IoT accessibility and assistive technology innovations.

Keywords: emerging assistive technology; information technology; disruption; Internet of Things (IoT)

Introduction

The confluence of digital technologies, increasing availability of high-speed wireless connectivity, and application of localized computing applications have given rise to a set of technology uses typically referred to as the Internet of Things (IoT). The term, however, has been applied in a variety of senses depending on the specific use case. Here we adopt the NTIA's use of the term "Internet of Things" as an umbrella term to reference technological development in which a greatly increasing number of devices are connected to one another and/or to the Internet (NTIA, 2017).

IoT technologies, including sensors, smart objects, and wearables, are powerful tools that can provide the user with a variety of inclusive and assistive information services in real-time (Domingo, 2012). Intentional application of Inclusive design and development can enable the IoT to realize its potential to empower all citizens, especially people with disabilities, to achieve an improved quality of life and greater social and economic inclusion. While in recent years, notable progress has been made toward more accessible technology, many IoT designers and developers still do not have a clear understanding of (a) technical accessibility parameters, (b) end-user needs, preferences, experiences, and expectations, and (c) inclusive design approaches that can address these needs (Baker, Gandy, & Zeagler, 2015). Key user demographics of interest here include those with sensory, cognitive, physical, perceptual disabilities, as well as elderly, aging, and those aging into disabilities. Given Covid-19 pandemic-related changes in social and economic conditions and potential technology use applications, this diversity of end-users increases the challenge, and the need, for inclusive strategies for the development and deployment of IoT. As with the general U.S. population, those with disabilities have become significant users of the Internet and wireless technologies, and hence, by extension, constitute a critical population of IoT users (Moon, Baker, & Goughnour, 2019).

The application of IoT technology comes from a variety of forms, and of particular interest is the technology's capacity to enhance public health and safety, as well as wellness (Javaid et al., 2020). This does not necessarily have to fall into specific medical uses, but more broadly, into providing information that can help the individual make better decisions about everyday activities or even assist them in maintaining awareness of environmental risk. According to Pew Research, about 20% of Americans use a smartwatch or fitness tracker (Vogels, 2020). These fitness devices can monitor one's health and track changes and physical activity. The alerting and notification features of the devices also underscore their potential for assistive capabilities in a variety of settings. For instance, reminders of the need to take prescriptions for people with certain attentional or cognitive limitations enable them to have great degrees of independence (Moon, Baker & Goughnour, 2019).

The recent implementation of sensors has opened possibilities (though not yet fully reliable) to use of the technologies as ancillary environmental indicators, for instance, in terms of measuring an individual’s temperature fluctuations or changes in their blood oxygen saturation (SpO2), both of which could indicate potential Covid-19 infection (Perry, 2020). Particularly for sensitive and vulnerable populations, the availability or innovative use of embedded sensors and data collection capabilities provide, for individuals -- a degree of security in daily living and for public health entities -- an intriguing way to potentially monitor changes in health status at the population level.

IoT can be similarly diversified to fulfill a number of strategic objectives in tackling the Covid-19 pandemic. Digital-based uses can involve big data analytics using aggregated data generated from IoT devices, integrating national health insurance databases, tracing travel history from individual’s location databases, and predictive, preventive, and personalized approaches for pandemic management based on social engineering and connected devices. (Radanliev et al., 2020)

Related Social and Economic Factors

It is useful to consider the varied ways in which the Covid-19 pandemic has disrupted IoT technological systems as well as society. Following an analysis of pertinent academic literature and industry reports, we generated a summary of these as well as the subsequent IoT impact in the Table (1) below.

The dramatic circumstances of the COVID-19 pandemic have accelerated several unique characteristics that affect the development of IoT-based technology. Socially, an added layer of caution when interacting with others encourages the swift enrollment of major changes in areas where people publicly interact or in technologies that minimize the need to interact with others or provides environmental information that enhances a sense of security (Martin p.2, 2020). This is offset by previous research, which indicates that a great barrier for IoT-technology deployment relates to cybersecurity and privacy -- how much trust exists in the technology involved, both from people enrolling the technology and from people affected by it (PricewaterhouseCoopers, 2019).

The pandemic has also driven IoT technology developments that offer a substitute for close connection, reliable communication, and in-person interaction. For instance, contact tracing, integrated health databases (Radanliev et al., 2020), remote symptom monitoring (He, 2020), and patient monitoring (Center for Devices and Radiological Health (CDRH), 2020) demonstrate the innovative feedback loop of IoT technology: increased connectivity allows for the utilization of solutions dependent on increased connectivity. More solutions derived from increased connectivity encourage greater advancement of technology and policy oriented toward increasing connectivity and ability for vulnerable populations to participate in the workforce and societal engagement.

Pandemic-related economic realities are also driving new development and conceptualization of IoT technology. While the pandemic has disrupted ordinary business interactions by reducing in-person workplaces and public transportation use, most industries have, of necessity, adapted telework initiatives. IoT offers possibilities beyond established tools such as cloud computing, "[videoconferencing and project management software, online chats], remote computer access, device synchronization, VPN, and mobile-first apps" (Infraspeak, 2020). Such strategies involve maintaining the (physical) workplace as a location where work (can) occurs but deploys IoT tools to track inefficiencies (Martin p.3, 2020), provide information, or monitor the well-being of workers. In healthcare and assistive living environments, these tools are increasingly of use (Marques et al., 2019). The environment of IoT deployment is otherwise such that the direct logistics of technology actively shapes the opportunities and directions of IoT. Cyberattacks that damage connected systems or violate user privacy are an ever-present threat and weakness of IoT, with much investment going toward checking and reducing that threat (Gold, 2020).

Finally, there is the technology used in IoT itself. In this, IoT development emphasizes cost reduction and performance improvement (Newman, 2020). The benefits of IoT technology scale with the quality and quantity of connectivity of IoT devices, the more diverse, the more potential (He, 2020). This qualifies for both public health purposes (Radanliev et al., 2020) and more general circumstances. One industry expected to be heavily impacted by IoT technology is that of the healthcare industry. In 2018, Syed Zaeem Hosain, predicted a number of radical consequences for the IoT market: “[i]t has been estimated that 40% of the global economic impact of the IoT revolution will occur in healthcare, more than any other sector. And IoT-driven companies can gain a competitive edge in that sector—specifically in areas such as user experience, operational costs and efficiencies, and global expansion” (Hosain, 2018, p. 149).

Use cases, as well as market potential, are drivers of IoT development. For instance, the global market for aging users, in addition to the recognized assistive-devices market, the global “Elderly and Disabled Assistive Devices market” is projected to reach $39.17 billion by 2026, from $23.36 billion in 2020, a compound annual growth rate of 9.0% during 2021-2026 (360 Research Reports, 2020). There are also opportunities to reach new customers without disabilities, as many IoT products and services designed for people with disabilities rise to mainstream popularity” (Smith et al., 2019).

Table 1: Evaluating the Impact of the Covid-19 Pandemic

Factor	**Societal Consequence**	**Impact on IoT**	**IoT Change Opportunities**
Social	▪ Need to maintain social distancing ▪ Significantly reduced travel ▪ Increased reticence for routine medical care ▪ Increased isolation of individuals with disabilities ▪ Increased mental health impacts	▪ Perceived need to bolster public trust in IoT innovation and data use ▪ Changed patterns and behaviors generated from social circumstances inform the design and implementation of IoT	▪ Public health initiatives involving contact tracing and big data analytics ▪ Use of remote symptom monitoring ▪ User monitoring and support
Economic	▪ Routine business and healthcare rely more heavily on telework ▪ Business less dependent on confined space and near proximity ▪ Increased demand for products and services that decrease spread of virus ▪ Additional forms of public stimulus investment ▪ Reduction and/or near elimination of certain industries	▪ Data, sensor, and monitor use in telework ▪ Benefit derived from IoT technology implementation recursively encourages further investment and deployment of IoT technology	▪ Increased broadband infrastructure conducive to telework ▪ Increased effort in using IoT to create adaptable work environments ▪ Increased and compounding investment into IoT technology

Logistic	▪ Allocation of scarce health resources in manufacturing and distributing essential health technologies to relevant parties ▪ Increased demand for goods being distributed directly to homes instead of central distribution sights ▪ Policies and recommendations designed to optimize scarce medical resources ▪ Exacerbated complexity in managing health centers ▪ Disrupted global trade supply chains	▪ Use of automated labor mitigating human labor shortage/risk ▪ Need for effective IoT security to maintain stable technological effectiveness ▪ Use IoT technology to effectively and reliably maintain logistical demands in everything from industrial supply chains to home-office network connectivity	▪ Technologies with insufficient security that are nonetheless dependent on IoT are vulnerable to cyberattacks ▪ After the pandemic began influencing supply chain logistics, workplace infrastructure benefits from the deployment of IoT technology that made such infrastructure feasible
Technology	▪ Increased reliance on technology overall ▪ Design technology that helps maintain correctly applied procedures ▪ Incentive for different groups to collaborate on developing new and or improved technology ▪ Industry sector shift of technology investment in development ▪ Need to subsidize negatively impacted technology industries during a pandemic	▪ Companies are looking to reduce the cost of data logistics and increase overall data aggregation ▪ Integration of IoT-derived information from available sources ▪ Increased need for touchless technology ▪ Increased need for technology that mitigates the need for social distancing	▪ Increased sophistication of public resources to handle public health emergencies ▪ Emphasis on technology connectivity ▪ Increased technological connectivity between a wide assortment of IoT

Innovation Factors

From workplaces to education centers, IoT technology's opportunity lies in adaptability. Students with disabilities, when presented with obstacles derived from inaccessibility, will often find pursuing their education more difficult than those with their obstacles removed. IoT technology can help remove those obstacles by disseminating hardware and software like smartboard materials, caption, and lecture monitoring equipment (Hollier & Abou-Zahra, 2018). These can help bridge the education gap, although consideration should be taken for “privacy, security, and interoperability” (Hollier & Abou-Zahra, 2018).

Adaptability of technology also means adaptability in the resolutions warranted for people with different disabilities. IoT's key characteristics include its location and context-related display and sensors, as well as personalizability to meet the needs of specific users. For instance, people with visual disabilities may find the IoT display helpful, while people with physical disabilities on the navigation spectrum could discover greater utility from smart home devices like “IoT lights, thermostats, speakers, and appliances” controllable via smartphone or voice (Bureau of Internet Accessibility, 2018). Accessible website designs, virtual assistants, and self-driving cars fulfill different services for people with different disabilities. Meanwhile, the overall aging of the U.S. population results in a proportionate increase in aging-related disabilities. Individuals with aging-related disabilities may find “larger screens, text, buttons, and alternate input methods” helpful for them to have easy access to their IoT products and services (Bureau of Internet Accessibility, 2018).

Moreover, there are already some IoT based technology that brings medical information to and from the average user. These include “devices, such as heart monitors and pacemakers” that “collect and send patient health statistics over various networks to healthcare providers for monitoring, analysis, and remote configuration. Other, smaller “wearable IoT devices, such as fitness trackers and smartwatches, can track a user’s physical activities, basic vital data, and sleeping patterns” (Figliola, 2020, P.1)

Discussion

Disruptive opportunities flowing from Covid-19 pandemic on IoT. The saying that necessity is the mother of invention has been evidenced by the Covid-19 pandemic. As one industry leader recently observed, implementation of COVID-initiated processes like monitoring and detection, business automation, social and workplace engagement interaction projects that probably would have previously taken 18 months to do formal proof of concepts, test, and deploy have been deployed in a matter of two or three weeks. (Martin p.2, 2020). Similarly, the opportunity for inclusive design arises from the growing collaborations between technological innovators and with public sector entities, such as IoT companies teaming up with NGOs and governments to develop new technology solutions that can be used to help fight COVID-19. These same approaches can be applied to the specific objective of enhancing the assistive nature of IoT technologies to allow greater independence for people with disabilities.

For example, IoT can be used to monitor patient compliance once the potentially infected persons enter into quarantine. Public health personnel can track which patients remain quarantined and which patients have breached the quarantine. The IoT data could also help track down who else may be exposed due to the breach. IoT scalability can prove useful for people who may not require care in a hospital but should still be quarantined. For instance, with IoT, users can have their temperatures or activity data uploaded to the cloud for analysis.

Conclusion

The convergence of the pandemic and IoT technological development involve contextual challenges influenced by several factors, including security, privacy, and cost considerations. But we offer that the disruptive nature of the pandemic also opens opportunities for rethinking the various private and public sector use of IoT that could be implemented to provide enhanced assistive capabilities. Innovations such as single platform integration, evolution to "agnostic solution," and the role of standards and best practices can be used to create, integrate, deploy, and maintain inclusive IoT design and development that advance increased societal participation for people with disabilities.

The IoT embodies a set of technological solutions that can be diversified to fulfill many strategic objectives in tackling pandemic-related challenges. Predictive, preventive, and personalized application solutions are based on integrating IoT, wearable devices, mobile apps, and individual data inputs and are dependent on strong security and privacy protocols (Radanliev et al., 2020). These characteristics, of course, are critically important in designing applications of utility to people with disabilities. The pandemic demonstrates that accessibility to assistive technologies and resources (used here in the broadest sense of enabling actions to occur) is not only universally important but can be improved, and rapidly so when the need is perceived. The objective of inclusivity can be further enhanced by being mindful of usability, that is, coupling accessibility with the efficacy of product design.

It is a bit disconcerting that these design objectives, long of importance to workers with disabilities, has come to the forefront when it impacts society as a whole (Shew, 2020). With such IoT-related connectivity and accessibility innovations as sensor technologies for health and wellbeing to locational and guidance functions, people with disabilities can enjoy more equal opportunities as a routine rather than special social accommodation. In turn, we believe that insights generated by broader use of IoT in a socially and technologically assistive manner will produce new, more usable inclusive innovations that ultimately will improve the wellbeing of people with disabilities.

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The WEA Video Platform: Emergency Alerts in Many Formats Allow Access for All

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Abstract

Wireless Emergency Alerts (WEAs) are a part of the Emergency Alerting System (EAS), the national public warning system that allows communication of relevant information during an emergency. WEA messages are displayed in a text-based format that describes the type of emergency event, the time of the event, recommended protective action, and the issuing agency. These messages can present barriers for individuals with text-based disabilities. We present the development process for the WEA Video Platform (WEA-VP) and the results of comparative usability testing with Deaf individuals who primarily spoke American Sign Language (ASL). Results of the testing show significantly increased understanding of the events in the WEA message when presented with ASL compared to traditional text-based content. The testing also showed areas where improvements to WEA messaging could be made.

Keywords: deaf, communication, emergency

Introduction

People with disabilities, an estimated 26% of the United States population, or 61 million people (National Center on Birth Defects and Disabilities - Centers for Disease Control and Prevention, 2020), are more seriously impacted during disasters. Their mortality rates resulting from disasters are two to four times higher than the general population (World Health Organization, 2013). There are a few reasons for this. People with disabilities are less able to evacuate areas of impending disasters, in part because their evacuation plans need to account for transportation of power wheelchairs, hospital beds, ventilators, and other durable medical equipment, as well as the equipment necessary to maintain power or recharge these. Additionally, people with disabilities experience barriers to communication that make them less knowledgeable about impending emergencies and less able to communicate with first responders in the immediate aftermath of an emergency (Federal Emergency Management Agency, 2004, 2015).

Federal law mandates emergency communications to be *inclusive* of people with disabilities. Among its other accessibility provisions, the Twenty-first Century Communications and Video Accessibility Act (CVAA) required an advisory committee to be established for “achieving equal access to emergency [communication] services by people with disabilities ("The Twenty-first Century Communications Video Accessibility Act," 2010),” while the Federal Communications Commission (FCC) continues its efforts to ensure emergency communications are accessible and inclusive all people, including those with disabilities. These efforts have taken on considerable importance because of the continued growth in the use of wireless devices by people with disabilities, with 88% of respondents to a Wireless RERC survey indicating that they owned or used at least one wireless device (Moon, Griffiths, LaForce, & Linden, 2020).

The United States Federal Emergency Management Agency (FEMA) achieves its mission of helping people before, during, and after disasters by raising risk awareness *before disasters*; alerting, warning, and messaging *during disasters*; and coordinating recovery efforts and providing resources *after disasters (Federal Emergency Management Agency, 2019).* FEMA operates the International Public Alert & Warning System (IPAWS) to provide authenticated emergency and life-saving information to the public through mobile phones using Wireless Emergency Alerts (WEAs), the Emergency Alert System (EAS) through radio and television, and on the National Oceanic and Atmospheric Administration’s (NOAA) Weather Radio. Because they are delivered through an individual’s mobile phone, WEA messages are geotargeted, meaning that only wireless devices in the areas immediately impacted by the emergency event receive the incoming communication [5].

Wireless device users are notified of incoming WEAs through audible and tactile signals. These allow the alert to be detected by the wireless device user with more than one sense. This increases the chances that a person with vision or hearing limitations will notice a WEA message soon enough to be able to take actions that will protect themselves, such as seeking immediate shelter or evacuating an area (Federal

Communications Commission, 2013). The WEA message is provided using a Common Alerting Protocol (CAP). CAP is a digital format that allows the dissemination of consistent emergency messaging simultaneously over many different communications systems (Federal Emergency Management Agency, 2012). CAP allows for messages to include a variety of content components, including photographs, maps, and streaming video. The components that are issued in a communication are dependent on the capabilities of the platform involved. Prior to 2016, wireless devices capabilities included displaying WEA messages in a text-looking format that appeared to be much like a text message. The CAP components included were the type of alert, the time of the alert, recommendations for protective action, and identification of the issuing agency within a 90-character limit (Federal Emergency Management Agency, 2012). Later changes to the FCC regulations required wireless handsets to allow free-form text fields and an expanded 360 characters for 4G LTE networks and beyond (Federal Communications Commission, 2016). Despite these changes, most WEA messages still use the original 90-character protocol. An example message from the National Weather Service (NWS) would be "Tornado warning in this area until 10:00 am. Shelter in place – NWS."

Unfortunately, WEA messages are difficult for people with sensory, cognitive, or learning disabilities to access the information that they need in an emergency. Although the message appears like text, it is frequently not readable by voice output (screen-reader) software. This makes the message inaccessible and easily misunderstood for those with vision, learning, and cognitive disabilities. Emergency information is best understood in one's primary language (National Council on Disability, 2014), which for many people who are Deaf, is American Sign Language (ASL). Those who are Deaf and primarily rely on ASL for communication have low written English literacy levels (Paul & Jackson, 1993; Strong & Prinz, 1997), which presents barriers to understanding the message content. In attempts to improve the accessibility of WEA messages for people with vision and hearing disabilities, the National Alliance for Public Safety GIS Foundation (NAPSGF) developed a series of 48 symbols to describe emergency events (National Alliance for Public Safety GIS Foundation). A formal study of whether these symbols improve the understandability of the WEA messages has yet to be undertaken.

This paper reports on developing a software app that demonstrates the technical feasibility of providing WEA messages in multiple formats, namely text-based messages, spoken messages, symbology, and ASL video with captions, to improve the accessibility of the messages for all receivers. The results of a usability study examining how people who are Deaf understand the emergency messages in multiple formats are also described.

Development Process

The team produced the Wireless Emergency Alert – Video Platform (WEA-VP), a smartphone application (App). The goal of the WEA-VP was to provide WEA message content in multiple accessible formats to make it accessible to people with a variety of disabilities. Thus, the WEA-VP was designed to support text-based messages, spoken messages, symbology, and ASL video with captioning. The app allowed each of the formats to be enabled independently. As a result, the user could determine which formats they wished to view. The App was developed with Android Studio for the Android Operating System. This platform was selected as it remains significantly more open to development than the Apple IOS (formerly iPhone Operating System).

At the time of development, FEMA had incorporated 28 individual symbols from the NAPSGF Symbology set. The team acquired high-resolution symbols from FEMA to be included as necessary with text-based messages.

The ASL video creation process utilized the Common Alerting Protocol (CAP) to streamline message generation. The team recorded and captioned individual videos for 28 events and seven (7) protective actions, as well as event times that represented 15-minute increments throughout a 24-hour day. Each of these videos was trimmed so that they could be assembled and streamed as a single, seamless video. As a result, with the creation of 35 short videos, the WEA-VP could display any of 129 event / protective action combinations that could be sent through the platform. Note that not all event / protective action combinations are relevant. For example, the event “Shelter in Place” would not be followed by the action “Evacuate Now.”

The WEA-VP was developed to be phone-based rather than a web-based App. The phone-based app has a few critical advantages that pushed this decision point. Both of these advantages relate to the ability of a phone-based App to trigger from the incoming WEA message. First, the incoming WEA message is only a few bytes in length. This is much more likely to be received during emergencies where infrastructure may be damaged, and wireless services may be inconsistent. The trigger would initiate a video sequence played from the phone rather than requiring streaming of video components from a web platform. Second, triggering from the incoming WEA message allows the WEA-VP App to take advantage of WEA geotargeting. Thus, messages would be received only when relevant to the phone's location, rather than through a web-based subscription service that might not provide relevant messages if the user travels outside their typical geographic area.

There are a few disadvantages of a phone-based app. First, it will require regular updating as IPAWS includes additional events and protective actions in its CAP repertoire. Second, the videos and symbols would need to be stored on the phone, which takes up data space for the user. Finally, the phone-based App requires FEMA / IPAWS to allow the app to trigger through the incoming WEA message. These disadvantages were outweighed by the need to ensure communication-based on the phone's geotargeted area when video streaming might not be available. Triggering from the incoming WEA message required cooperation from the Joint Interoperability Test Command (JITC) laboratory at FEMA / IPAWS. However, this can be accomplished by demonstrating a working prototype and completing a Memorandum of Understanding regarding the testing.

In lieu of being able to trigger from an incoming WEA message, the team developed a web portal subscription service to develop, test, and demonstrate the technical feasibility of triggering the App from an external signal. The web portal was designed to send a text message to phones that were subscribed to the App. Upon receiving the text message, the App would decode the event, time, and action codes and display an emergency message using the formats selected by the end-user. The web portal employed a graphical user interface (GUI) to select the CAP components and send the messages.

Usability Testing

The App seeks to provide increased message comprehension through the provision of accessibility enhancements. Two of these accessibility enhancements (symbology and ASL WEA videos) would potentially increase comprehension for those who were Deaf and use ASL for communication. Upon completion of the development of the App, a study was conducted to determine whether and how accessibility enhancements impacted message comprehension for those who were Deaf.

Participants who were Deaf and primarily use ASL for communication were recruited to participate from the greater San Antonio Metropolitan area. To reach the population who rely on ASL for communication, recruitment was carried out in ASL through video calls and distribution of recruitment materials through blogs for people who are Deaf and other Deaf-focused social media communication channels. After the informed consent process was complete, participants were asked to view six messages through the WEA-VP App. An Advanced Certified ASL interpreter facilitated each participant's test session.

The message content and formats were randomly selected for each trial to test the impact of both the format and the symbols. The eleven events and eight protective actions could be assembled into 88 potential messages. Twenty of these messages were excluded as the event and action would be contradictory and create confusion. For example, the event "Shelter in Place" would not be followed by the action "Evacuate Now." From the remaining 68 messages, a pool of twenty were randomly selected to be viewed during testing. We selected four message formats – Text Only (TO), Text with Symbology (TWS), Text with ASL Video (TWA), and ASL Video Only (AVO) – to allow us to compare the standard WEA Message Format to the symbology and ASL Video enhancements.

After viewing each message, participants were asked two questions: 1) What did the message say? And 2) What would they do if they received that message? The answers were recorded by video, transcribed, and coded for analysis. Answers were coded specifically to determine if the participants correctly understood what was happening and identified the correct action to complete. Additional participant comments were recorded to determine patterns and insights. Quantitative analysis was completed to determine if certain message components created confusion or if certain symbols were better understood by the participants. Chi-Squared Analysis was employed to examine the impact of message format, the event occurring, and the recommended protective action on the participants' understanding of events or actions. The Chi-Square analysis employed Yates Continuity Correction.

Results

Sixteen (16) people who were Deaf and primarily used ASL for communication participated in the study. Eight were male, and eight were female. All but one participant was prelingually Deaf. One participant was post-lingually Deaf and voiced for himself during the study. Each subject provided informed consent through an Advanced Certified ASL interpreter.

A total of 96 messages were viewed. The randomization scheme was designed to be balanced for twenty subjects. Four recruited participants did not show for the study. Further, during testing, one of the ASL video messages did not play appropriately, and when this occurred, the next message for that format was selected for viewing. As a result, the distribution of events, actions, and message formats, which were intended to be balanced, did not achieve balance. The distribution of events, actions, and message formats for the viewed messages are shown below. It should be noted that not all events held associated protective actions. For example, the emergency alert system test message does not have an associated action with it. Further, for evacuation events, a separate action is not generally indicated in WEA messages, and, therefore, understanding the protective action was not coded separately from understanding the event.

Table 1: Message Formats viewed with percentage of events and protective actions that were understood by the participant.

Format	Count	% of understood Events	% of understood protective actions
Text Only (TO)	23	30%	40%
Text with Symbology (TWS)	22	45%	29%
Text with ASL Video (TWA)	24	74%	52%
ASL Video Only (AVO)	27	67%	48%

Table 2: The type of event viewed with a percentage of times the message event was understood by the participant.

Event	Count	% of understood messages
Blizzard	3	67%
Civil Danger	5	20%
Dust Storm	4	75%
Earthquake	4	50%
Evacuation Immediate	5	40%
Evacuation to Shelter	6	17%
Fire	4	50%
Flash Flood	4	75%

Hazardous Material	4	25%
High Wind	7	71%
Hurricane	5	80%
Law Enforcement	5	60%
911 Outage	7	43%
Nuclear Power Plant	4	50%
Shelter in Place	5	60%
Tornado	5	60%
Tropical Storm	6	100%
Tsunami	5	40%
Winter Storm	4	50%
Test Message ("This is a test …")	4	75%

Table 3: The type of protective action recommended with the percentage of times the protective action was understood by the participant.

Protective Action	Count	% of Understood Messages
All Clear	15	27%
Avoid Hazard	9	56%
Evacuate Now	10	40%
Evacuate to Shelter	11	36%
Monitor Radio	12	33%
Monitor TV	7	57%
Take Shelter	16	50%

There were 23 viewed TO messages, and 20 of them recommended protective actions. Participants correctly identify seven (30%) events and eight (40%) of the actions. The addition of symbology had mixed results. There were 22 viewed TWS messages and all but one of the recommended protective actions. Participants correctly identified 10 (45%) events and 6 (28%) of the actions. Of the 27 viewed TWA messages, 23 recommended protective actions. Participants correctly identified 20 (74%) events and 12 (52%) of the actions. Finally, the 24 AVO messages recommended 21 protective actions. Participants correctly identified 16 (67%) events and 10 (48%) of the actions.

Chi-squared distribution analysis shows that the presence of ASL videos (TWA and AVO formats) resulted in participants being almost four times more likely to understand the description of the emergency event in the message ($p < 0.01$). However, distribution analysis did not show a statistically significant increase in the understanding of protective actions with the presence of ASL video. The presence of symbology did not improve the participants understanding of either the event or the protective action. Of the 80 viewed messages with protective actions, participants understood both message components (event and protective action) in one-third (27) of them. Of these messages that included ASL, participants understood both components of 17 (41%) of them while understanding 10 (25%) of the viewed TO and TWS messages.

Across all message formats, participants understood 17% - 100% of the messages for each event type. All participants understood the tropical storm warning, while 80% of them understood the hurricane warning. Messages calling for immediate evacuation were the least understood, with only 17% of these events identified correctly. The presence of the symbology for this event seemed to be confusing; three out of the four times that this symbology was viewed, participants stated that it indicated they should "go slow" or "walk don't run." Five participants who understood that the event was asking them to evacuate explained that they didn't know where to go, one clarifying, "I don't know where the safe places are." Only 20% of the Civil Danger events were understood when viewed. For the one participant who understood the words, they didn't know what the emergency entailed, wondering if it meant there was an active shooter. The Hazardous Materials event was only understood by the person who saw the message in TWS format. He stated that the presence of the "chemicals" in the symbol helped him understand the word Hazardous. Chi-squared distribution analysis did not show statistically significant differences in understanding events based on what events were occurring.

For each protective action, participants understood 27% - 57% of each recommended action across all message formats. Almost two-thirds of the participants who viewed a message that contained an "All Clear" indicating that the event was over-described actions that they would take if the event were happening. For example, one participant indicated he would "stay in the house" when viewing an all-clear after a tornado warning. Participants understood and stated that they would follow the recommended protective action more than half the time for "Monitor TV" (57%), "Avoid Hazard" (56%), and "Take Shelter" (50%). Despite these wide variations, Chi-squared distribution analysis did not show statistical differences in understanding based on the protective action.

Discussion, Recommendations, and Future Work

Participants generally understood messages that contained events that they commonly experienced, regardless of the message format. For example, since people in the San Antonio Metropolitan area commonly experience hurricane and tropical storm events, the words, and symbology used to describe these events were more familiar to our participants than those for other activities that were not common to their area; particularly "Winter Storm Warning." This should carry forward for other messages not included in the study, such as warnings for avalanches. ***As a result, future studies should include individuals in other geographic areas of the country***.

The usability study results showed that people who are Deaf were four times more likely to understand the event contained in the message when the messages format contained ASL. Surprisingly, the presence of ASL did not have a similar impact on the understanding of the recommended protection action. A potential reason for this is that, within each message, the event and recommended protective action are not always independent of each other. Thus, the individual participant's understanding of the event contained in the message had a potential impact on their ability to understand the recommended protective action. ***This shows a limitation in presenting the messages in their entirety but coding components of the message separately.*** However, the authors felt that it was important to present the WEA messages in their entirety as they are displayed according to the CAP. Results of preliminary research by the team impacted this decision, specifically that 1) participants did not necessarily understand that WEA messages were geotargeted to the specific area under the impact of the event, and 2) participants indicated that they would not act when they did not understand the reason why the action was necessary (i.e., the event). These patterns bore out in the present study, where some participants indicated that they wouldn't act because they didn't know if the message applied to them. As one subject stated, "Well, it said flood, but it didn't say where." Regarding a Law Enforcement alert, another subject stated, "It's a warning to avoid an area, and I don't know why. I'd read the alert, and then I'd put the phone back in my pocket and go about my business."

TWS messages showed higher rates of understanding of the event and lower rates of understanding the recommended protective action over TO messages, although these differences are not statistically significant. This mixed result could stem from the fact that, per NAPSGF recommended practice, only one symbol was included in each message. The proposed symbology set reflected the events rather than the recommended protective actions, keeping in mind that WEA "events" included "Shelter in Place" and "Evacuation Immediate." As a result, participants either understood what was happening but not what protective action to take, or they understood they were to shelter in place or evacuate, but not why that was necessary. Even though these are related, the relation would appear not to be strong enough for one symbol to convey the entire content of the message. As discussed above, for people to take the recommended action, they need to know why it is necessary and that the message applies to them. ***As a result, if symbology is used to improve message comprehension, multiple symbols should be used to convey both the event and the protective action.***

The results of the usability study show that continued education about WEA is important. For example, participants did not understand that "All Clear" meant the emergency was over, even when they saw that message in ASL. As a result, they indicated they would take protective actions appropriate to the nature of the event involved (e.g., taking shelter during a tornado event). Some events had ambiguous meanings for participants. For example, most participants did not understand what a "Civil Danger" alert might entail. As a result, they stated that they would not follow the protective action recommendation (Take Shelter) because they didn't understand how the event pertained to them. As one participant stated when viewing a Civil Danger message in TWA format, "There's some danger, but I am not sure what. Maybe it's private. I don't think it pertains to me. I wouldn't run away. But I don't know what it means." These results indicate that ***people who are Deaf need further education about specific terms, and geotargeting are necessary for WEA messages to be most effective.***

Two events and two protective actions use the word “shelter.” The events are “Evacuation to Shelter” and “Shelter in Place,” while the protective actions are “Evacuate to Shelter” and “Take Shelter.” In each pair, one indicates sheltering where you are, and the other means traveling to find shelter. This dual use of the same word created confusion among participants, who, when the message indicated that they should “Shelter in Place,” stated that they would go to a shelter. It is likely that this confusion would exist among those with cognitive difficulties as well as for individuals for whom English is a second language. ***Distinguishing between these activities and events through the use of different words would be beneficial.***

More broadly, however, our results show that terms and symbology included in WEA messages do not adequately consider the backgrounds, contexts, and experiences of those who will view the message. The understandability of symbology used to augment text would be improved if these symbols were better correlated with ASL signs used to represent the words or concepts. FEMA and IPAWS should consult with ASL users and test both the text-based language and symbols used in messaging to improve comprehension of critical information for the population of people who are Deaf. A similar approach would benefit those with cognitive disabilities, including the growing population of older adults with mild cognitive impairment.

The App was developed to include multiple accessibility enhancements so that the messaging could be inclusive of people with a variety of sensory impairments, in addition to learning disabilities and cognitive limitations. ***Further work should include other populations of people with disabilities targeted by the App Development***.

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The Unstoppable Utility of YouDescribe: Audio Description and Innovation

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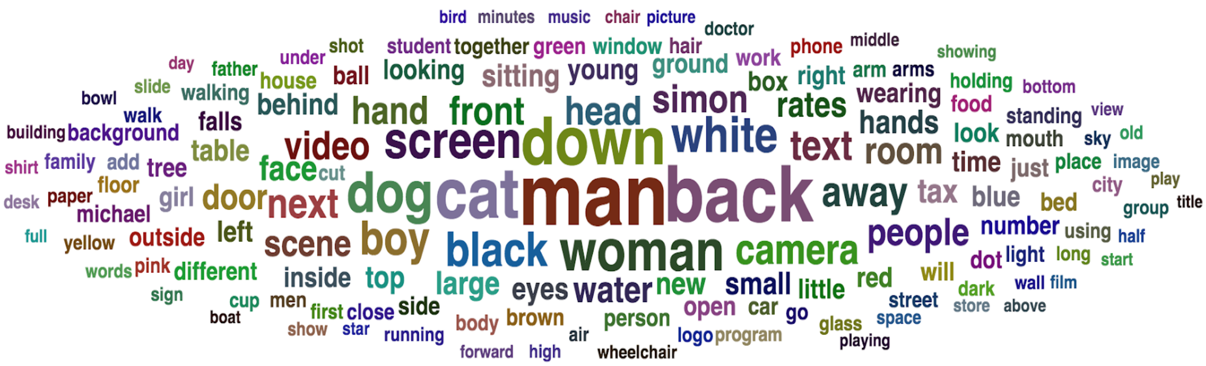

Abstract

This paper highlights a technological advancement related to video description, also referred to as audio description. The resource, YouDescribe, was developed to make videos more accessible, particularly media that lacks descriptive text because it is cost-prohibitive, time-intensive to initiate, or perceived lack of importance. The YouDescribe software stores audio tracks in a database then pairs them with timed tracks and YouTube videos. A survey was utilized to assess the existing video catalog, which allowed for identifying which content has been given descriptions since the program's launch in 2017. This paper also provides details on the recent developments with YouDescribe and its future direction.

Keywords: audio description, video description, accessibility, media, disabilities, inclusive design

Introduction

Audio description (sometimes called video description) is an additional audio track for visual media, giving a brief but detailed description of what is happening on screen to enhance the user experience for blind viewers and others. This paper outlines the way in which an innovative video description technique using crowdsourcing to generate descriptions of any YouTube video is transforming the traditional model of professional description by including more participation in both the provider and user communities.

Background

Audio description includes text on-screen, visual setting, infographics, and information not conveyed by audio cues (Snyder, 2005). While audio description was first implemented for blind and vision-impaired viewers to enhance accessibility and provide more inclusive classrooms and workplaces, it has found utility with many other communities as well. Sighted viewers seated in dim rooms too far from the stage or screen, secondary language learners, and individuals needing support with inferential thinking all benefit from audio description. As educational agencies have included more video content, viewers have increasingly demanded audio description (Snyder, 2005). Lawsuits of both public and private entities are soaring (Randazzo, 2019). To comply with a growing set of media accessibility laws, including sections 504/508 of The Rehabilitation Act, The Americans with Disabilities Act (Title II, public entities and Title III, places of public accommodation), and The 21st Century Communications and Video Accessibility Act (with audio description being phased in between 2010-2020), even niche market websites and educational portals need to be inclusive of screen readers and have accurate captioning and audio description (Gilbert, 2019).

YouDescribe

YouDescribe was uniquely designed to make accessible media available for those videos that would normally be left undescribed due to prohibitive cost, lack of time, or perceived lack of importance. It eliminates cost barriers, addresses concerns about distribution/copyright, and makes it possible for communities with a minimal budget to provide audio description on a popular, easy-to-use video platform. This innovative design, which stores audio tracks in a separate database, then plays the timed tracks and YouTube video in parallel earned Smith-Kettlewell scientist Dr. Joshua Miele the FCC 2014 Chairman's Award for Advancement in Accessibility. Our current iOS app and desk-top app have over 4,000 registered community members. On average, 70 people a day visit YouDescribe on their tablet, phone, or computer to view and create audio description. An average of 125 volunteer-described videos are posted each month. Our current video library has over 4,000 active, published videos.

YouDescribe was first launched in 2013 to meet a growing audio description demand. Professional audio description takes quite a bit of time and money to produce. As such, only big-budget entertainment firms and theaters offer recorded or live, audio description for viewers. As such, one of the greatest areas of need was an audio description tool for teachers of the visually impaired (TVIs). While classrooms in the past might have shown videos sporadically as an adjunct to lecture and experiential learning, the advancement of relatively inexpensive classroom devices such as wireless laptops and tablets, as well as the ability to cast media from a phone to a larger screen, has made videos a common, daily occurrence (Rackaway, 2012). In addition, as teachers in all settings (K-12 settings, college and universities, and workplace learning) employ a greater variety of multiple means of engagement, representation, and expression, as encouraged by Universal Design for Learning (UDL) practices, the viewing of videos – as well as the making of original video content as a learning exercise – has increased (Kay, 2012). YouDescribe makes it possible for teachers to make audio description as needed for their students and present those videos to the whole class. In this way, audio description can enhance an already strong UDL curriculum. A savvy instructor uses the audio description opportunity to decode text, highlight new vocabulary, offer alternatives to visual information, and highlight critical features leading to increased learning for every student in the inclusive classroom (Kearney, 2013). Students creating their own video content for classroom assignments can upload their video to YouTube, and add valuable audio description through YouDescribe, gaining writing skills, public speaking skills, and a greater understanding of accessibility (Kearney, Jones, Roberts, 2012).

More than crowdsourcing, YouDescribe is a community of people who want accessible materials, who combined with volunteers, have a vested interest in creating useful content. Our wish list, a curated list of what videos viewers want to have described, weighted for when the video was requested, and how many "up-votes" each video has (videos requested multiple times go to the top of the queue) is one of our most important features. Viewers have an active role in requesting the content that is important and enjoyable to them. YouDescribe focuses on functionality for individual viewers and ease of use for our volunteer describers. Our current catalog of videos has requested and described videos from every YouTube category: Auto and Vehicles, Comedy, Education, Entertainment, Film and Animation, Gaming, How-to and Style, Movies, Music, News and Politics, Nonprofits and Activism, People and Blogs, Pets and Animals, Science and Technology, Shows, Sports, Trailers, and Travel & Events. Viewers can easily access our videos from their iOS phone or tablet (the most popular brand of phone for blind users), share them by text or email, rate the audio description for viewed videos on a scale from 1-5, and request videos for our wish list. Viewers can take valuable classroom materials, workplace training, and fan favorites with them wherever they travel. Our describer platform has incredible portability and can be accessed from any laptop with a strong internet signal through YouDescribe.org. A quiet room, a laptop, and a microphone mean our crowdsourced volunteers can make audio descriptions almost anywhere. Brand new describers of all ages and backgrounds report their first 2–3-minute video takes 1-1.5 hours to create. After 3-5 videos are completed, intermediate describers take 15-20 minutes for that same 2-3 minutes of video content.

A survey of our currently described video catalog shows what content has been described since our new interface launch on May 18th, 2017, and continues successfully in the present. Some of our most requested content is from the entertainment category. While educational videos for classroom and workplace learning are, of course, of great importance, providing timely, described content that viewers want to experience just for fun is also significant. The world of accessibility tends towards the bare minimum of necessity as an afterthought rather than robust, inclusive design at conception. YouDescribe fills a huge need for an inclusive community. On the surface, YouTube videos of cats, recipes, and animated shorts seem frivolous to some, but casual video sharing among friend groups, work colleagues, and fan groups is an important part of community building. Watching videos on YouTube seems a lot less important than trying to get into a business meeting or checking in for a flight. Still, a dismissal of entertainment in accessibility projects overlooks how relationships are formed, maintained, and expanded in a world that is increasingly virtual and visual. Sharing on social media is a huge part of that equation, and visual media is the social currency of the internet. YouDescribe is a tool that fills the gaps in video media accessibility and creates more inclusive communities.

Our newest version of YouDescribe, our updated iOS app (December 2020), and the auxiliary application YouDescribeX (an experimental version with human-in-the-loop artificial intelligence with automated scene transitions, AI-generated descriptions, text to speech, and viewer informed on-demand descriptions) have more data collection and tracking capabilities. This allows Smith-Kettlewell scientists to study anonymized data for patterns of audio description requests and creation to better understand who is currently using the application successfully, map how we can improve YouDescribe for our blind and vision-impaired viewers and discover what our new describers need to move from novice to expert.

YouDescribe's carefully protected audio description data is fueling exciting developments in human-in-the-loop machine learning for automated audio description. Through a partnership with Computer Science graduate students at San Francisco State University (SFSU) under the supervision of Dr. Ilmi Yoon, the YouDescribe platform will soon have the option of artificial intelligence (AI)-generated audio descriptions in two different forms: a streamlined describe platform to make describing videos faster and easier, as well as an info-bot (like the popular Siri and Alexa) that allows the viewer to pause a video and ask specific questions about the scene that are answered exclusively by the AI. While the bulk of our described content is marked as educational, the wish list highlights a larger demand for entertainment videos. Around 7% of wish list videos are described by our volunteers, leading to a long queue of greatly desired but still undescribed video content. We hope our new interface will decrease cognitive load and lead to a greater percentage of wish list videos being described by our volunteers.

Test viewers are excited about the possibility of having on-demand descriptions for a single frame of video via a video chat-bot interface. Allowing a viewer to ask questions about the content that is playing gives a more active and independent role in the description process, fueling greater agency and autonomy. Describers are looking forward to the option of machine-generated "text-on-screen" tracks and faster script writing with an algorithm providing possible script text that can be edited to suit the viewer's needs by a human describer. Describers who prefer not to record their voice have the option of typing in text and having a premium text-to-speech narrator voice the description at the appropriate timestamp. Text-to-speech has the added benefit of reducing the need for low/no sound environments to record audio tracks- meaning audio descriptions can be created truly wirelessly- in a cafe, in a busy classroom, or while traveling.

We hypothesize that a partially automated system will decrease the time investment and cognitive load describers face when starting, increase the number of videos experienced describers can make accessible to the public, give viewers the option of on-demand detailed computer-derived descriptions, and eventually make it possible for blind and vision-impaired users to annotate their own videos independently. A proof-of-concept version got rave reviews with blind students at SFSU.

With shelter in place guidelines being followed for much of the world during the COVID-19 pandemic, learning, sharing, and collaboration have changed dramatically from a mix of in-person and virtual to almost exclusively wireless (Watlington, 2020). YouDescribe is uniquely poised to support and document the changing accessibility needs of blind and vision-impaired viewers worldwide. As classrooms and businesses around the world shuttered, YouDescribe traffic doubled, leading to a much-needed expansion of our YouTube data API key (the amount of data we have access to from YouTube, on a daily basis). From March 2020 to March 2021, 1,517 videos were published with audio description, a 50% increase from the 945 videos published the previous year.

Conclusion

While the utility of YouDescribe as a wireless technology has been well received and bridged a much-needed video media image poverty gap, image description, and audio description lags far behind what could be possible (Fleet, C. 2020). As audio description expands and becomes a standard feature for all video media, YouDescribe is utilized to address videos that would remain undescribed, but much work remains to be done. While many entities publish audio description content and quality guidelines, audio description remains a hard-to-qualify art. In addition to the differences in viewer content needs from genre to genre, a lack of metrics and description quality markers hinder the standardization of FCC-required audio description services. This creates confusion for volunteer and professional describers and slows the development of computer and machine learning options. Some identified examples of audio description variables are in urgent need of serious, rigorous study; volunteer voice describer vs. professional describer, voices at different pitch and vocal qualities, synthetic voices vs. recorded speech, professional editing quality vs. volunteer editing quality, and a detailed analysis of describer word choices, like plain language (PL) in contrast to descriptive language. For audio description to become as commonly offered as captioning, robust research needs to be done to clarify standards for audio description variables. Our continued goal is to provide an easy to employ tool to increase global access to useful and timely audio description and eventually offer a wireless application that blind and vision-impaired users can use to annotate and describe video content without the support of a sighted helper.

Acknowledgments

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SWAN 2.0: Research and Development on a New System for Wearable Audio Navigation

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A System for Wearable Audio Navigation (SWAN) has been developed that aids a user in navigation, orientation, and situational awareness. SWAN provides support to persons with temporary or permanent visual impairment. SWAN has undergone many iterations, with the common requirement for mobility via wearable computing platforms, spatialized audio output, and robust position/orientation tracking of the user.

Keywords: wayfinding; mobility aid; blind and vision-impaired; auditory display

Introduction

There is an urgent need for wayfinding and navigation aids for the visually impaired. This need applies to individuals who have suffered physical vision loss (e.g., full or partial blindness) as well as those affected by temporary vision impairment, such as firefighters in a smoke-filled building. For a person with vision loss, the two fundamental tasks of navigating through a space and knowing what is around can be challenging. Thus, it is important to develop a system that communicates a range of information about the environment in a non-visual manner, to allow a person greater knowledge, connection to, and more effective navigation through the space. Audition is the obvious choice for display modalities due to the excellent human ability to localize the source of environmental sounds.

There are approximately 32 million adults in the United States (representing about 13% of adults) who report having trouble seeing, or who are totally blind (Blewett et al., 2019), over 500,000 children with vision difficulty in the U.S. (ACS, 2019), and perhaps shocking to note, “at least 2.2 billion people have a vision impairment” globally (World Report on Vision, 2019; emphasis in original). Many can remain very productive even with diminished eyesight, so long as they can get to and from work and move about the office building safely and effectively. Spatial orientation is the major mobility problem encountered by all individuals with profound vision loss (LaGrow & Weessies, 1994; Blasch, Wiener, & Welsh, 1997), but is especially difficult for people whose onset of vision loss occurs later in life (Blasch et al., 1997; Levy & Gordon, 1988).

Wayfinding (the ability to find one's way to a destination) depends on the ability to remain oriented in the environment in terms of the current location, heading, and direction of a destination. Even experienced blind pedestrians exhibit movement error large enough to occasionally veer into a wall or into a parallel street when crossing an intersection (Guth & LaDuke, 1995). These problems persist when the person is indoors. While there has historically been a lot of research in electronic travel aids for obstacle avoidance, there has not been comparable research and development of wayfinding devices that keep one apprised of location and heading (Blasch et al., 1997).

In addition to visually impaired workers, there are many situations where sighted individuals cannot use vision for navigation. For example, a firefighter in a smoke-filled building may not be able to rely on vision, and any resulting disorientation can have serious consequences. Sonification of navigation data can help these individuals find their way while being constantly aware of their surroundings.

Previous Work

Historically, the primary presentation modality of existing path planning auditory displays has been synthesized speech used to speak instructions to the user. The early Personal Guidance System (PGS) (Loomis, Golledge, Klatzky, Speigle, & Tietz, 1994; Loomis, Klatzky, & Golledge, 2001; Loomis, Golledge, & Klatzky, 2001) was typical of that class of devices used primarily for research: the computer created words that seem to come from the same place as the object or feature to which they refer via virtual speech beacons. “Doorway here” would sound as if it came from the real doorway. Other examples have included the Mobility of Blind and Elderly People Interacting with Computers (MoBIC) system (Strothotte et al., 1996) and the Drishti system (Helal, Moore, & Ramachandran, 2001; Moore, 2002).

There have been two notable commercially available navigation systems for the visually impaired. One is the Humanware Trekker[92] and the other is the Sendero BrailleNote GPS. Both support basic navigation tasks via speech presentation and are intended to supplement a user’s existing obstacle avoidance techniques.

There are several drawbacks to using speech sounds in this way. Speech beacons are harder to localize in a virtual environment than non-speech beacons (Tran, Letowski, & Abouchacra, 2000). Users also give speech beacons low ratings for quality and acceptance (Tran et al., 2000). The speech-based interface cannot display a large amount of information, as two or more speech beacons presented simultaneously are difficult to track (e.g., Mowbray, 1953). It is also difficult to use a speech-based interface for navigation and carry on a conversation simultaneously (see, e.g., Wickens, 1992; Walker & Lindsay, 2006). Further, spoken messages in such a system are generally more than a second long, so the system is often talking. This is not a major issue for occasional spoken directions (e.g., “Turn left”). However, if the system simultaneously presents other sounds representing the upcoming curb cut, a low hanging branch, etc., the inherent inefficiency of speech can result in a cluttered listening environment. Research has also shown that using non-speech cues leads to better performance than speech cues in situations where there is a significant cognitive load, such as simultaneous tasks (Klatzky, Marston, Giudice, Golledge, & Loomis, 2006). One

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[92] http://www.humanware.com/en-usa/products/blindness/talking_gps

possible alternative may be spearcons (Walker et al., 2013), compressed speech stimuli that have shown superior performance to artificial speech, auditory icons (Marila, 2002), and earcons (Brewster, Wright, & Edwards, 2003); see, also, Dingler, Lindsay, and Walker (2008).

While it is true that presenting a number of non-speech sounds around the user could also lead to a busy listening experience, the acoustic flexibility and brevity of non-speech sounds provide the designer with considerably more control. An immediately recognizable sound similar to knocking on a piece of wood could be an aesthetic and effective means of indicating the location of a door, without speaking "Door" aloud, especially if there are scores of doors present along the hallway of an office building or school. One final concern with spoken navigation commands that are not spatialized is that it simply takes many words to describe non-rectilinear movement: a 20-degree turn must be described as "Veer to the left" or "Turn a little bit to the left." In our experience, simply walking toward a beacon sound is easier than translating "57 degrees" into a movement action. Thus, while speech-based navigation sounds have been useful in some cases, our design approach leaned more towards using non-speech sounds for most purposes.

SWAN 1.0 Implementation

The System for Wearable Audio Navigation (SWAN), originally described in 2007 (Wilson, Walker, Lindsay, Cambias, & Dellaert, 2007) and developed over the course of many years, addresses the limitations of previous speech-based navigation aids by using non-speech audio presentation of navigation information whenever possible. SWAN provides an auditory display that enhances the user's ability to (1) keep track of her current location and heading as she moves about, (2) find her way around and through a variety of environments, (3) successfully find and follow a near-optimal and safe walking path to her destination, and (4) be aware of salient features of her environment.

SWAN supports these goals through sophisticated position tracking technologies, sonification of navigation routes and environmental features, and implementation of a database of information relevant to the user's navigation needs. SWAN allows users to record their movements or paths through the environment. These paths are used to create a personally relevant set of maps for the user. Additionally, the user can annotate the environment, including locations, features, and obstacles. This could include, for example, a favorite coffee shop, a co-worker's office, or a section of sidewalk prone to flooding after rain showers. The map can also be queried for directions to a particular location.

The Technology (woes) of SWAN 1.0

SWAN requirements include a portable computing device, an audio processor, audio output hardware, tactile input devices, and position/orientation tracking. The original SWAN 1.0 (Wilson et al., 2007) involved a laptop computer, external soundboard, and multiple GPS receivers, all of which had to be carried in a backpack. Users listened to the auditory user interface via bone conduction headphones ("bonephones"), which at the time were cutting-edge technology (Walker & Stanley, 2005; Stanley, 2006).

The SWAN 1.0 system worked well as a research platform and proof of concept. Walker and colleagues describe a series of research projects and user tests that validated the concept and refined the user experience (Wilson et al., 2007; Walker & Stanley, 2005; Stanley, 2006; Dingler et al., 2008; Palladino & Walker, 2008; Walker & Lindsay, 2003; 2004; 2006a; 2006b). However, the technology was simply not available at the time to make a viable commercial product. The mobile computing devices were insufficient for reasons of form factor, computing power, and battery life. Note that the now-ubiquitous smartphones were just emerging (the first iPhone went on sale in June 2007,[93] the same year SWAN 1.0 was described).

Tracking technology was crude, and even the useful global positioning system (GPS[94]) signals had challenges from intentional downgrades (so-called "Selective Availability"), and there were competing efforts and approaches to overcome these limitations (e.g., Differential GPS; Wide Area Augmentation System). Though the US government stopped degrading the GPS signal in the early 2000s, GPS remained too inaccurate for pedestrian applications, especially in urban settings where multipath reflections result in further accuracy decreases.

Indoor tracking was even more problematic since GPS signals do not penetrate very far into buildings. Large-scale WIFI networks were not prevalent (universities were often the exception), and indoor localization was slow to develop (with efforts that included early versions of Ultra-Wideband (UWB[95]), as well as TalkingLights[96], TalkingSigns[97], Bluetooth beacons, and other indoor tracking systems).

Thus, while the SWAN research supported developing a system to help individuals with vision impairment move through their world, the engineering did not facilitate a solution. Even the advanced sensor fusion scheme called "MERGE" (Wilson et al., 2007) developed for SWAN 1.0 was insufficient to provide a reliable location and pose in indoor or urban outdoor contexts.

SWAN 2.0: A Tale of Stop and Go

A decade after work on SWAN had slowed down, we assessed that the technological landscape might have finally evolved to the point where a viable

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[93] https://en.wikipedia.org/wiki/History_of_the_iPhone

[94] https://www.gps.gov/systems/gps/

[95] https://en.wikipedia.org/wiki/Ultra-wideband

[96] http://sciencenetlinks.com/science-news/science-updates/talking-lights/

[97] http://www.talkingsignsservices.com

consumer-ready SWAN could be developed.

In terms of mobile computing power, various smartphones and ultra-mobile PCs were becoming available with (relatively) substantial computing horsepower and memory and running a range of more mainstream operating systems, including iOS, Android, and Windows. Connectivity through Bluetooth was reaching higher throughput with lower latency, meaning fewer wires between system components. And smartphones included built-in GPS and other sophisticated location services and motion sensors.

Mobile data streaming became reasonably useful and pervasive, including faster wireless services (4G then LTE, then the beginnings of 5G) and pervasive WIFI (e.g., the ubiquitous network of cable WIFI hotspots; open WIFI at places of business, etc.).

And, finally, it looked like tracking services, using a combination of GPS, WIFI, radiofrequency and time-of-flight tracking from cell towers, and other data sources would make a SWAN renaissance possible.

Wireless RERC and SWAN 2.0

The Wireless RERC supported a project to leverage the extensive work done on SWAN 1.0 and produce a completely new mobile-phone-based version (SWAN 2.0) that could take advantage of the latest hardware, software, and tracking technologies.

SWAN 2.0 User Experience

Much of the SWAN 2.0 user experience leverages the approach from the SWAN 1.0 system. The primary design philosophy is the emphasis on non-speech auditory display. This approach draws from the foundation of Multiple Resource Theory (Wickens, 2002). The objective is to allow for an efficient flow of information without overburdening the user’s cognition or attention. Furthermore, the user needs to hear and interpret environmental sounds in the presence of SWAN audio output. Given that speech processing is a low bandwidth capability for the user, non-speech audio transmits information efficiently and allows the user to dedicate speech processing to external interactions like talking with others.

Path Sonification. A naïve approach to indicating a path to a destination is spatializing audio as if it is emitted from a real-world position. This position could be a waypoint along the path or the final destination. The problem with this approach is that the time when a new waypoint is introduced is (a) when the user is farthest away from the waypoint and is (b) when the relative position information is most pertinent to the user. If conventional spatialization is used, the perceived loudness of the waypoint will be attenuated to a low volume initially and get louder as the user approaches. Initially, perceiving a newly presented waypoint is more difficult for the user at an attenuated volume. This fact motivates an alternative solution. SWAN does not attenuate waypoint sonifications. Instead, a direction vector from the user towards the waypoint is determined (updated constantly as the user moves and rotates). A spatialized sonification is placed at a fixed distance along this direction vector. Therefore, there is no variation in loudness. Unfortunately, without loudness attenuation, there is no longer a cue for distance. Instead, SWAN maps distance (or, actually, proximity) to tempo. The waypoint audio is of short duration and is designed such that the user can effectively identify simulated direction cues such as Interaural Timing Difference (ITD) and Interaural Intensity Difference (IID). A submarine SONAR ping and guitar string plucks have both been identified as sounds that are effective for user orienting in SWAN. The short duration allows for repeating the sound at a varying tempo. The tempo of the repeated sounds is increased as the user gets closer to the waypoint. Upon successfully reaching the waypoint, the user is presented with a "success" sound, followed immediately by the waypoint sound playing from the direction of the next waypoint. This extends the critical listening period for the user to orient to the new direction of travel. One problem with simulating ITD and IID is that the user may perceive the sound as coming either from their front or their back. Therefore, an additional sonification strategy to identify the front or back direction is useful. The method used in SWAN is a rising two-note ("bah-bing") sequence if the waypoint is currently in front of the user and a diminishing two-note sequence ("bing-bah") if the waypoint is behind the user.

Environment Features. SWAN is built on a flexible audio system that can sonify a variety of environmental features using auditory icons, earcons, and spearcons. Features in the environment that are sonified are generally static (e.g., park benches, mailboxes) but may also include dynamic obstacles depending on sensing capabilities (e.g., a rolling cart in a hallway). Environment sonification may include potential obstacles that the user should be cautious around (e.g., stairwell) or provide situation awareness and opportunities for community participation (e.g., entrance to a bakery).

Interactive Annotations. The authors have previously explored social app features that allow users to contribute to the community via environment annotations. For instance, a user may discover a closed sidewalk, a low-hanging branch, etc. The user could add an entry to the cloud to remind themselves in the future and provide support to other SWAN users. It is hoped that these features can be revisited as SWAN transitions to modern platforms.

Auditory Menus. There are several ways to control the system (e.g., tell SWAN where you want to go). One method is via a speech recognition/voice command interface. However, in practice, such an input method is neither reliable nor private enough to be seriously considered for continuous user input to a navigation system. Thus, we implemented a simple and effective audio menu system to be used instead.

SWAN 2.0 Research and Evaluation

The program of research supporting SWAN 2.0 focused on: (a) the user interface; (b) prototyping and interface building; and (c) the indoor localization capabilities. May (May, Sobel, Wilson, & Walker, 2019) conducted extensive research into the design of sounds for the SWAN 2.0 audio user interface (AUI), focusing in particular on the "last meter" of a path. That is, the earlier versions of the SWAN AUI focused on getting a user from start to finish along a path; the latest designs also feature the capability to help a user find an object at the destination. For example, consider a user who needs to get from her office to her laboratory and then retrieve a notebook in the lab. That notebook might be on a counter, but it might also be on a shelf or in a cabinet above or below the counter height. Helping the user identify where, in vertical space, the object is located required an additional set of sounds. Variants of those sounds were designed and evaluated with participants in a real physical environment supported by a virtual scene constructed with the Unity VR toolkit. See (May et al., 2019) and Figure 1 for more details on this aspect of the SWAN 2.0 AUI.

Figure 1. VR testing environment for SWAN 2.0 user interface, focusing on objects' "last meter" vertical location.

The second line of research involved the tools and methods that could be used to lay out, prototype, evaluate and refine a complete sonic environment. That is, when determining the sounds that will be used to represent the many features and events in, say, an office building, it is necessary to have a prototyping environment that supports rapidly implementing sounds to try, allowing users to experience the spatially laid out sounds and (virtually) walk around in the space, and then port those sounds and design choices to the real-time run-time environment. May (May, Tomlinson, Ma, Roberts, & Walker, 2020) developed a VR system that allowed the sound designer to mock-up and seek feedback on a sound design/layout, supporting rapid changes and on-the-fly revisions based on in-the-moment feedback from participants (see Figure 2).

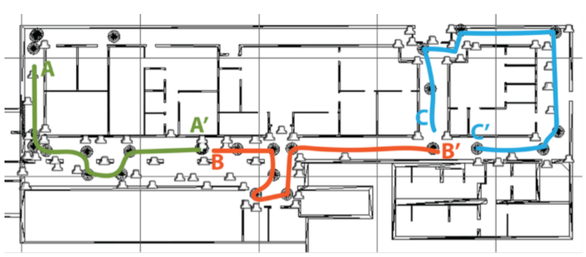


Figure 2. Tool developed to place sound sources in a (virtual) map of the real environment for prototyping sound designs and layouts.

SWAN 2.0 Localization

The third major line of research supporting the development of SWAN 2.0 has been in indoor tracking. As discussed earlier, localizing the user, particularly inside a building, has been a major hurdle for wayfinding systems, including SWAN. Very recent innovations in indoor location sensing have now made it possible, at least at the prototype stage, to identify where a person is located. The two main technologies include the Thales/Intersense IS-1500 and the Vortant smart pedometer.

The Intersense IS-1500[98] is a small sensor the size of a stick of chewing gum that includes a camera and an inertial sensing unit. The system can track indoors (or outdoors) using a combination of inertial motion sensing, visual point cloud sensing, and visual identification of pre-placed special images ("fiducials").

The Vortant[99] smart pedometer also uses inertial sensing to determine the distance and direction traveled by a pedestrian. The hope is that one or both of these technologies, in combination with WIFI, GPS (when available), and other localization methods, can provide a robust and accurate position fix, thereby supporting the wayfinding functions of SWAN indoors and in GPS-diminished outdoors locations.

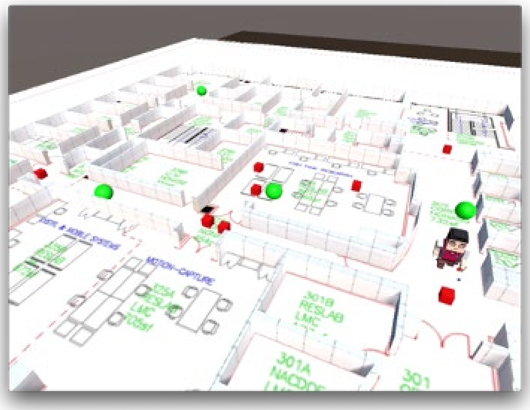
The SWAN 2.0 team researched the deployment, validation, calibration, and use of these technologies, as a foundation for our new system (see Figure 3). The technologies are being refined, and we are coping with bugs and system incompatibilities. This tells us that (1) the location and tracking technologies are very promising, but (2) there remain technical challenges before a full indoor wayfinding system such as SWAN 2.0 can be fielded.

Figure 3. Indoor localization testing, using the mounted fiducials for the Intersense IS-1500 tracking system.

As we move past the various minor bugs, we have continued to implement the various sub-systems for the new SWAN, and to support integration and further testing, we have implemented an indoor virtual test system (see Figure 4). This is similar to that developed by May (May et al., 2020) but at a higher level of fidelity and with the various inputs and outputs included (or simulated, if necessary). This virtual environment allows us to test path planning algorithms, obstacle avoidance, sound placement, and location tracking subsystems.

[98] https://www.intersense.com/is-1500

[99] https://www.vortant.com



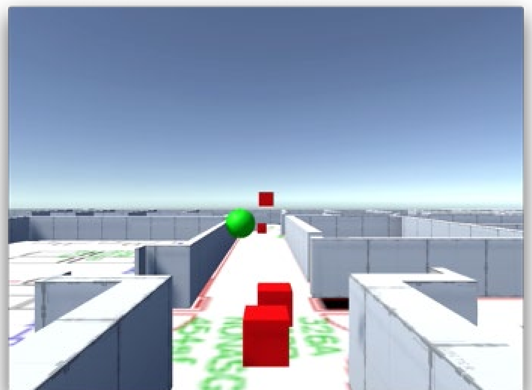


Figure 4. Design and prototyping tool (two views shown here) built-in Unity for integrating real and simulated data sources, path planning, and auditory interface for the System for Wearable Auditory Navigation (SWAN 2.0).

One promising area of progress with SWAN 2.0 indoor tracking is that we can map floor plans in high fidelity, given accurate floor plans. This allows tracking of navigable space with a navigation mesh (or NavMesh). The NavMesh provides a means of coordination of the static navigable space (walls, doorways, etc.) and temporary/dynamic obstacles detected by the camera (rolling cart, people, etc.). In real-time, the NavMesh data structure can be refined as obstacles are detected. A wayfinding path can then be automatically revised to go around the obstacle or take an alternative route if completely blocked.

SWAN 2.0 Hardware

Identification of the SWAN 2.0 hardware is challenging, given the rapidly evolving landscape of personal computing devices. In particular, augmented reality (AR) hardware is beginning to be commercialized with rumors of devices from major manufacturers. SWAN will certainly benefit from headphones with built-in inertial measurement units (IMUs). This feature will allow for head-tracking, which benefits audio spatialization. Also, SWAN users will benefit from headsets (possibly in an eyeglasses form factor) that provide camera systems for optical tracking, audio output (possibly via bone conduction), etc. Even if the user is unable to take advantage of AR visualizations in such AR glasses, the other I/O features could be very useful to the SWAN application.

In the absence of cutting-edge AR capabilities, a smartphone in a breast pocket with a camera protruding such that it views the user's local environment could be a useful platform. Alternatively, a user could wear a phone case suspended by a lanyard around the neck. For this scenario, the smartphone provides local computing capability as well as I/O for the SWAN application. The smartphone approach does not place tracking capability on the user's head, but we have found that users can learn to localize audio based on torso orientation rather than turning the head.

SWAN 2.0 Future

One aspect of the emerging consumer AR product space is that visual display requires considerable computation and power consumption. For this reason, it is desirable to minimize the use of visual capabilities only to important interactions and then go back to low power utilization. However, auditory display has a much lower impact on power performance. For this reason, SWAN 2.0 and similar technologies have the potential to become a primary form of interaction for a broad range of AR users. SWAN could become much more than an accessibility-oriented platform and instead contribute to the Universal Design of AR technology.

Conclusion

Over many years we have developed a System for Wearable Audio Navigation (SWAN) with powerful localization capabilities and a novel and effective auditory interface. SWAN aids a user in safe pedestrian navigation and includes the ability for the user to create and store personal pedestrian navigation paths. Emphasis is placed on the use of non-speech sounds through a process of sonification. SWAN serves as a foundation for research into a variety of aspects of psychoacoustics, human-computer interaction, and novel tracking technology. SWAN 2.0 represents the potential for a state-of-the-art commercializable system that can finally reach its potential to increase safety and independence for any who must navigate with vision impairment or blindness.

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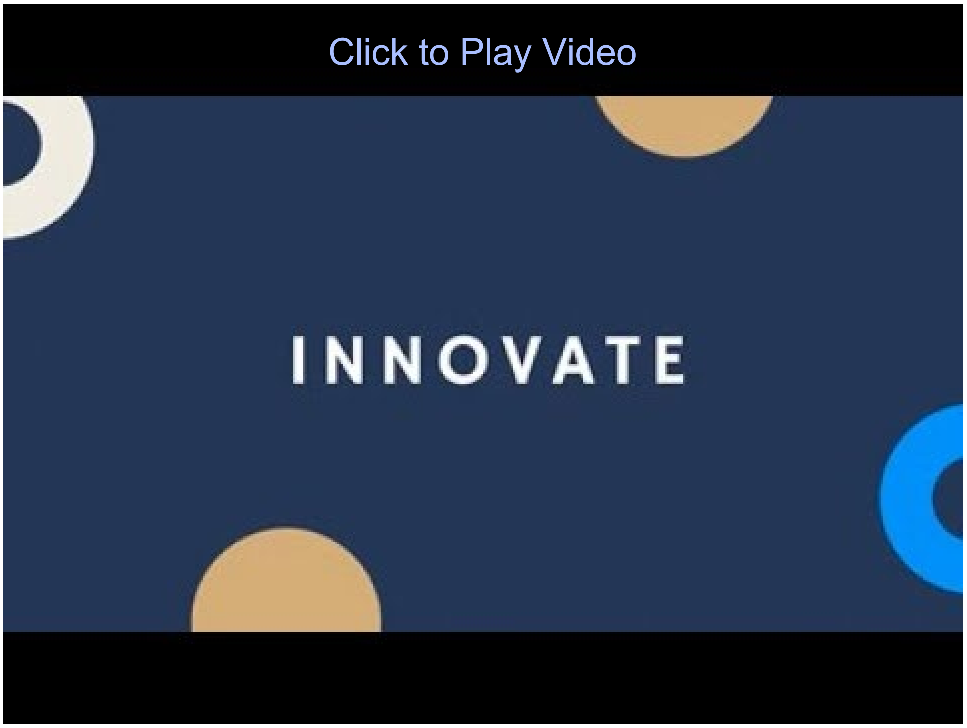
CHAPTER 4: HUMAN & ROBOT INTERACTIONS



Theatre & Robots - Envisioning Interdisciplinary Collaborations Beyond the Stage

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Abstract

An interdisciplinary team representing Theatre-Liberal Arts, Social Work, Kinesiology, and Engineering academic units collaboratively envisioned and conducted an innovative study designed for caregivers of adult children with intellectual and developmental disabilities (IDD) to interact with a socially assistive robot (SAR) and develop an approach to providing temporary respite for older adult caregivers. The transformative perspective to engage and include young adults with an interactive SAR respite scenario involved a programmable robot (employing computer science and engineering), and a multi-modal narrative, based on theatrical methodological theory,

infused with insights from social work, kinesiology, and engineering. Although the theatrical approach of the narrative is primarily described in this article, it is the interdisciplinary approach among the multiple team members that yield a transformative solution.

Keywords: theatre, interdisciplinary, socially assistive robot (SAR), intellectual or developmental disabilities

Introduction

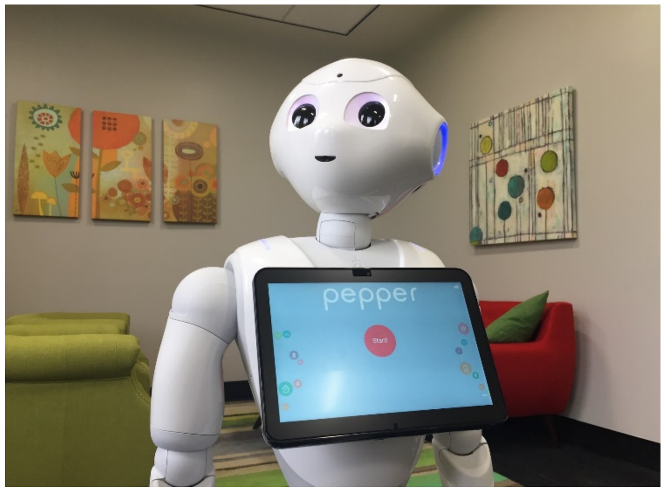

Figure 5: Pepper, Emotional Robotics Living Lab

An interdisciplinary team of university faculty and graduate students representing Theatre-Liberal Arts, Social Work, Kinesiology, and Engineering academic units collaboratively envisioned and conducted an innovative study designed for caregivers of adult children with intellectual and developmental disabilities (IDD) to interact with a socially assistive robot (SAR). As an interdisciplinary team, we worked collaboratively to jointly frame and address a common interest (i.e., Adya, 2015; Ameredes et al., 2015; Darbellay et al., 2014) - to develop an innovative approach to providing temporary respite for older adult caregivers. Interdisciplinary research is associated with transformative innovation and a transformative process that integrates knowledge in such a way as to produce novel understanding (Hesse-Biber, 2016; Rice et al., 2017). The transformative approach to engaging young adults with an interactive SAR respite scenario involved a programmable robot (employing computer science and engineering) and a multi-modal narrative, based on theatrical methodological theory, infused with insights from social work, kinesiology, and engineering. Early in the project's design phase, the team identified several domains for which a theatre perspective would make a critical contribution. First, previous studies have shown that proxemics – how space and distancing influence communications, comfort, and relationships – have a bearing on human and robot interactions (Mumm & Mutlu, 2011), as do relative positions (i.e., frontal vs. lateral placement) with repercussions for socio-emotional bonding and engagement (Papadopoulos et al., 2016). In the context of longer in-home interactions, such as we might anticipate with respite robots, a study by de Graaf and colleagues found that the robot's attractiveness, social presence, and enjoyment were factors in long-term acceptance (de Graaf et al., 2016). Our study sought to address these considerations and incorporate design features fostering social presence, appropriate proxemics and placement, enjoyable interactions, and an attractive robot learning scenario. The theatrical approach was key to achieving these aims.

Although the theatrical approach of the narrative is primarily described in this article, it is the interdisciplinary approach among the multiple team members that yield a transformative solution. The narrative story that the SAR recited was conceived and based on foundations of the Three-Act Structure, generally attributed to be originally conceived by Aristotle, and sourced throughout literature by Shakespeare, Moliere, Chekhov, and others, and currently as recently as the late 1970s for cinema-making (Field 1979). Three-Act Structure broadly frames three portions of a narrative story labeled as the Set-up, Confrontation, and Resolution. Specifically, our story featured a Setup, usually referred to in the theatre as exposition, followed by a dramatic conflict or confrontation, eventually allowing the participant with IDD to learn a lesson of resilience, anxiety-coping mechanisms, and companionship through the resolution. Multi-sensory domains of aural, physical, visual, affective, and story-making text perspectives were created to support the dramatic structure. In this way, the application of the theatre methodology theory working in tandem with our diverse and collaborative disciplines developed a multi-modal experience of engagement between the young adult with IDD and the SAR for the respite of their adult caregivers. Data were gathered through semi-structured qualitative interviews and quantitative analysis.

The emergent technological confluence of theatre, social work, kinesiology, computer science, and engineering provides an innovative and potentially transformative examination of how a social robot might enhance engagement for young adults with IDD, providing respite for their caregivers. The interdisciplinary nature of the team was particularly significant to the framing of the study and, more specifically, to the development of the narrative.

The care of young adults with developmental disabilities who live with their older (50+) parents is a complex issue needing a variety of interdisciplinary solutions (Brennan 2017). As parents age, the ability to care for their children is taxed (Fujira 2014). Caregiver respite is a significant issue in healthcare and long-term disability communities. Additional resources are needed to provide adequate respite care for children with IDD and their parents (Genik et al., 2020). Our interdisciplinary team sought to examine innovative solutions in this exploratory study as a collaborative University of Texas at Arlington – University of Minnesota, Twin Cities research project within the Georgia Tech Rehabilitation Engineering Research Center for Wireless Inclusive Technologies (WIT RERC), funded by the National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR*)*. Interdisciplinary teams promoted the potential of new methods of inquiry to spur innovative research, "Participatory theatre as a research method involves both participants and researchers in articulating their desires for social transformation, democratizing the research process and the relationships between researchers and participants" (Erel et al., 2017). In this essay, the theatre methodologies were programmed through the sensory modalities of sight, sound, speech, emotion, and physicality. The team developed the narrative to highlight themes of resilience and companionship between the SAR and the IDD care recipient, reiterating the team's objective of temporary respite for older adult caregivers.

The narrative that was created by the team was developed out of pre-focus group interactions between the theatre collaborator, interdisciplinary team members, and the parents of the young adults with IDD. We structured the actions within the intervention to broadly explore respite concepts the robot may perform, such as 1) limiting the supervision required by the parent of the young adult child, 2) programming the SAR to be a tool in reducing repetitive behavior and, 3) accompanying, or playing with the young adults and performing companion-like relational concepts drawn from theatre methodology theory that highlight connection, engagement and/or relational interaction.

This article primarily focuses on the role played by the narrative that highlights the applied theatre methodologies transforming the structure of human-robot communication to a more nuanced, subtle exercise. This is needed to capture the complex issues surrounding human social communication and awareness. The traditional term of "applied theatre" references theatre-based methodologies and exercises that exist and are meant to be applied outside a live stage event's typical and traditional performance platform.

One such specific caregiver request included the SAR's ability to provide a distraction for repetitive behavior and the physical movement from one location to another. The narrative was introduced with a change of location suggestion for the SAR to perform and for the young adult with IDD to interact with. In that way, the narrative was the significant catalyst in preventing repetitive behavior. The team did not intend to infringe on the parent's autonomy and relationship with their young adult children but rather fill a gap in caretaking that potentially may allow the older parent respite to undertake their role with renewed stamina. This is a reproducible research perspective for a community and society that may benefit from robot-human interactions and companionship. The team anticipates that the analysis of theatre techniques in research studies will continue to inform and provide innovative foundations for the programming of SARs as potential companions for young adults with IDD as they age.

Inclusion, Innovation, Transformation

This study is not the first to integrate engineers, artists, researchers, and computer scientists (Hoffman 2011, Jochum 2016, Lu 2011); however, this interdisciplinary team furthers the positive collaborative possibilities of applied theatre methodologies that fundamentally support research and examination of the innovative solutions occurring from interdisciplinary collaborations. This emerging use of applied theatre and social robotics is unique, inclusive, innovative, and transformative. By articulating the interdisciplinary research study for temporary caregiver respite, this article advances the role of applied theatre in healthcare domains and STEM-centric disciplines.

Materials and Methods

The interdisciplinary team submitted an Institution Research Board (IRB) protocol governing human participant research which was approved. Caregiver-care recipient participant dyads were recruited from a local private school for individuals with Down Syndrome and similar intellectual or developmental disabilities. Eleven (11) dyad participants completed the study and qualitative analysis at the close of the study. The study took place at the University of Texas at Arlington's Emotional Robotics Living Lab, providing a space for the interaction of the SAR, young adults with developmental disabilities, and their caregivers who viewed an approximately 15-minute interview from a separate room through a streaming video process. The use of streaming video was intended to make the entire scenario and SAR-young adult learning collaboration transparent in real-time. This setup was important in providing the caregiver with assurances not only of appropriate and helpful interactions but also in orienting family members to how the robot provides care, as a further basis for trust, and as an affirmation of their values and wishes (Johansson-Pajala et al., 2020).

The Emotional Robotics Living Lab (ERLL) at the University of Texas at Arlington dedicates a portion of its space to a home-like environment to bridge the gap between standard lab facilities and participant's homes. The use of physical space and the arrangement of furnishings was purposeful and calibrated to promote comfort and ready engagement with the SAR while also appealing aesthetically.

The interaction between the SAR and the young adult was one-on-one with several research team members in the same room to assure the safety of the participants and the completion of the intervention. The team in the lab included an engineering graduate student overseeing technical operations, a director of the lab and professor of Theatre initializing the introduction of the SAR to the young adult, and a professor of Kinesiology providing support and guidance for the young adult during the multi-step intervention.

Safety for the participants was a fundamental concern. Consequently, a blue circle was placed on the floor encircling the robot to extend a visual limit to the participant's proximity to the robot. The blue circle also served as a marker for the adult child with IDD, setting off the space for interaction from the space reserved for the SAR. Participants were encouraged to fist bump, not hug the SAR, after observing a team member mirror the fist bump physicality with the SAR. The Softbank Robotics Pepper© (Figure 1 below) unit was the SAR chosen for its humanoid shape and features, communication attributes, and safety and maturity in the social robotics market. Pepper is an approximately 4 ½ foot tall humanoid SAR weighing 65 lbs. It is a fully programmable social robot used in research, industry, and education. The robot includes a tablet located on its chest which can be used for visual communication through programmable text or figures. The design for text for the narrative story below was developed for the cognitive level appropriate of a 12-13 aged young adult.

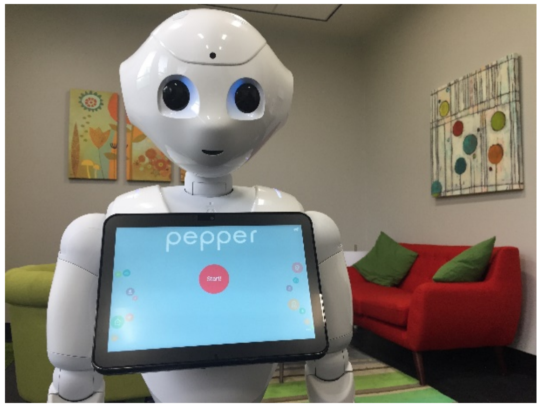

Figure 1. Pepper, (SAR) Emotional Robotics Living Lab, UTA, Greer photo

The narrative design includes the creation of text, aural sound modalities, visual modalities, physicality, and affective elements. In this way, the team consistently brought innovative interdisciplinary perspectives and approaches to the programming between the IDD participant and the SAR. These design components emphasized the facilitation of temporary respite for an older adult caregiver, assuaging safety concerns while also providing a stimulating, inviting, and engaging learning environment for their adult child.

Narrative. The narrative text was an interdisciplinary collaboration based on text-based themes of resiliency, communication, connectedness, and anxiety mitigation as guided through a multimodal sensory platform. The story is recited with the robot verbally speaking narrative text aligned with aesthetically pleasing visual images appearing on the SAR's tablet. The text of the study follows:

> **"It was a beautiful morning, and the sun was shining and birds chirping happily. It was my first day of school. I was so excited to meet new friends and to learn many new things. But I was a little scared too.**
>
> **When I arrived at school, I became a little anxious. It seemed like everyone did things different than me. The teacher tried to help, but I was still a little sad. This continued for a few days.**
>
> **Suddenly, one fine day, a friend like you showed up, and we ate lunch together. The music you played made me feel happy. I felt like a superhero and was happy being with you. I enjoyed moving, dancing, and playing with you, my friend. And I liked this robot dance. When I went to school the next day, I talked to the teacher and even smiled at the other students. That felt good, too. My friend and I do many things. We even go shopping for groceries. There are days when I am a little down, but friends like you always make it better. That was my happy little story. I would love to hear a story about you now. Would you like to tell me a story? You can say yes or no."**

Text. The story's text is conveyed by a first-person narrator describing an exciting, albeit complex, event - the first day of school. It was essential to the team not to present a homogeneous story narrative of cliché emotion or to hurriedly disregard the difficulties that may occur on this significant day in a young person's life. "**It was my first day of school. I was so excited to meet new friends and to learn many new things. But I was a little scared too."** Theatrical methodology and theory cannot exist without conflict, and both excitement and trepidation can exist in the same moment. The interdisciplinary team maintained the story's narrative strives to reveal the complexities and nuance of the young adult participant's emotions that may occur on an event as significant as the first day of school. In the text below, conflict, support, and emotional realism are noted in two ways. Affirmative words are coded in green and include: beautiful, shining, happily, excited, learn, help, happy, superhero, happy, enjoyed, liked, smiled, good, better, happy, and love (16 words total). Negative words are coded in red and include: scared, anxious, different, sad, and down and are coded in red (5 words total). Linguistic resources were utilized with the term "a little" before negative terms. "A little" quantifies the meaning of the word for listeners to allow a larger range of affective connections and customizes the text for participants to feel both "scared" or "a little" scared (Hakulinen, ed., and et al., 2005).

> **"It was a beautiful morning, and the sun was shining and birds chirping happily. It was my first day of school. I was so excited to meet new friends and to learn many new things. But I was a little scared too.**
> **When I arrived at school, I became a little anxious. It seemed like everyone did things different than me. The teacher tried to help, but I was still a little sad. This continued for a few days.**
> **Suddenly, one fine day, a friend like you showed up, and we ate lunch together. The music you played made me feel happy. I felt like a superhero and was happy being with you. I enjoyed moving, dancing, and playing with you, my friend. And I liked this robot dance. When I went to school the next day, I talked to the teacher and even smiled at the other students. That felt good, too. My friend and I do many things. We even go shopping for groceries. There are days when I am a little down, but friends like you always make it better. That was my happy little story. I would love to hear a story about you now. Would you like to tell me a story? You can say yes or no."**

In addition to understanding theatrical literature as a sign system that codes and defines its meaning in multiple modes (Aston et al., 2002), the narrative text was purposefully created to provide dynamic tension and theatrical conflict (Heim, 2016) between affirmative and negative words. The addition of the dual emotions in a single event led to the narrator's realization that they may experience a sense of being different or an outsider, and at this point, do not feel the camaraderie of friends, but rather the emotional tone of an outcast or outsider. This narrative concept is not meant to assume all young adults with developmental disabilities would feel scared on the first day of school. It is a trope that demonstrates that all humans from time to time feel ostracized as a reaction to a particular situation. "**It seemed like everyone else did things differently than me."** Although the young adult has support from the teacher, they still feel sad. The text introduced a new type of friend, a friendly, social robot. The visual is a cartoon robot meeting a young adult. **"I enjoyed moving, dancing, and playing with you, my friend!"** This text illustrates that a SAR has the potential to fill a gap and complement human companionship and become a friend to a young adult with developmental disabilities. A programmable social robot integrated to provide companionship for a young adult with disabilities can provide the temporary caregiver respite and needed support for communication and resilience in difficult situations. "**...even smiled at the other students. That felt good, too."** Finally, the story again reiterates the narrative conclusion that a companion SAR will not remove all difficult emotional situations and events that make us scared and anxious. Still, it allows more comfort and security to encourage the young adult to interact more fully with others during stressful times.

Aural Modality. The aural sensory modality of the study was a significant contributor to the overall presentation of the narrative. There were two major aural areas in which the participant interacted with the SAR. They were 1) Pepper's programmable voice tone and pitch and 2) a digital classical music accompaniment to the text.

Tone in voice production is the characteristic subjective understanding of the meaning of the words. Pitch in voice production is the range between low and high tones. The Pepper SAR voice can be programmed to fit a variety of vocal pitches from low to high. A low range of pitch has been associated with authority (Lowen, 2011). A higher range of pitch is associated with a younger, child-like personality. A combination of pitch and tone components can simultaneously imply complex social communication "a robot with a child's voice was more likely to be perceived as having an extroverted, passionate, and relaxed personality. (Dou et al., 2019). The team determined a higher tone voice was appropriate for the SAR to encourage connectedness between the IDD participant and the robot.

The classical music accompanying the text set a mood for the story, not unlike a soundtrack in a cinematic feature. Two separate pieces were selected. The first selection was chosen for its soothing, affirmative tone. The piece played continually until the sentence "**Suddenly, one fine day…"** At that time, the second piece began and seamlessly flowed into an upbeat, energized musical movement that reflected the story's affective change from anxiety to well-being. Current research has indicated that aural studies in human-robot interaction are understudied, most specifically in the realm of affective communication. A hearing/aural modality may have significance beyond our primary vision modality, "voice-only communication increases empathic accuracy over communication and across senses "(Krause, 2017). Consequently, utilizing voice and pitch in digital voices may lead to better engagement, trust, and connection in human-robot interactions.

Visual Modality. The visuals in the study were presented on the SAR-mounted tablet and ran concurrently with the textural story, augmenting the meaning of the narrative and creating unique meaning to the narrative. The visual modality included animated graphics of a sunrise, birds chirping, friends dancing, multiple cartoon superheroes, a school, a sad, anxious face, and a robot. The tablet screen on the SAR was approximately two feet from the seated participant, approximating eye level for the young adult. The choice of brightly colored, animated figures was used to engage and animate the textual aspects of the story. Current research in graphic animation for robot communication includes culling the 12 principles of animation from the golden age of Walt Disney animators (Schulz, 2019). "Animation techniques (for HRI) improves an individual's interaction with robots, improving the individual's perception of qualities of a robot, understanding what a robot intends to do, and showing the robot's state or possible emotion." The use of static or moving visuals to intensify and heighten the affective communication between a human and a robot has interdisciplinary roots that the team was encouraged to support in creating the narrative's visuals on the tablet for the understanding and meaning of the IDD participant.

Physical Modality. The physical modality that accompanies the narrative is developed through the parent pre-focus group meetings. A desire on behalf of the parents was to create a robotic physicality that interrupted repetitive behavior. It was created through the robot moving from one location to another location in the lab, encouraging the IDD participant to join them. In our study, the participants freely moved with the SAR to the Emotional Robotics Living Lab couch and back again to the center of the lab. Other physical interactions included a fist bump. After interdisciplinary deliberation, the fist bump was programmed to allow the participants to interact with the Pepper SAR in a safe, fun, and engageable manner. It was determined a handshake was too formal and a hug was not safe, as the SAR has moving joints and limbs that could capture the young adult's clothing with IDD. The major physical components of the study included a fist bump, gestures during the narration of the story, and breaking repetitive behavior by moving from one location to another in the lab.

Affective Communication. Affective and emotional communication in recent affective computing studies encourages the understanding and application of emotion in human-machine interactions (Breazeal, 2004, Franzoni et al., 2019), particularly as an aid to learning (Cuadrado et al., 2016). The use of affective human-robot connection through the narrative was of primary significance to the team. The interdisciplinary team focused on themes of resiliency, companionship, friendship, and human-robot interactions to encourage an affective connection between the IDD and the SAR. The team postulated the development of engaging, trustworthy emotional content between the IDD participant, and the Pepper SAR would significantly impact the study. The parent groups spoke to the affective companionship qualities needed in a SAR to be successful for temporary respite and connection with their children. Family 8 stated, "It allows peace of mind. I can walk out of the room, I can walk out of the house, I can even run to the store without worrying about it 24/7. And now, yes, is she okay if something happens? Does she know how to call? But Pepper is there and could fill…It takes so much weight. That's the value" (mother caregiver, female)."

Discussion

Post-study qualitative interviews with the caregiver and care recipient connected the affective quality, as well as the communicative nature of the narrative, to a personal and positive individual response for both members of the dyad. "It was amazing. And I thought the story…it was so, so, so emotional" (Family 1 CR, female). Another participant remarked how the interaction of telling a story – robot to human and human to robot – allowed the care-recipient to enjoy the narrative portion of the intervention in a specific and meaningful way, "It was amazing how he told his story, and you know, and how I told my story…I was actually excited because when I was looking at him, um, he kind of like read me, like an actual book" (Family 2 CR, male). And finally, a caregiver expressed great interest in narrative uses for the interaction and that it was a manner of communication that their child (young adult) was especially fond of, "…She loves books so having a story read to her…she loves to be read to and stuff…" (Family 8 caregiver, female). The addition of a multi-modal narrative based on theatrical methodological theory and combined with insights from social work, kinesiology, and engineering is an effective asset for collaboration in an interdisciplinary research study. So too were the considerations of scene and setting as informed by a theatrical approach. The findings of this proof-of-concept study on SAR as a temporary respite provider make a good case for integrating a theatre perspective into interdisciplinary research on human-robot interactions.

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Using Socially Assistive Robotics (SAR) to Provide Respite for Caretakers of People with Developmental Disabilities

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Abstract

The research team piloted a study examining a socially assistive robot (SAR)'s ability to offer respite for caregivers of young adults who have cognitive and developmental disabilities. This pilot utilized an exploratory mixed-method research design with the qualitative method of focus groups informing the process. It led to the quantitative development portion of the research project, which entails the SAR intervention and pre/post-survey. After the intervention, the researchers conducted follow-up interviews. The study's findings include that older caregivers positively perceive the SAR, but the caregiving burden and physical and mental health did not improve significantly after the intervention. This paper offers recommendations for entities interested in exploring SARs as a tool to alleviate the strain for caregivers of young adult children with intellectual or developmental disabilities (IDD).

Keywords: intellectual or developmental disabilities (IDD), Socially Assistive Robot (SAR), adaptive robotic system, humanoid

Introduction

This pilot study explores how a humanoid, socially assistive robot (SAR) Softbank Robotics Pepper could provide a brief respite for older adult family caregivers of young adult children with intellectual or developmental disabilities (IDD). Our interdisciplinary team consisted of seven researchers: six faculty members (one from kinesiology, one from theatre, and four from social work) with one engineer.

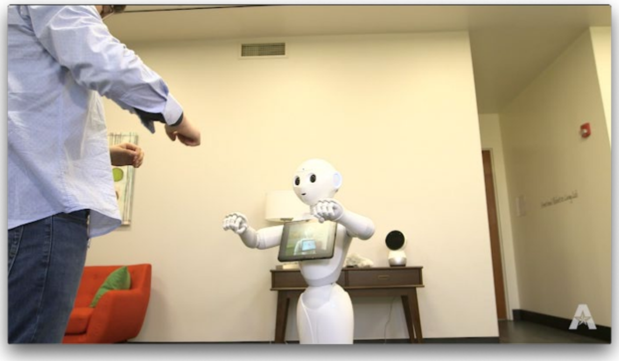
A mixed methods embedded research design was used in which we collected qualitative data before the intervention (i.e., Phase I, focus groups) to help with the development of the SAR program as well as after the intervention (i.e., Phase III, individual interviews) to enrich the interpretation of the experimental results. Qualitative data can lay a strong foundation for subsequent pilot intervention work by facilitating the development of an underlying study conceptualization, providing recruitment feasibility estimates, helping establish clinically meaningful inclusion criteria, and providing support for face validity of newly developed interventions (Akard et al., 2013). It can also be particularly useful when data or information is limited, and a greater understanding is desired for collecting information on the acceptance and usefulness of new technology (Schneider et al., 2011).

Pilot Study

Phase I: focus group. We recruited 11 dyad pairs of older adult family caregivers and young adult children with IDD. A semi-structured focus group guide was used to allow for the use of probing, follow-up questions. Data were analyzed using conventional content analysis from four focus groups: two of older adult caregivers and two of adult children receiving caregiving. The focus groups were small, ranging from 4-5 participants in each group, but within the range indicated by the literature, specifically for adult children with developmental disabilities, for which smaller focus groups are indicated (Kroll, Barbour & Harris, 2007). Moderators were aided by an assistant from a community agency to provide support and ensure sufficient experience with disability groups (Kroll et al., 2007). Across the focus groups, caregivers offered insight and recommendations regarding respite care and the activities of the social robot, Pepper. Several themes emerged: 1) length of time for the respite; 2) safety as part of respite; 3) robot as companion; 4) interactive engagement; 5) positive reinforcement; 6) activities that promote independence; 7) trust and building trust; and 8) privacy.

Phase II: intervention and pre/post-survey. After listening to the participants' feedback and expectations about social activities of the SAR in respite care during Phase I, the research team programmed the robot named Pepper. We listened closely to the caregivers' concerns and hopes for the care recipients (CRs) and their values (participant safety, well-being, positive learning environment, and growth) to craft an interactive learning experience consistent with a values-based participatory design (Iversen et al., 2017). This allowed us to set some parameters around the type and intensity, as well as the aim of the interactions.

The interactions programmed were mainly social activities, such as reading a story, playing fun activities, dancing together, etc. A beta test of the robot program was arranged with an 8-year-old volunteer with no disabilities (with parental assent) because the CRs displayed moderate to severe IDD at an age-equivalent level of about eight years of age (Smith et al., 2005). After revising the programing based on observations of the beta test and feedback from the volunteer, the full demonstration of the program was applied to the participants. The 11 CRs interacted with Pepper individually, and each demonstration took approximately 15 minutes, while their older family caregivers took respite in another room where a video was set up for them to observe their child's interaction. Pre- and post-surveys were administered by trained interviewers before and after the program for caregivers and their CRs, respectively. Each survey took approximately 10-30 minutes.



Results from the pre- and post-test surveys showed that both older caregivers and their CRs had favorable scores of the social presence of robot Pepper (*Mean* = 44.25 for caregiver, *Mean* = 59.17 for CRs, *Range* = 7-70). For social engagement, the caregivers reported a maximum score of 5 while CRs thought their participation was 4.8 out of 5. Dyads also reported their satisfaction with Pepper (*Mean* = 14.25 for caregivers, and *Mean* = 16.17 for CRs, *Range* = 5-20). Caregivers reported specific perceptions of Pepper in terms of anthropomorphism (*Mean* = 19.4, *Range* = 5-25), animacy (*Mean* = 24.60, *Range* = 5-30), likeability (*Mean* = 25.00, *Range* = 5-25), perceived intelligence (*Mean* = 20.80, *Range* = 5-25), and perceived safety (*Mean* = 14.80, *Range* = 3-15). In terms of the dyads' well-being, results from the Paired Wilcoxon Signed Ranks showed that caregiving burden, physical, and mental health did not improve significantly after the intervention. CRs also reported quality of life, with relatively high levels of emotional well-being (*Mean* = 13.57, *SD* = 1.78, *Range* = 4-16), material well-being (*Mean* = 22.85, *SD* = 4.19, *Range* = 7-28), physical well-being (*Mean* = 22.57, *SD* = 2.95, *Range* = 7-28), and social inclusion (*Mean* = 17.91, *SD* = 3.44, *Range* = 4-24).

Phase III: dyads interview after the intervention. After the full demonstration, the caregiver and CR, as a family dyad, took a post-test survey that included open-ended questions in another room, which lasted approximately 30 minutes. The interviewer asked dyads' opinions about the social presence of Pepper, social engagement with Pepper, their most liked or disliked parts of the intervention program, as well as their suggestions for future programming/intervention.

Results from the interviews suggested that the dyads were open and positively receptive to the SAR. Both caregiver and the adult child (CR) responded positively to Pepper's presence, including how the robot engaged the CR in learning new movements while also building a relationship. Several participants reported that Pepper could be an addition to their family or that they just loved 'hanging out' with the robot. Content analysis from the interviews suggested that the SAR may offer companionship and/or friendship as well as promote independence, safety or monitoring, interactive engagement, and physical and/or emotional respite.

Discussion

In general, these findings suggested that the SAR engaged the CRs in a series of stimulating exercises and interactions, as well as provided physical/emotional respite for their older family caregivers. The Phase I focus groups provided key input for the Phase II program implementation design, which is consistent with previous participant-informed interventions for family caregivers. This contributes to the literature on family-centered and participation-focused caregiving models sensitive to the special needs of study participants (Mirza et al., 2020; Wilcox et al., 2010). A family and/or participant-focused intervention is the latest approach aimed at achieving individualized support for people with IDD and improving their quality of life (Ratti et al., 2016; American Speech-Language-Hearing Association, ASHA, 2020).

The findings from Phase II showed both older caregivers and CRs scored the social presence of Pepper favorably and were satisfied with Pepper. These results were consistent with a previous study showing that older adults had positive reactions after exposure to SAR activities (Beuscher *et al.,* 2017; Vandemeulebroucke et al., 2018). However, the present study makes a unique contribution to the literature by focusing on older family caregivers of persons with IDD. In Phase II, no significant changes were found in caregivers' stress/burden or the well-being of CRs. The lack of significance might have been influenced by the "dosage" of the program (i.e., one-time-only, approximately 15 minutes) that may have been insufficient to impact the caregivers' burden or well-being.

Content analysis from the Phase III interviews suggested that the SAR may offer physical/emotional respite for caregivers because of its potential for providing companionship as well as promoting independence, safety/monitoring, and interactive engagement with the CRs. These findings were consistent with a previous study that showed SAR's potential to enhance engagement, promote child independence during rehabilitation exercises, and support a rehabilitation program when a human therapist is not accessible (Butchart *et al.,* 2019). Findings from Phase III underscore previous research suggesting that SAR could potentially enhance well-being and decrease the workload on caregivers (Kachouie *et al.,* 2014).

Follow Up after the Pilot Study

Older Adult Caregiver Interviews. Our team conducted follow-up remote (telephone or video call) interviews of seven of the 11 older adult caregivers who participated in the robot respite study. The follow-up interviews aimed to explore caregiver's experience and perceptions of the initial response to COVID-19, their coping strategies during the pandemic, and the role of assistive technology (such as our socially assistive robot) in their coping process. Each interview lasted about 45-60 minutes. Below are some highlights of the findings based on a preliminary analysis of the interview data.

As of this writing, there have been few published studies of COVID-19 surveys on the pandemic's psychosocial impacts and the role of technology. Linehan and colleagues (2020) have published a protocol for a global survey exploring the impact on individuals with IDD and their caregivers, while Bernard and colleagues (2020) have proposed a novel survey of the impact of COVID-19 on persons with disabilities. Both efforts are prospective and have yet to launch.

Our preliminary findings suggest several key impacts of COVID-19 relevant to robot respite caregiving, clustering around six themes: (1) disruption of family-life balance, (2) heightened communication and social interaction barriers, (3) positive expectations of assistive technologies, (4) ethical concerns, (5) gratitude and a sense of community, and (6) risk control.

Family-life balance. COVID-19 has abruptly altered the activities available to both older adult caregivers and their adult children with IDD. Examples include cancelation of Special Olympics, cessation of classes at school (for persons with disabilities), and cancelation of bowling activities, family gatherings, and in some cases, termination of employment (caregiver and/or CR). In response to these challenges, one family moved physically to another state to gather with other family members while the caregiver works from home.

Barriers to communication and social interaction. Explaining the rationale for altering family and individual activities to the CR was challenging. A closely related theme is heightened barriers to social interaction, which led to increased use of virtual platforms and communication media, such as online gaming, remote learning, virtual activities (family, friends, and church members). The net impact of these barriers was variable. Some respondents reported less stress due to the decrease in travel and external caregiving activity obligations, and others reported a better division of caregiving, diminishing stress levels. By contrast, others reported more strain due to the absence of diversions and communal activities and the increased social isolation.

Positive IAT expectations. Positive anticipation of intelligent assistive technologies (IAT), particularly Pepper and other SAR, as helpful in coping with some effects of social isolation was another theme. Pepper's social presence was viewed favorably, particularly the robot's physical presence rather than remotely, as a virtual robot.

Ethical concerns. Despite their largely positive perspectives on Pepper's potential for bridging social isolation, there were ethical concerns. Access and usability of technology is a concern implicit in the desire to have an actual robot rather than a virtual one, and researchers have commented on flattening access barriers during COVID-19 (Kaplan, 2020; Rosenblum, 2020). Another concern was that data automatically collected by Pepper while interacting with the CR would be vulnerable to breaches of privacy or hacks. Other authors have anticipated privacy concerns around the greater use of technology as a consequence of COVID-19 (Elmas et al., 2020; Kaplan, 2020).

Gratitude and sense of community. COVID-19 also caused a shift in the locus of control and extended sense of community in some respondents. Diminished opportunities for face-to-face social contacts and external activities led some respondents to look inward and focus on the control they can exert on their attitudes, particularly the ability to focus on gratitude for the choices and interactions they have available. Bridging a more empowered self and others, the greater connectivity achievable through virtual platforms and digital media have expanded the horizons of time and space for some respondents, enlarging their perspective on possibilities, present, and future. This suggests an interesting and paradoxical result of COVID-19 disruptions and constraints for at least some people that bears further examination.

Risk control. Interviewees placed some emphasis upon control over possible safety and privacy risks. This theme resonates with the extant literature. The perception is that Pepper brings with it some safety risks (robot caused harm) and ethical (privacy) concerns that are best mitigated by putting the control directly in the hands of the participant with IDD and their family member(s). This entails literally having *an on/off switch for Pepper* that can be activated if necessary, and some indicator that would assure the users that Pepper was not recording without their knowledge *safeguarding the caregiver-CR privacy*. Whatever recording might be needed for the research protocol should not be shared. A virtual Pepper would have the added benefit of removing immediate safety concerns while ensuring that users could disable the transmission at any time if needed. The best modality for a virtual Pepper would be using a *laptop, both to enable the CR whose familiarity* with the device would give him/her more control and enhance his/her engagement.

Discussion. While acknowledging the potential of COVID-19 ‘connectivity’ technologies to expand networks, relationships, and perspectives, it is also important to acknowledge that the mediating effects of technology on the social and psychological distancing effects of COVID-19 have yet to be adequately assessed (Robb and colleagues (2020). Negative correlations between levels of technology-mediated social connections and anxiety have been found (Robb et al., 2020). Our preliminary work and other COVID-19 studies suggest that the relationship between COVID-19, social connections, coping, and technology are multi-factorial and contingent upon individual circumstances, characteristics, and the social environment context.

Community Partner Interviews. As we began to plan for future research, we were strongly encouraged by our research participants’ stated interest in robot- and AI-mediated caregiver respite. The context of participant recruitment, particularly in the context of COVID-19 and virtual research, is challenging, and the bridging role played by our community partners became even more salient. This is particularly true for research participants – the majority comes to us through the auspices of our community partners and for whom the community partners have a fiduciary responsibility. Identifying, engaging, and recruiting participants is largely made possible through our community partners: community-based organizations (CBO). CBOs are inclusive of non-profits, advisory boards, grassroots and civil society intuitions, and schools, playing an indispensable role, not only in their capacity as a pipeline but also as collaborators in the knowledge development process and implementation (Wilson et al., 2010).

The virtual research context brings with it complexities of communication, planning, trust, and relationship building. There is a paucity of research on how researchers engage CBO (Adebayo et al., 2017; Bloom et al., 2009), so what we learned in the COVID-19 era will also enhance the general knowledge base. There is evidence pointing to CBO as sources and partners for research that enhances knowledge-building and exchange in service of people with developmental disabilities (McDonald & Stack, 2016) and older adults (Syed et al., 2017), further suggesting that we conduct research to update and enrich our understanding of relationship building and support for our community research partners in the virtual research context. Arguably, in the COVID-19 era, the role played by our community partners in the lives of our participants is even greater, serving as a virtual connection between researchers and participants. To not overstate those connections, we note that CBO staff do not always reflect nor have first-hand knowledge of the issues of most importance to research participants. Researchers, community partners, and consumers have distinctive interests that must be negotiated, along with the roles and boundaries of each stakeholder group (Collins et al., 2018).

It is with the purpose of exploring researcher-community partner relations in the era of COVID-19 that we interviewed our community partners. These interviews complement our previous follow-up interviews of research participants, with the added dimension of a focus on supports we might offer our partners, bearing in mind their needs and those of the clients they serve (e.g., our research participants). We developed nine (9) interview items guided in part by a semi-systematic review (see Snyder, 2019) to generate themes for further exploration from two related research literatures: (1) research on virtual teams and (2) on interdisciplinary research teams. To supplement the limited existing literature on virtual research teams (Hanebuth, 2015; Munro & Swartzman, 2013), we drew upon our own team's experience across a variety of studies, reasoning inductively. This combined process led us to identify four themes for exploration in our community partner interviews: (1) what do virtual interdisciplinary research teams (VIRT) need to do to contribute to relationship building, trust, and clear communication? (2) what roles and types of stakeholder collaboration, facilitated by VIRT, are best adapted to the COVID-19 research environment? (3) what ethical considerations are key? (4) what issues are paramount for VIRT to engage with and address? We interviewed community research partners in several states, using the results to develop insights suggesting how our VIRT (and others) can better engage partners and participants as co-creators of knowledge while pointing to strategic virtual research 'resets' for the COVID-19 era. The principal shift that we wanted to capture was the impact of COVID-19, especially around virtual communications, relationship building, and participant engagement, as the connection to our community partners and the research environment shifted abruptly from in-person to virtual.

Shared perspectives. The preliminary results show some role-based differences in perspectives but also shared views, particularly with respect to value-based priorities and shared appreciation for the need to accommodate and support diverse participant needs and aspirations. Several common themes emerged across interviewees: the importance of value/mission alignment, data security, robust communication tools, protocols and practices, well-articulated and clearly shared planning processes, training for participants in the necessary devices, platforms, and systems, mutual respect, realistic timelines, learning opportunities for all parties, clarity of intention, and thoughtful collaboration.

Pre-COVID-19 relationship building. When asked about key relationship-building attributes before COVID-19, the respondents pointed to sharing background information, getting to know each other personally and professionally, clearly defined roles, being open to learning from what does not work, valuing the partnership equally, and developing structured research programs that are sustainable.

Relationship building. In response to the question of how COVID-19, and the shift to remote communications, changed expectations and activities, interviewees noted the increased need for secure communication and data sharing, weekly/regular/routine meetings, plus sustained communication. They pointed to the benefits of remote exchanges in terms of health, safety, risk, and access, but with that comes greater anxiety, owing to fewer tangible contacts, making participants and their families perhaps less eager to participate in follow-up/future studies.

Fostering trust. To foster more trust in the COVID-19 virtual (remote) environment, interviewees suggested the co-design weekly meetings, advanced planning, more interactive research learning, and online communication to foster a sense of community among participants in a safe environment. They observed that virtual environments underscore the need for ample bi-directional communication. New ethical concerns emerging from the virtual research milieu include the need for strong cyber security safeguards at every stage to ensure privacy and confidentiality, as well as clear communication of benefits, risks, and expectations to ensure voluntarism, safety, transparency, and accountability.

Accessible technology and platforms. Respondents indicated that the needs of each group of participants (i.e., those with various developmental disabilities and/or older adults) are accommodated, and an environment of trust is created that allows participants to acknowledge challenges, be vulnerable while receiving assistance to build needed capacity. Making available the appropriate (multi-modal) technologies, training (staff, intern, and participant), and an interactive, risk-rewarding, positive learning environment were also deemed important for virtual research teams to provide community partners and participants.

Discussion. Our finding of a strong emphasis on mutual accountability, respect, and ongoing efforts at relationship building are consistent with those of other contemporary investigators in the domain of community-engaged research (i.e., Wallerstein et al., 2020). The strongest validation for equitable relationships, respect, and collaboration for mutual benefit was expressed by the CEO respondent, no doubt reflecting their role-based experiences and priorities. The respondents' perceptions that the research team's focus, priorities, and capacity align with those of the community partner and take into account the current COVID-19 context was shared by respondents in both the CEO and research director role, were consistent with findings of other investigators whose work focused on university-community bridge-building and equitable collaborations (i.e., London, et al., 2020). From the research director's perspective, the availability of accessible, appropriate technology and the digital literacy training needed to participate in virtual research is most salient. Recent studies highlight the importance of technology tools and skills as necessary for older adults and people with disabilities to engage with the new technologies of contemporary life (i.e., Smith et al., 2020; Van Jaarsveld, 2020), and in the same vein, virtual research.

Conclusion

The pilot study served as a proof-of-concept that a SAR (Pepper) could provide temporary respite for older adult caregivers of adult children with disabilities and be positively perceived while providing meaningful engagement in a climate of safety and learning. We then conducted two sets of virtual follow-up interviews after COVID-19; one with the caregiver study participants, followed by one with community research providers. The participant interviews revealed how a combination of direct COVID-19 concerns around safety and isolation and virtual-format-related concerns around ethical and accessibility challenges create new barriers and opportunities for robot respite depending upon family circumstances and experiences. Meanwhile, the community partner follow-up interviews articulated supports, resources, and concrete steps researchers could take to better engage with them and the clients they serve to ensure ethical, trustworthy, equitable, respectful, and accessible robot respite research. The importance of participatory, value-based research design, robust communication, equitable processes, and attention to all stakeholders' accommodation needs and aspirations emerged as common themes through all phases of the study and the follow-up interviews. COVID-19 underscored the importance of mutual respect, collaboration, and purposefully building a community of learners (researchers, community partners, and participants) to co-create a safe and effective environment for robot respite.

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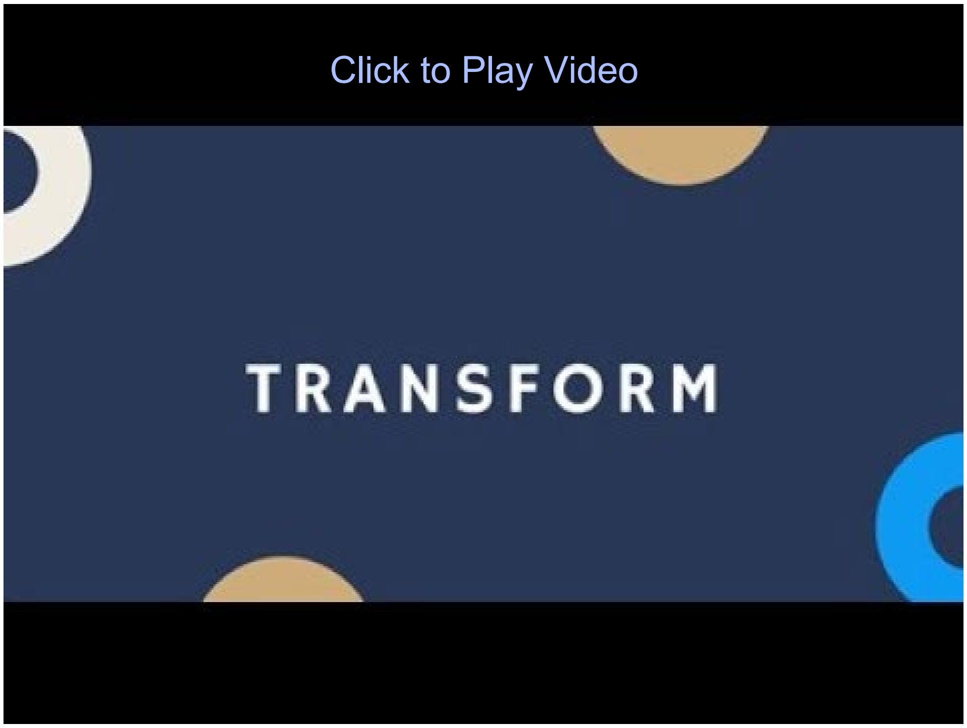
CHAPTER 5: TRANSFORMATIONS



The following topics emerged from the Forum as critical to ensuring a future that is accessible for all.

Key Activities to Generate Inclusion

Stakeholder Engagement

The COVID-19 pandemic that dominated 2020 underscored the importance of building communities comprised of researchers, community partners, governmental entities, and citizens. Engaging across stakeholder groups will result in creating inclusive, safe, and effective environments. The importance of participatory research design, inclusive communications, equitable processes, and attention to accommodation needs emerged as common themes—the following highlight items needed to facilitate stakeholder involvement.

Industry

- Industry engagement with consumers with disabilities can provide insights into their experiences and how products help or hinder user independence and inclusion. In addition to user needs, collaborative engagement can guide empirical data collection on access, use, and usability of the wireless technologies they sell. Industry's commitment to incorporate accessibility, as they

engage in the design and development process, can yield transformative technologies and services.
- Results of participatory user-experience-based design experiments highlight the challenges of designing accessible products that actually meet the end-user's needs. Many industrial product designers do not have the access, domain expertise, or experience to incorporate accessibility and usability considerations into their designs. As such, restructuring industry practices to include trans/interdisciplinary teams could stimulate new approaches to developing inclusive technology design, making the device more accessible, usable, and socio-culturally acceptable.

Capacity Building
- Capacity building in the classroom involves providing the same problem to groups in different courses, and thus over time, strengthening the skills needed to understand the concerns of various stakeholders. This can lead to generating a collection of possible technology prototype solutions.
- Inclusive design workshops can engage students in meaningful design activities while providing a unique experience for other stakeholders. The success of workshops is, to an extent, dependent on the participants, so having a mix of domain experts, researchers, student designers, industry members, and representatives of the target demographic (e.g., older adult/person with a disability) is recommended.
- Adoption of innovative, new training approaches, such as applied theatre methods and social robotics, can generate inclusive and transformative ideas, products, and solutions. Integrating engineers, researchers, artists, and computer scientists into interdisciplinary teams, can further the positive collaborative possibilities and examination of novel solutions.

Individuals with Disabilities
- Surveys of end-users with disabilities suggest that all users, including people with disabilities, are moving toward a more holistic view - from smartphones to more connected devices as part of a personal ecosystem. New applications, intrinsic to the devices themselves and connected devices, including wearables, smart home technologies, sensors, and Internet of Things (IoT) applications, consequently, enjoy wider use among individuals with disabilities.
- For many, policymaking may be perceived as remote to their daily lives, but many decisions that affect access to technologies, services, and programs are made at the federal level. Stakeholder input is sought to construct rules and regulations that protect consumers and encourage innovation, investment, and market competition. Disability stakeholder engagement in the policymaking process can be reflected in rulemakings, having, therefore, the possibility to impact industry practices regarding accessibility and usability. Strategies to

bolster such engagement should be integral to organizations working in the disability access and inclusion space.

- Usability studies show that continued education about wireless emergency alerts (WEA) is important. American Sign Language (ASL) is a critical part of understanding messages for people who are Deaf. Efforts such as outreach to the Deaf community about the meaning of specific emergency management terms and geotargeting for WEA messages are needed for ASL-interpreted WEA messages to be most effective.

Legislators and Regulators

- The applicability of the Americans with Disabilities Act of 1990 (ADA) (as amended) to websites has long been interpreted by the federal courts, with the burden of proof falling on the individual or group that has experienced differential access. Amending the ADA to include websites as a place of public accommodation would take the uncertainty out of whether people with disabilities accessing websites for employment, entertainment, education, e-commerce, or otherwise were protected by the ADA.
- Following from an ADA amendment concerning websites as a public accommodation would be the development of U.S. Department of Justice accessibility standards for companies, which they could incorporate by reference, the Web Content Accessibility Guidelines 2.1 (WCAG), which addresses mobile apps and mobile web accessibility.
- It is important for federal agencies (e.g., DHS, IPAWS, FEMA, and the FCC) to continue to work with researchers, industry, and end-users to create more robust multimodal, interoperable and flexible systems that will allow emergency management and the public to receive timely, user-friendly emergency messages and alerts on any device. Training of emergency management and first responders remains of great import to quickly institute the timeliest response solutions during a crisis, whether human-made or natural. In addition, FEMA and IPAWS should consult with people whose primary language is ASL and certified Deaf ASL interpreters to improve comprehension of critical information for the population of people who are Deaf.

Research Agenda

Findings generated by the Survey of User Needs, conducted among users with disabilities, reveal that accessible wireless technologies continue to experience high use levels, based on their utility to certain groups. Assessments also point to the ability to include, when needed, the deployment of rapid research response for health and wellbeing and potential opportunities to advance IoT accessible and assistive technology innovations. The following are potential research strategies to advance the inclusion of people with disabilities.

- The use of screen readers and screen magnifiers by individuals who reported blindness or vision-related disabilities demonstrates that built-in accessibility remains vital to technology access. Research to quantify the extent of cross-over use of these accessibility features by people with varying disabilities could bolster the argument for the inclusion of accessibility options across mobile devices, making device selection for people with disabilities equitable to people without disabilities.

- The research field needs to represent data in a way that makes sense to all types of stakeholders because what works for academia may not be suitable for industry, government, or practitioners.
- Increasingly, smart devices can sense, collect, store, and often act upon or induce user actions based on data received and displayed, bridging physical and digital environments. These devices can facilitate innovative approaches to health promotion, community integration, and independent living. However, researchers should explore and evaluate how to overcome the trust factor as an impediment to adoption.
- Researchers should explore which types of wireless devices are most intuitive for people with intellectual and developmental disabilities (IDD). At the same time, deduce which are the most financially feasible. Research teams should also develop and evaluate digital literacy training for students with IDD to help them overcome access barriers, bolster parents' and professionals' confidence in students with IDD connecting online, and maximize their outcomes. Individuals with IDD should further be included as a target population in research on technology and social connectedness.
- The FCC requires that a certain percentage of media be audio-described for viewers with visual disabilities. But there remains a gap for many videos made to live online and used in classrooms and workplace settings. YouDescribe has addressed this gap with a mobile app that blends user-generated descriptions with automated descriptions. However, for audio description to become more ubiquitous, standards and metrics for audio description quality need to be developed.
- Insights from social work, kinesiology, and engineering effectively enable collaboration in an interdisciplinary research environment. For instance, a proof-of-concept study indicated that older caregivers positively perceive socially assistive robots (SAR), but the caregiving burden on their physical and mental health did not improve significantly. Still, SARs may offer physical/emotional respite for caregivers because of their potential for providing companionship and promoting independence, safety/monitoring, and interactive engagement with the care recipient when a human therapist is not accessible. Continued research on identifying factors that would impact health and wellbeing and independent living outcomes is recommended.
- The use *of personas* (constructed "persons") is a tool that can be used in furthering research to enhance the inclusion of different groups and perspectives. A significant aspect in developing personas is maintaining a strategy in research to gather as much reliable depth of each persona as feasible. For example, applying personas inclusive of minorities can educate other population entities to

spread awareness, increase the inertia for policy reforms, reduce stigma, increase empathy, and challenge narratives sustained by majority groups.

Development Agenda

Access to technologies and resources is not only universally important but can be improved and, when necessary, rapidly deployed. Innovations such as single platform integration, evolution to "agnostic solutions," and the role of standards and best practices can be used to create, integrate, deploy, and maintain inclusive design and development. The use of technological approaches such as the Internet of Things (IoT) in a socially assistive manner can produce new, more usable, and inclusive solutions that ultimately will improve the wellbeing of people with disabilities. The following are key technology development observations to create positive end-user experiences and increase the usability of current, emerging, and yet to be known devices and services.

- Optimize the value of IoT systems to people with disabilities through design that fosters a trusting relationship between the user and the technology. Examples included augmented and mixed reality overlays of the physical environment that provide users with information, guidance, and support in daily activities.
- Wirelessly connected wearable devices allow for enhanced capabilities such as coordination between devices, complex computations performed via distributed cloud computing services, sharing of data across applications and platforms, personalized, accessible interfaces for public systems, and communication between humans as well as computers. By deploying the Wearable Technology Designers Web Tool (WTDWT), those who design connected, wearable technology begin the design process with a better understanding of how their choices affect accessibility and the usability of the devices they create.
- Efforts to include the DeafBlind community in the design and development of devices and services continue to lag behind the inclusion of other disability groups. This may be, in part, due to the perceived difficulty in accommodating people who are DeafBlind in person or virtually. One perception is that if companies and developers stretch past the discomfort and include the DeafBlind community in product development, untold innovations in access and inclusion will ensue for the DeafBlind community specifically and the sensory disability community, generally.
- A System for Wearable Audio Navigation (SWAN) with powerful localization capabilities and a novel and effective auditory interface was developed, emphasizing the use of non-speech sounds through a process of sonification. SWAN serves as a foundation for research into various aspects of psychoacoustics, human-computer interaction, and novel tracking technology, representing the potential for a state-of-the-art system that can increase safety and independence for any who must navigate with vision impairment or blindness. Developers should scale up SWAN 2.0 and validate its efficacy in vivo.

- Technologies such as augmented reality (AR) and tangible augmented reality (TAR) have become more accessible to regular users as computing devices have become smaller and more powerful. There is encouraging evidence that time spent on the front end of product design to build AR and TAR product concepts out digitally can provide early-stage user-informed data and a reasonable expectation of enhancing usability (efficiency, satisfaction, and effectiveness) without the need for advanced design and testing to create a functional prototype. Further, the ability to quickly iterate, test, and evaluate more radical applications of wireless devices and services that take forms that do not currently exist today will be especially important in developing acceptable (and successful) next-generation products.
- In the field of robotics and theater, the interdisciplinary approach shown by the emergent technological confluence of theatre, social work, kinesiology, computer science, and engineering provides an innovative and potentially transformative venue, particularly in the development of how a social robot might enhance engagement for young adults with intellectual and developmental disabilities (IDD).
- Important to the evolution of alerting systems has been understanding how they work, the capabilities of devices that receive alerts, and then through exploration, knowledge on what operating parameters of a device best fit an individuals' needs, lifestyles, and modes of receiving the emergency alerts and notifications rapidly. Developing emergency apps to include multiple accessibility enhancements should include people with a variety of sensory disabilities, learning disabilities and cognitive differences, and other populations of people with disabilities. By example, 5G can reduce latency and provide increased speed, enhance location accuracy, and support real-time information dissemination, including receiving emergency information and alerts.
- One author noted that "Applications using artificial intelligence, which employ highly advanced machine learning, predictive technology, object detection, voice-activated digital assistants, and facial recognition, can be transformative for disability communities, providing boundless opportunities to enhance self-sufficiency."

APPENDICES

Forum Program

Tuesday, March 23rd

8:45 – 9:00	**Get Connected – Stay Connected** Salimah LaForce, Wireless RERC
9:00 – 9:10	**Welcome** Helena Mitchell, Principal Investigator, Wireless RERC
9:10 - 9:30	**Rapid Fire Research** Short, targeted presentations highlighting RERC research projects that generated innovative technological solutions. Young Mi Choi, Augmented Reality as a Design Tool John Bricout, Socially Assistive Robot for Respite Care
9:35 – 10:20	**A Discussion of the State of Research** Facilitated by Paul M.A. Baker, Wireless RERC Nathan Moon, Survey of User Needs Paper Presentation A look at where we were in 2016, where we are today, and future research directions—join a guided discussion on the asked and unasked research questions that could generate new evidence, practices, and innovations for the field. Together we will identify how research can better inform inclusive technology policy and regulations.
10:20 – 10:30	**10-MINUTE BREAK**
10:30 – 11:00	**Lightning Development Demos** A quick look at exciting development projects with promising potential to build capacity for delivery of inclusive emergency response, design, and educational content. Maureen Linden and Brad Fain, Inclusive Emergency Lifelines Maribeth Gandy Coleman, Wearable Design Tool James Coughlan, Tactile Graphics Helper
11:05 – 11:50	**A Discussion of the State of Technology Development** Facilitator, Maribeth Gandy Coleman, Wearable Computing Center Bruce Walker, Swan 2.0 Paper Presentation A look at where we were in 2016, where we are today—join a discussion on development directions to move the needle forward on transformational technologies for access and inclusion. We will identify how technology development can more universally result in inclusive products and services, including what needs to be preserved and sustained for compatibility purposes.
11:50 – 11:55	**3-MINUTE BREAK**
11:55 – 12:40	**A Discussion of the State of Stakeholder Engagement** Facilitator, Karen Peltz Strauss, National Disability Advocate David Dzumba, Microsoft

	Richard Ray, City of Los Angeles Discussion of mechanisms to engage consumer, industry and governmental stakeholders in policy and technology development to advance the mission of access and inclusion. Session will include a history of and novel methods for high impact stakeholder engagement, including the use of accessibility teams, advisory bodies, dispute resolution, and other collaborative methods to meet the accessibility challenges of evolving 21st century technologies.
12:40 – 12:45	**Instructions for Day 2** Salimah LaForce, Wireless RERC
Wednesday, March 24th	
9:15 - 9:30	**Welcome Back and Get Connected Again**
9:30 – 10:00	**Highlights of Select Papers** Claire Donehower, Facilitating Social Connectedness Sarah Farmer, Personas for Technology Policy Design Julienne A. Greer, Theatre and Robots
10:00 – 10:05	**InsightOut -** Video Presentation
10:05 – 10:25	**Perspectives** A distillation of day one discussions and kick off for the closing session. Reactors will share their observations, professional takeaways, recommendations as to how to implement ideas that arose during the Forum. Avonne Bell, CTIA DeeDee Bennett, SUNY-Albany David Dougall, BlackBerry Limited
10:25 – 10:30	**5-Minute Break**
10:30 – 11:45	**Themed Discussion *"The best way to predict the future is to invent it."*** ~Alan Kay, computer scientist Facilitated by Helena Mitchell, Wireless RERC 1. What are the issues that researchers, technologists and stakeholders believe need attention now? Brad Fain, Center for Advanced Communication Policy Kay Chiodo, Deaf Link 2. What are the remaining challenges and opportunities for the future? Joan Durocher, National Council on Disabilities Paul Schroeder, American Printing House for the Blind 3. What are the next steps to help define what lies ahead? Bill Belt, Momentum Dynamics Stephen Bauer, National Institute on Disability, Independent Living, and Rehabilitation Research
11:45 – 12:00	**Wrap-up & Thank You** Salimah LaForce, Wireless RERC

PowerPoint Slides

Wireless Inclusive RERC Forum 2020one

Include. Innovate. Transform.

Welcome to the Forum

March 23 - 24, 2021

Helena Mitchell, Ph.D. (PI)

Helena@gatech.edu

The Wireless RERC is funded through a grant for the National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR grant #90RE5025). NIDILRR is a Center within the Administration for Community Living (ACL), Department of Health and Human Services (HHS). The contents of this presentation do not necessarily represent the policy of NIDILRR, ACL, HHS, and you should not assume endorsement by the Federal Government.

Wireless Inclusive RERC

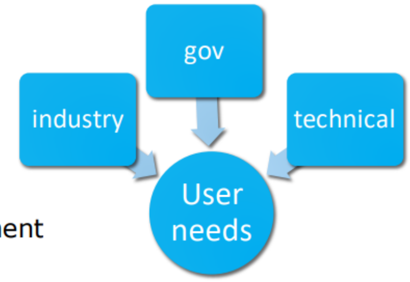
Our Mission

CACP is the home of the Wireless RERC who with its partners promotes a transformative future where individuals with disabilities achieve independence, improve quality of life, and enhance community participation

- User-Centered R&D
- Accessible Solutions
- Neutral Authority to Inform Policy
- Student Training
- Dissemination

Evolved Perspective & Forecast

- User experiences and expectations
- From survey, to focus groups, to simulations, to prototypes, to testing, to recommendations, to market...access and inclusion
- ***TODAY:*** R & D projects
  Dynamic demos
  Stakeholder engagement
- ***TOMORROW:*** Hot topic papers
  Perspectives
  Predicting the future



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A Discussion of the State of Research

Paul M.A. Baker, Ph.D. (Moderator)
Nathan W. Moon, Ph.D. (Presenter)

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A Discussion of the State of Research

- Shift from a focus on wireless technology, to applications of technology, to the ***use context*** of wireless technologies.
- Research adaptability: an approach to research which considers sustainability of research outputs. (What happens when the developer goes away?)
- Virtue of necessity – The COVID19 effect.
- Opportunities for bottom-up observations of wireless technologies in changing environment. (What does the user want?)
- What are the key research areas that appear to be important?
- Looking forward – what is the future research agenda for inclusive connectivity?

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Next Generation Wireless Device Use and Adoption

Findings from a National Survey of User Needs

Nathan W. Moon, PhD

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Survey of User Needs (SUN)

- "Foundational" survey for Wireless RERC research; updated and administered continuously since 2002
  - Version 7 – 2017-2018 Version 8 – 2019-2020
- Major Themes
  - Increased smartphone adoption among consumers with disabilities; now higher than general population
    - 2015-16: **71%** → 2017-2018: **88%** → 2019-2020: **89%**
    - Longer-than-average duration of ownership: **4 years or more**
    - Increased ease-of-use: 2017-2018: **76%** → 2019-2020: **78%**
    - Increased satisfaction: 2017-2018: **75%** → 2019-2020: **77%**
  - Decreasing use of basic cell phones (cell phones) with similarly low usability and satisfaction

Other Key Themes

- Continued importance of assistive technologies: screen reader and screen magnifier technologies
- Growing use of **real-time text (RTT)** and use of **intelligent assistants** such as Siri, Alexa, and Google Assistant, and importance of **voice control**
- Toward a holistic view: From the smartphone to a "**personal ecosystem**" of devices
  - Wearables
  - "Smart home" technologies
  - Other sensors and the Internet of Things

A Discussion of the State of Technology Development

Facilitator, Maribeth Gandy Coleman, Wearable Computing Center
Bruce Walker, Swan 2.0 Paper Presentation

- 30-year history of assistive wearable & ubiquitous computing research
  …and yet many barriers to translating this work into consumer products

- **Advancements since 2016**
  - Hardware (processors, sensors, displays)
  - Multi-modal and immersive displays (smart watches, Google Glass, Oculus)
  - New types of user-experiences becoming more common
  - Users increasingly empowered to "make" their own UIs and services

- **Existing Barriers**
  - Prototyping and development tools/processes
  - Fast dev cycles that overlook diversity of user needs and contexts of use
  - New generation of UX designers and developers needed

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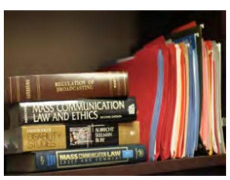


SWAN 2.0: Research and Development on a New **System for Wearable Audio Navigation**

Bruce N. Walker & Jeff Wilson

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SWAN (1.0) History

- Wayfinding is a major challenge for persons with vision disabilities
- Also, for situational blindness
- Developed in 2000-2009
- Audio-only user interface
- Destination, path, waypoints
- Environmental features, transitions, locations
- Stymied by mobile computing and indoor localization technology

SWAN (2.0) R & D

- Advances in mobile computing
- Advances in indoor localization
- Rebuilt SWAN 2.0
  - Leverages fiducials, smart pedometer, integrated location services
  - Design and layout of auditory user interface
  - Localization

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A Discussion of the State of Stakeholder Engagement

Facilitator: Karen Peltz Strauss
National Disability Advocate
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Panelists: Richard Ray, City of Los Angeles (Retired)
David Dzumba, Microsoft

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A Discussion of the State of Stakeholder Engagement

A Changing World with Fast Paced Innovations: Facilitating Access and Inclusion through Stakeholder Engagement Models

Perspectives: Consumer, Industry, Governmental

Successful Models: Advisory bodies, working groups, forums, conferences, roundtables, outreach

Successful Outcomes:
Implementation of the CVAA, 911 Access, IP Closed Captioning, Audio Description, HAC Access

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Facilitating Social Connectedness

Dr. Claire Donehower

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Facilitating Social Connectedness: Focus Group Themes

- *Hardware and Software*
- *Accessibility Features*
- *Reasons for Connecting Socially*
- *Barriers to and Supports for Connectivity*
- *Concerns or Fears about Connectivity Outcomes of Social Connectivity*

Social Connectivity Activity and Device Use Across Participants

Activity	Devices					
	Cell Phone (%)	Tablet (%)	Activity Tracker (%)	Wireless Headphone (%)	Bluetooth Earpiece (%)	Gaming Device (%)
Keeping up with friends and family	IDD: 68.7 F: 80.6 SP: 85	IDD: 43.3 F: 77.4 SP: 80.0	IDD: 7.5 F: 9.7 SP: 20.0	IDD: 13.4 F: 61.3 SP: 65.0	IDD: 17.9 F: 51.6 SP: 70.0	IDD: 6.0 F: 32.3 SP: 35.0
Meeting people	IDD: 43.3 F: 48.4 SP: 50.0	IDD: 26.9 F: 38.7 SP: 75.0	IDD: 3.0 F: 3.2 SP: 5.0	IDD: 4.5 F: 16.1 SP: 25.0	IDD: 6.0 F: 16.1 SP: 20.0	IDD: 7.5 F: 32.3 SP: 55.0
Safety	IDD: 52.2 F: 61.3 SP: 65.0	IDD: 23.9 F: 29.0 SP: 25.0	IDD: 9.0 F: 29.0 SP: 55.0	IDD: 7.5 F: 9.7 SP: 55.0	IDD: 6.0 F: 19.4 SP: 45.0	IDD: 1.5 F: 3.2 SP: 10.0
Fitness/ competition	IDD: 28.4 F: 22.6 SP: 25.0	IDD: 16.4 F: 16.1 SP: 30.0	IDD: 29.9 F: 64.5 SP: 75.0	IDD: 7.5 F: 6.5 SP: 20.0	IDD: 4.5 F: 9.7 SP: 10.0	IDD: 3.0 F: 19.4 SP: 20.0
Networking	IDD: 49.3 F: 45.2 SP: 45.0	IDD: 44.8 F: 51.6 SP: 40.0	IDD: 4.5 F: -- SP: 5.0	IDD: 9.0 F: 25.8 SP: 25.0	IDD: 13.4 F: 32.3 SP: 25.0	IDD: 3.0 F: 12.9 SP: 15.0

Note. IDD = Individuals with intellectual and developmental disabilities; F = Family members; SP = Service providers.

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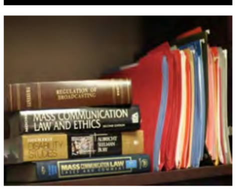
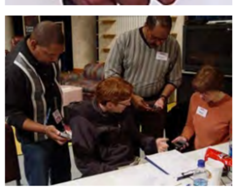

Inclusivity, Usability, and the Application of *Personas* for Technology Policy Design

Sarah Farmer
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Inclusivity, Usability, and the Application of *Personas* for Technology Policy Design

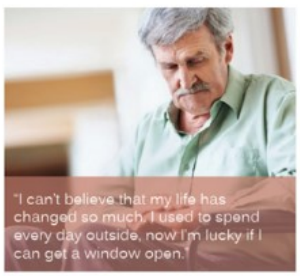
- Personas: "fictitious, specific, concrete representations of target users" (Pruitt & Adlin, 2006)
- Traditionally used for user-centered design
- Personas can also apply to human-centric policy design, to:
    1. Represent the various stakeholders
    2. Include underrepresented populations
    3. Guide mitigation undesirable constraints
    4. Gather feedback from stakeholders

We created data-driven personas based on end-user data collection:

- Assistance from others
- Devices utilized
- Mobility aids utilized
- Home modifications
- Physical accommodations
- Damages to the home
- Barriers to mobility
- Changes over time
- Ideal solutions

- One major challenge or issue was selected

Ben



Introverted | Private | Outdoorsy

Age 78
Occupation Retired Pilot
Gender Male
Status Single
Location Rural North Carolina
Archetype The Outdoorsman

Bio

Ben loves to be outside, he was always an avid camper and fisher. He believes fresh air and sunshine are the two most important things in life. Ben does not have a big family, and only sees his nieces and nephews once in a while.

He is a rather private person and does not mind the solitude. He has always felt more comfortable being alone and in the woods than surrounded by a lot of people.

Medical History

- Ben was diagnosed with Parkinson's disease when he was in his 50s
- Since his diagnosis, his disorder has progressed to advanced Parkinson's disease and he now requires a wheelchair to get around.

Goals

- Enjoy the summer months with the doors open
- Feel more in tune with the outside in his everyday life
- Remain somewhat independent

Abilities & Limitations

- Cannot bend very far at the waist, which limits his range of motion
- Dependent on a wheelchair to get around
- Decent upper body strength
- Problems with coordination and dexterity

Top Motivators

1. Fresh air
2. Privacy
3. Health Stability
4. Independence
5. Family

Environment

- He lives in a fully wheelchair accessible home
- He has a small back porch that needs repairs before he can use it
- He lives in an active neighborhood with lots of neighbors

Challenges

- Has trouble propping open the back door
- Opening and closing his blinds every
- morning and night is difficult
- Cannot open windows
  Does not like people looking into his house, especially at night

Speaker Bios

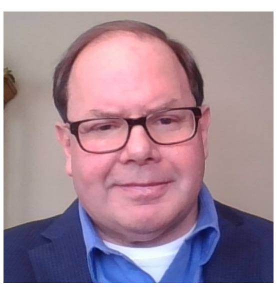
Paul M.A. Baker, Ph.D., is Senior Director, Research and Strategic Innovation, at Georgia Tech's Center for Advanced Communications Policy (CACP), and Interim Chief Operations Officer, Center for the Development and Application of IoT Technologies (CDAIT). He is also a Principal Research Scientist with the School of Public Policy. Paul serves as Co-PI, project director and operations manager of the Rehabilitation Engineering Research Center for Wireless Inclusive Technologies (Wireless RERC). He is currently researching the role of innovation networks in workforce development, policy approaches for advancing technology and universal accessibility goals for persons with disabilities; the operation of online communities and virtual spaces, and the public sector use of information and communication technologies (ICT's). Baker earned his Ph.D. in Public Policy from George Mason University, a Master's in Urban Planning from University of Virginia, and a B.S. in Zoology from University of Wisconsin.

Steve Bauer, Ph.D., from 2014 to 2021 he has been a program officer at the U.S. National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR). In 1992, he earned a PhD in Electrical and Computer Engineering from SUNY Buffalo and was formerly a co- or principal-investigator for several NIDILRR–funded Rehabilitation Engineering Research Centers and Disability Rehabilitation Research Projects. Steve's expertise pertains to technology development, transfer, and adoption (non-governmental and governmental perspectives, optimization of), assistive services and products (industries, models, design, classification of), and the administration, monitoring, and management of federal grant programs. It's been Steve's great privilege to work closely and become friends with many brilliant, innovative, and passionate people throughout his long career.

Avonne Bell, J.D., is the Director, Connected Life at the wireless industry association, CTIA, where she focuses on policy and legal issues for wireless communications vertical sectors like connected and automated vehicles, drones, and telehealth. Ms. Bell is an alumna of the Wireless RERC. She worked as a graduate research assistant with the CACP while pursuing her master's degree in public policy at Georgia Tech. She credits that position with introducing her to the area of communications and internet policy, which has been her focus ever since. Ms. Bell worked as a homeland security and telecommunications policy consultant for several years before deciding to pursue her law degree at George Washington University. Since law school, she has been a fellow with the FCC's Office of General Counsel, senior government affairs manager at the Telecommunications Industry Association, and an Associate at the firm Kelley Drye & Warren. Ms. Bell also holds a bachelor's degree in Aerospace Engineering with Information Technology from the Massachusetts Institute of Technology.

Guillermo (Bill) Belt is senior director of standards development and technology policy at Momentum Dynamics, which develops high power inductive charging technologies for the automotive and transportation industries. Before joining Momentum Dynamics, Belt was president of Cinturon, LLC, which specializes in representing the interests of companies that fuel progress by building products and services needed to improve our lives. He has served more than 30 years in the high-tech sector, mostly on broadband internet deployment, technology standards development, and the public policies that drive innovation. Before founding Cinturon, Belt was senior director of technology and standards for the Consumer Technology Association (CTA). CTA owns and produces CES, the world's largest annual technology trade show. Belt led standards development projects and provided key engineering and technology policy support to CTA member groups. Tech standards produced under Belt's leadership are referenced by the EPA, DOE, FTC, FCC and other government agencies. Belt represented CTA's technical interests in industry and international venues related to spectrum management and policy, accessibility, product safety and energy efficiency. Belt is a frequent speaker at industry conferences and seminars and has been widely quoted in the press. Belt holds a B.S. in electrical engineering from Syracuse University.

DeeDee Bennett Gayle, Ph.D., is an Associate Professor in the College of Emergency Preparedness, Homeland Security, and Cyber-security at the University at Albany, State University of New York. Her research interests include emergency management, socially vulnerable populations during disasters, emergency communications, disaster policy, and mobile wireless communications. Of note, she was the PI for the NSF INCLUDES -funded, Scholars from Under-represented Groups in Engineering and Social Sciences Building Capacity in Disaster (SURGE), design and development launch pilot. She administers the annual state of the community survey of emergency management academic programs on behalf of the Federal Emergency Management Agency. Her previous appointments include Assistant Professor and Director of the Emergency Management and Disaster Science program at the University of Nebraska at Omaha (UNO) and Research Scientist at the Center for Advanced Communications Policy at Georgia Institute of Technology. Dr. Bennett Gayle received her Ph.D. from Oklahoma State University in Fire and Emergency Management, an M.S. in Public Policy, and a B.S. in Electrical Engineering from the Georgia Institute of Technology.



John Bricout, Ph.D., is a professor at the UMN School of Social Work. He served as the director of the SSW from 2017-2020. Professor Bricout's research examines the socio-cultural aspects of participatory, ethical design for robotics and intelligent assistive technologies to enhance the capabilities and well-being of people with disabilities in a variety of settings. He also studies virtual interdisciplinary teamwork, community-engaged research partnerships, workforce learning, and inclusive design processes with diverse stakeholders. He has received funding from NSF, NIDILRR, and the CDC. Professor Bricout has taught graduate and undergraduate courses in ethics, research, policy practice, evaluation, community development, human diversity, and human behavior. He has a strong interest in international work and served as a Fulbright Specialist in the Republic of Georgia.

Kay Chiodo has over 30 years of experience in providing services to persons with sensory disabilities and is considered a leading Subject Matter Expert on the topic of accessible communications. In 2002, Ms. Chiodo founded Deaf Link, Inc. and developed the nation's first Accessible Hazard Alert System (AHAS) to provide first responders and emergency managers with the tools to help ensure communication access to emergency information for persons with sensory disabilities. In 2007, Ms. Chiodo founded No Barriers Communications (NOBACOMM), a non-profit organization that provided services to Doctors without Borders during the 2010 cholera outbreak in Haiti. Since then, NOBACOMM has provided services and acted as an advocate and educator regarding the need for equal access in all areas of life. Ms. Chiodo is the recipient of the 2008 – 21st Century Achievement Award / COMPUT- ERWORLD, for Accessible Communications.

Young Mi Choi, Ph.D., is an Associate Professor in the School of Industrial Design at the Georgia Institute of Technology. She also serves as Associate Chair and is the Master's of Industrial Design Program Coordinator. She teaches both product development as well as human factors and ergonomics. Her research activities focus on applying evidence-based design in innovation and human-centered design. Her research focuses on topics related to the roles played by users, industrial designers, engineers, and marketers during the process of creating new products and assistive technologies. In particular, current projects are focused on how new tools such as mixed reality technologies can be effectively utilized to both enhance design decision making and allow enhanced communication with and involvement from end-users during the design process. Dr. Choi received her Ph.D., from the Georgia Institute of Technology, College of Architecture in Industrial Design.

James M. Coughlan, Ph.D., received his B.A. in physics at Harvard University in 1990 and completed his Ph.D. in physics there in 1998. He is currently a Senior Scientist at The Smith-Kettlewell Eye Research Institute in San Francisco, California, where he is Associate Director of the Rehabilitation Engineering Research Center on Low Vision and Blindness. His main research focus is the use of computer vision and sensor technologies to facilitate greater accessibility of the physical environment for blind and visually impaired persons. Current and past accessibility projects include developing systems to provide audio-haptic access to physical objects such as documents and 3D models, the ability to find and read signs and other textual information, and navigation assistance indoors and at traffic intersections. He shared the 2020 Dr. Arthur I. Karshmer Award for Assistive Technology Research for his publication, "Towards Accessible Audio Labeling of 3D Objects," which was awarded for the best submission to the Science/ Research Journal Track of the CSUN 2020 Assistive Technology Conference. In 2020 he was appointed to the NIH National Advisory Eye Council.

Claire Donehower, Ph.D., is an Assistant Professor in the Department of Learning Sciences at Georgia State University. She received her doctorate from the University of Central Florida in the Exceptional Education Program. Her research focuses on improving aca- demic, social and behavioral outcomes for students with autism spectrum disorders (ASD) using innovative technology. In addition to her work with the Wireless RERC, Dr. Donehower currently serves as the Principal Investigator for a U.S. Department of Education Stepping Up Technology grant focused on integrating robotics/coding and social skills instruction for students with intellectual and developmental disabilities. Prior to her doctoral studies, Donehower worked at the Kennedy Krieger School Programs for nine years as an assistant teacher, special education teacher and assistant principal. She received a B.A degree in psychology from Boston College and an M.S. degree in special education of severe and profound disabilities from the Johns Hopkins University. Additionally, Donehower is a board-certified behavior analyst and has post-graduate certificates in the Education of Students with Autism and Other Pervasive Developmental Disorders and Special Education Leadership and Administration.

Dave Dougall, MBA, is the Compliance and Sustainability & Accessibility Director at BlackBerry Limited, which provides intelligent security software and services to enterprises and governments around the world. BlackBerry leverages AI and machine learning to deliver innovative solutions in the areas of cybersecurity, safety, and data privacy solutions and is a leader in the areas of endpoint security management, encryption, and embedded systems. In his role, Dave manages global regulatory requirements, policy development, and consumer outreach related to the accessibility of BlackBerry products for customers with disabilities. Dave manages environ- mental sustainability considerations for BlackBerry products and manages BlackBerry's corporate carbon footprint. Dave is a member of the National Advisory Board for the Rehabilitation Engineering Research Center for Wireless Technologies and the National Advisory Council for the Rehabilitation Engineering Research Center for Advancing Cognitive Technologies. Dave holds a Bachelor of Science degree from Kettering University (GMI) in Flint, MI, and an MBA from the Ivey Business School at Western University in London, ON.

Joan Durocher, J.D., is the National Council on Disability's General Counsel and Director of Policy. The National Council on Disability (NCD) is an independent federal agency charged with advising the President and Congress about the broad spectrum of issues impacting the lives of people with disabilities. She has previously served as NCD's Interim Executive Director and Senior Attorney/Advisor. In these roles, she has overseen the development and publication of hundreds of recommendations and reports on issues affecting the lives of people with disabilities. Ms. Durocher served for almost a decade as the Designated Federal Official for International Watch, a Federal Advisory Committee tasked with advising on the development of policy proposals that will advocate for a foreign policy that is consistent with the values and goals of the Americans with Disabilities Act. Ms. Durocher has a Bachelor of Arts degree from Michigan State University and received her law degree from the University of Maryland, where she was awarded an Asper Fellowship and received the BARC Community Service and Leadership Award for her work at the Maryland Disability Law Center in Baltimore.

David Dzumba, M.S., has been with the Microsoft Corporate, External, and Legal Affairs (CELA) team since 2013, where he works on accessibility standards, internal requirements, and conformance. Dzumba joined Microsoft after 15 years with Nokia. While at Nokia, he established the company's accessibility program, including early innovations of text-to-speech on devices for customers who are blind, and an inductive loop for t-coil-equipped hearing aid users. He has served as the co-chair of the FCC's Emergency Access Advisory Committee and as panelist for organizations including the European Year of Disabilities, NCLUDE/STAKES, Cost219bis, Tiresias, TAG, and U.S. Department of Homeland Security. Dzumba has a Master of Science in Engineering Telecommunications from Southern Methodist University in Dallas, Texas.

Brad Fain, Ph.D., is a Principal Research Scientist at the Georgia Tech Research Institute and executive director of the Center for Advanced Communications Policy (CACP). Housed in the Georgia Tech School of Public Policy, CACP focuses on key issues that influence the development, implementation and adoption of communications technologies. Fain directs Georgia Tech's HomeLab research initiative and leads a team that is pioneering research into issues and products designed to assist with successful aging in place. He also currently leads a project to build a virtual reality usability testbed for first responder technologies enabled by FirstNet for the National Institute for Standards and Technology (NIST). The Wireless RERC works with FirstNet will ensure that the FirstNet information streaming system includes the needs of people with disabilities at its implementation. Fain pioneered the development of Consumer Product Integration (CPI) as a design process for the realization of products with universal design features. He conceived and led the development of an information portal containing information pertaining to the design and procurement of accessible electronic and information technologies.

Sarah Farmer is a Research Scientist at Georgia Tech's Center for Advanced Communications Policy and the Georgia Tech Research Institute, as well as managing director of Georgia Tech's HomeLab. With a background in psychology and statistics, she has been executing research related to human performance and successful aging since 2012. She is a co-investigator in the RERC TechSAge research to assess user needs for home-based activities necessary to integrate effective technology into the lives of older adults with disabilities. As director of HomeLab, which is a home health test bed database of older adults in the metro-Atlanta area, Sarah has executed in-home studies that evaluated technologies that contribute to successful aging, including activity trackers, medication adherence technologies, and personal emergency response systems. She is the current technical lead for the evaluation of potential FirstNet first responder technologies in a novel virtual reality usability testing environment being constructed at GTRI. Sarah is currently the PI for HomeLab's involvement in the RADx initiative.

Maribeth Gandy Coleman, Ph.D., is the Director of the Interactive Media Technology Center in the Institute for People and Technology and a Principal Research Scientist at Georgia Tech. She received a B.S. in Computer Engineering as well as a M.S. and Ph.D. in Computer Science from Georgia Tech. In her twenty years as a research faculty member her work has been focused on the intersection of technology for mobile/wearable computing, augmented reality, human computer interaction, assistive technology, and gaming. She is the task leader for the Wireless RERC's Wearable devices and connectivity development project. Maribeth has led a wide array of projects in the 12 years she has been a faculty member at Georgia Tech; ranging from social therapeutic games for people with cognitive impairment, to wearable haptic displays embroidered into clothing, and augmented reality systems for helping older adults to use smart home technology. She also teaches the "Video Game Design" course and the "Principles of Computer Audio" (which she created in 2001) in the College of Computing at Georgia Tech.

Julienne A. Greer, Ph.D., is the Assistant Chair and Assistant Professor of Theatre: Social Robotics and Performance, with the Department of Theatre Arts at the University of Texas at Arlington. She is the Director of UTA's Emotional Robotics Living Lab, the home to multiple research social robots, and the UTA space for hands-on social robotic research for undergraduate and graduate learning. Dr. Greer earned a B.F.A in Drama from New York University's Tisch School of the Arts, an M.A. in Media Arts from Texas Christian University, and her Ph.D. in Humanities at the University of Texas at Dallas, School of Arts and Humanities. Greer is a multi-disciplinary scholar + artist who produces, directs, performs, and writes in theater, robotics, cinema, humanities, and game studies disciplines. She brings performance expertise based in applied drama, empathy, embodiment, and multi-modal sensory data to interdisciplinary collaborations. She is a member of Inter-Disciplinary.net 2011 - present, Actors Equity Association (AEA), and the Screen Actors Guild and American Federation of Television and Radio Artists (SAG/AFTRA).

Salimah LaForce, M.S., is a Research Scientist at the Georgia Institute of Technology, a senior policy analyst at Georgia Tech's Center for Advanced Communications Policy, and a project director for the Wireless RERC. She specializes in policy research, identifying and describing intended and unanticipated implementation outcomes. She has 14 years' experience conducting user needs and experiences research utilizing study results to inform policy and practice recommendations. Presently, Salimah is the Principal (PI) Investigator for the American Sign Language-Accessible Diabetes Education (ASL-ADE) project; PI for the COVID-19 Information Access and Vulnerable Populations project. Salimah is the senior editor of the Technology and Disability Policy Highlights, and has co-authored more than 86 conference papers, research reports, presentations, journal articles, and federal regulatory agency filings. Salimah earned her B.A. in English literature from Agnes Scott College and her M.S. in Clinical Psychology, applied research specialization, from the Harold Abel School of Social and Behavioral Sciences, Capella University.

Maureen Linden, M.S., directs the Inclusive Emergency Lifelines development project of the Wireless RERC. She is the Associate Director of Research for the Center for Inclusive Design and Innovation (CIDI) in Georgia Tech's College of Design. Her research focuses include accessible emergency communications and post-secondary education, workplace accommodations and accessible work environments, and assistive technology decision support tools. Much of this research is conducted incorporating data and social networking analytics techniques, as well as smart technologies and Internet of Things (IoT) data acquisition. Maureen delivered direct services to people with disabilities in both the medical and vocational rehabilitation service models under service standards required by Center for Medicaid and Medicare Services (CMS) and CARF. Linden has 15 years' experience in development of performance standards for wheelchairs, wheelchair seating, and transportation for people with disabilities through the Society for Automotive Engineers (SAE), American National Standards Institute (ANSI) and the ISO. Linden holds two degrees from the University of Virginia: A Master of Science in Biomedical Engineering and a B.S. in Electrical Engineering. Presently, she is the President of RESNA, the Rehabilitation Engineering and Assistive Technology Society of North America.

Helena Mitchell, Ph.D., is the Wireless RERC's principal investigator (PI). Dr. Mitchell is a Regents' Researcher at Georgia Tech. Her areas of specialty include accessibility of wireless technologies, regulatory and legislative policy, emergency/public safety communications, and advanced communications technologies. Helena has also been PI for several emergency communications projects funded by the U.S. Department of Homeland Security. Mitchell has held executive positions in academia, business, and government, contributing to her unique ability to see multiple perspectives. At the Federal Communications Commission, she was the Associate Chief, Strategic Communications for the Office of Engineering and Technology, Chief of the Emergency Broadcast System, and the first chief of the Emergency Alert System where her group received Organization of the Year. Previously she was director of telecommunications development for the National Telecommunications and Information Administration of the U.S. Department of Commerce, receiving the Silver Medal twice. Helena holds a Ph.D. from Syracuse University with a combined doctoral degree from the Maxwell and Newhouse schools. An M.S. from Syracuse, and a B.S. from S.U.N.Y. at Brockport.

Nathan W. Moon, Ph.D., is a Senior Research Scientist at the Georgia Institute of Technology, and he serves as Director of Research of CACP at Georgia Tech. His research focuses on increasing access to education and employment for people with disabilities, with specializations in the accessibility of information and communications technologies (ICTs), workplace accommodations and employment policy, broadening participation in STEM education, and program evaluation. Dr. Moon is also Project Director for the Wireless RERC, where he leads the RERC's Survey of User Needs and research on the sociocultural design factors for next generation wireless technologies. Moon is the Principal Investigator for a Field Initiated Project on the Contingent Employment of People with Disabilities (FIP-CE). This three-year research project is funded by the NIDILRR. FIP-CE investigates the participation of individuals with disabilities in contingent employment arrangements, including jobs obtained through web-based or app-based platforms associated with the nascent "gig economy" associated with services such as Uber, Lyft, and Handy. Dr. Moon received his Ph.D., in history and sociology of science and technology from Georgia Tech in 2009.

Karen Peltz Strauss, J.D., has spent four decades leading nationwide efforts to ensure that people with disabilities have access to communications and video programming technologies. In the Obama and Clinton administrations, Strauss served as Deputy Chief of the Federal Communications Commission's Consumer and Governmental Affairs Bureau, where she oversaw the agency's disability proceedings. Earlier in her career, representing Gallaudet University's National Center for Law and Deafness, the National Association of the Deaf, and Communication Service for the Deaf, Strauss wrote and led efforts to achieve passage of landmark disability laws on closed captioning, audio description, telecommunications relay services, hearing aid compatibility, and accessible communications devices and services, including the 21st Century Communications and Video Accessibility Act. Strauss has frequently presented expert testimony to Congress and regularly presents at national and international accessibility conferences. In 2006, Strauss wrote A New Civil Right: Telecommunications Equality for Deaf and Hard of Hearing Americans, providing a behind-the-scenes history of our nation's telecommunication accessibility laws. A graduate of the University of Pennsylvania Law School, Strauss also holds an L.L.M from the Georgetown University Law Center and an honorary doctorate from Gallaudet University, the latter for her work on communications access.

Richard Ray retired from the City of Los Angeles after serving over 35 years as an Americans with Disabilities Act Technology Access Coordinator while working in the field of telecommunication technologies, emergency services, and advocating for the civil rights of individuals who are deaf, deafblind, and hard of hearing in all levels of government. His goal is to ensure access for people with disabilities to all government programs, services, and activities through emerging technologies. He is actively involved as a co-chair of the National Emergency Number Association (NENA) Accessibility Committee and Federal Communications Commission (FCC) Disability Advisory Committee. Richard has served on the FCC Emergency Access Advisory Committee, North American Numbering Council, Interoperable Video Calling Working Group, Emergency Access Advisory Committee, Emergency Communications Subcommittee, and Optimal Public Safety Answering Point Architecture Task Force. He is involved in projects such as Text to 9-1-1, Real-Time Text to 9-1-1, Next Generation 9-1-1, Emergency Notification Systems, and other issues concerning communication access in support of federal, state, and local governments. Richard was named one of the top 25 Doers, Dreamers, and Drivers and featured in Government Technology Magazine in 2018. In 2019, he was inducted into the NENA's Hall of Fame.

Paul Schroeder is Vice President, Government and Community Affairs at American Printing House for the Blind. Paul serves as a key advisor on matters pertaining to all government activities at APH, including the activities related to the Act to Promote the Education of the Blind. He also educates U.S. Congress members by raising awareness of the unique learning needs of student with visual dis- abilities and the products and services they need. Paul has more than 30 years of experience and leadership in the field of blindness and visual impairment. Most recently, he was Vice President, Public Policy and Strategic Initiatives at Aira Tech Corp. He served in several leadership positions, including Vice President, Programs and Policy at American Foundation for the Blind (AFB). He also worked as the Director of Governmental Affairs at American Council of the Blind and as the Special Projects Coordinator at the Governor's Office of Advocacy for People with Disabilities, in Columbus, Ohio. Schroeder received his Bachelor of Arts, cum laude, in Political Science and International Studies from American University.

Bruce Walker, Ph.D., is a Professor at Georgia Tech, in the Schools of Psychology and Interactive Computing. His Sonification Lab studies the human-computer interaction (HCI) issues in non-traditional interfaces, ranging from mobile devices to cockpits and vehicle displays, to multimodal interfaces in education and in complex task environments. Particular research interests include sonification and auditory displays. Professor Walker teaches HCI, Research Methods, Sensation & Perception, Auditory Interfaces, and Assistive Technology. In addition to academic research leading to over 250 publications, he has worked and consulted on projects for NASA, state and federal governments, the military, and private companies.