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Assistive Technology Outcomes and Benefits

AT Innovations for Education, Employment, and Independent Living

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Assistive Technology Outcomes and Benefits Editorial Policy

Aim and Scope

Assistive Technology Outcomes and Benefits, published by the Assistive Technology Industry Association, is an open access, peer-reviewed journal that publishes articles specifically addressing the benefits and outcomes of assistive technology (AT) for Persons with Disabilities across the lifespan. The journal's purpose is to advance the AT industry by (a) fostering communication among stakeholders interested in the field of AT, including manufacturers, vendors, practitioners, policy makers, researchers, consumers with disabilities, and family members; (b) facilitating evidence-based demonstrations and case-based dialogue regarding effective AT devices and services; and (c) helping stakeholders advocate for effective AT devices and services.

Assistive Technology Outcomes and Benefits invites for consideration submissions of original papers, reports and manuscripts that address outcomes and benefits related to AT devices and services. These may include (a) findings of original scientific research, including group studies and single subject designs; (b) qualitative and mixed methods studies, such as focus group and structured interview findings with consumers and their families regarding AT service delivery and associated outcomes and benefits; (c) marketing research related to AT demographics or devices and services; (d) technical notes and usability studies regarding AT product development findings; (e) project/program descriptions in which AT outcomes and benefits have been documented; (f) case-based reports on successful approaches to service delivery; and (g) consumer perspectives on AT devices and services.

Submission Categories

ATOB welcomes scholarly contributions. However, many stakeholders engaged in the field of AT do not have an academic background. ATOB offers a unique opportunity for these stakeholders to contribute their expertise and experience in the context of achieving successful outcomes and beneficial impacts. ATOB understands that many potential authors may lack experience in authoring papers for peer- reviewed journal publication. Therefore, the ATOB Editorial Board is pleased to offer support in preparing and refining relevant submissions. Articles may be submitted under three categories:

Voices from the Field

Articles submitted under this category should come from professionals who are involved in some aspect of AT service delivery with persons having disabilities, or from family members and/or consumers with disabilities. Submissions may include case studies, project or program descriptions, approaches to service delivery, or consumer perspective pieces. All submissions should have a clear message and be written with enough detail to allow replication of results. See ATOB Editorial Policy for more details.

Voices from Industry

Articles submitted under this category should come from professionals involved in developing and marketing specific AT devices and services. Case studies, design, marketing research, or project/program descriptions are appropriate for this category. See ATOB Editorial Policy for more details.

Voices from Academia

Articles submitted under this category should come from professionals conducting research or development in an academic setting. Submissions are likely to include applied/clinical research, case studies, and project/program descriptions. See ATOB Editorial Policy for more details.

Types of Articles

Within each of the voices categories, authors have some latitude regarding the type of manuscript submitted and content to be included. However, ATOB will only accept original material that has not been published elsewhere and is not currently under review by other publishers. Additionally, all manuscripts should offer sufficient detail to allow for replication of the described work.

Applied/Clinical Research: This category includes original work presented with careful attention to research design, objective data analysis, and reference to the literature.

Case Studies: This category includes studies that involve only one or a few subjects or an informal protocol.

Design: This category includes descriptions of conceptual or physical design of new AT models or devices.

Marketing Research: This category includes industry-based research related to specific AT devices and/or services, demographic reports, and identification of AT trends and future projections.

Project/Program Description: This category includes descriptions of grant projects, private foundation activities, institutes, and centers having specific goals and objectives related to AT outcomes and benefits.

Approaches to Service Delivery: This category includes descriptions of the application of assistive technology in any setting (educational, vocational, home-life) to improve quality of life for people with disabilities.

Consumer and Caregiver Perspectives: This category offers an opportunity for product end users, family members, and caregivers to share their experiences in achieving successful outcomes and benefits through the application or use of AT devices and services.

Mandatory Components of All Articles

Authors must include a section titled Outcomes and Benefits containing a discussion related to outcomes and benefits of the AT devices/services addressed in the article. Authors must include a short description of the article's Target Audience and indicate the article's relevance to that target audience.

Publishing Guidelines

Review detailed Manuscript Preparation for Authors for information on formatting requirements and submission guidelines.

For More Information

Please see ATOB's Editorial Policy for more details regarding the submission and review process, ATOB's Copyright Policy, and ATOB's Publication Ethics and Malpractice Statement.

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Introduction to Volume 19

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Innovations in Assistive Technology Outcomes and Benefits

The field of assistive technology has a deep history of innovation. From creating solutions for people with disabilities to move freely throughout their community, to inventions such as voice recognition, text-to-speech, and eye-gaze technologies, we are surrounded by innovation. Innovations can be either incremental or disruptive. Incremental innovation involves small improvements to existing products, services, or processes. Disruptive innovation involves creating new products, services, or processes that disrupt existing markets or practices, fundamentally changing the way things are done. In either case, innovation requires us to take risks, challenge assumptions, and constantly learn and adapt to change. Issue 19 addresses both small and large-scale innovations.

Invited Voice

Dr. Sarah Elizabeth Baghun presented “Academia, Industry, and Policy: Data-Informed AI Policy Guidelines” at the 2025 ATIA conference. Her talk resulted in an invitation to submit a paper for this volume of ATOB. In her paper, she discusses how AI-driven AT and general use cases for AI will affect education, employment, and independent living activities throughout the coming years for people living with disability. Her policy recommendations on how to ensure that AI powered assistive technologies are designed to be effective and meet the needs of the community they serve were compiled following an extensive AI Delphi study conducted by the American Foundation for the Blind. The findings show that AI technologies have the power to transform accessibility, but only if they are developed ethically, and with a commitment to fairness, inclusion, and nondiscrimination.

Voices from Academia

The academic voices present in Volume 19 share work by researchers who are constantly innovating. In the article “Developing Artificial Intelligence Applications for Human Conversation: Perspectives, Tools, Exploratory Analyses,” Higginbotham et al. build on previous work on Artificial Intelligence (AI) in Augmentative Communication Technologies (ACTs) by providing a deep dive into the use of applying a conversational perspective for designing and evaluating the performance of Conversational AI-enhanced ACTs from a social interaction perspective. Utilizing an established set of interaction criteria for performance standards in real-time conversation including 1) Sufficiency and Sincerity; 2) Timing and Sequencing; and 3) content and manner, they investigate their ACT prototype using a personalized CAI to respond to spoken input from communication partners. Recognizing that conversational interactions present unique challenges to an augmented speaker, they created an initial framework for measuring and describing ACT performance in social interactions using CAI.

Spinal cord injury (SCI) impacts more than 300,000 individuals in the U.S., with 18,000 new cases annually. For this population, access to drinking water and the ability to groom oneself are important features leading to independence and improved quality of life. In “Water Access for Individuals with Spinal Cord Injury,” Jeng et al. conduct a usability test of the Access-H20 faucet activated by a hands-free smart feature to adjust the water spray outlet stream, temperature, and volume. Results showed a significant improvement in subjects’ levels of independence in water intake using the faucet, and a high level of usability for individuals living with cervical spinal cord injuries. This innovation represents a significant step towards greater independence and quality of life for those living with SCI.

In “Assistive Technology Innovations: Perceptions, Adoptions, and Desires,” McDonnall et al. conducted a survey of 329 employed individuals who are blind or have low vision to better understand their perception about, adoption of, and desires for AT innovations. Recognizing the potential of new and emerging technologies to have significant impact, they identified a need to increase our knowledge about *how* employed adults, either blind or low vision, perceive innovation. In this first-of-its-kind study, the authors’ findings indicated a potential lack of awareness about innovations already underway and key barriers such as expense, time availability for learning, and lack of training or support. The authors provide an array of recommendations ranging from improving knowledge of practitioners to improved functionality of new technologies to address these barriers.

Voices from the Industry

Burgos recognized that eating is often a shared activity, and being able to eat independently allows individuals to participate fully in family gatherings, social outings, and cultural practices associated with food. In her article “The Use of Obi Robot for Self-Feeding with Individuals with Upper Extremity Limitations,” she explored how upper extremity (UE) limitations impact individuals’ sense of autonomy and independence. This descriptive study examined the functional performance of self-feeding of 19 individuals with upper extremity limitations using Obi, a robotic self-feeding device. Results indicated that all participants successfully used Obi to independently feed themselves by activating switches connected to the device, with a 100% success rate in delivering food to their mouths by the final trial session.

Deutsch et al. recognized the long cane's inability to detect obstacles located in the upper body zone. In their study, they explored the use of "Eyewear with Obstacle Detection: Design of a Novel Travel Aid." They conducted exploratory workshops and interviews to understand the possibilities and challenges of eyewear as an assistive technology platform for people living with blindness and/or severe vision impairments. Three iterations of hardware prototypes were produced during the device design phase, comprising different components, layouts, and levels of miniaturization. Their results demonstrated that nearly all testers were able to understand when they were in danger of colliding with an obstacle and were enthusiastic about the possibility of wearing a stylish assistive technology device capable of enabling more independence and safety.

Schiefelbein et al.'s "Enhancing Independence: Outcomes of AngelSense Assistive Technology with Behavioral Strategies" combined assistive technology with behavior-analytic strategies, offering a practical and effective solution that enables real-time location tracking, communication, and remote support. Including a wearable device, a caregiver-controlled mobile app, integrated features, an assistive speakerphone, a configurable SOS button, and smart alert capabilities, the device addresses safety concerns, promotes skill development, and provides caregivers with tools to offer consistent, remote support in real-world settings. Their findings validated the program's effectiveness while highlighting its potential for broader implementation and refinement.

Voices from the Field

Elevating an innovative set of modules and supporting materials specifically designed to strengthen special education transition-related instruction and the use of individual assistive technology, Gullen et al. reported their work in "Michigan Transition to Independence (MITTIN): Strengthening Transition Services through Accessible Digital Resources." MITTIN combines mixed-reality (MR) digital and curricular resources to provide extended learning opportunities for students, fostering collaborations between educators and families. Created with universal design principles, MITTIN also incorporates one-touch gamification, ensuring seamless integration with a variety of assistive technology tools and accessibility features to support the development of independent living skills and promote social inclusion. MITTIN is an ongoing and evolving project with the potential to change the lives of people with disabilities and their families.

In "Education and Alternative Drive Controls for a Client Diagnosed with a Spinal Cord Injury and Schizophrenia," Thelander et al. provide a fascinating case report describing the assessment, technology education, and skills training required to increase independence for a client who experienced a steep learning curve related to his schizophrenia diagnosis. Although more work remains, their results (and careful documentation) suggest it may be possible to improve the ability of a person who experiences schizophrenia to use high-tech assistive devices.

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Invited Voice
Academia, Industry, and Policy: Data-Informed AI Practice and Policy Principles

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Abstract

Artificial intelligence (AI) is transforming employment, education, and accessibility, with significant implications for people with disabilities. While AI can improve efficiency and access, it raises concerns about bias and accuracy. This study by the American Foundation for the Blind (AFB) used a Delphi methodology with 32 experts from Academia, Industry, and Policy to develop AI principles. Findings emphasize the need for human oversight, disability inclusion in AI development, and proactive regulations. The study presents data-driven recommendations to engineer equitable AI, prevent discrimination, and enhance accessibility for people who are blind or have low vision, providing a framework for policymakers, developers, deployers, and assistive technology stakeholders. By integrating responsible AI principles into research, development, and policy, ATOB readers can help create fair, inclusive technologies that expand access for people with disabilities. These principles guide organizations to create, deploy, and use AI effectively for people with disabilities, especially assistive technology users.

Keywords: artificial intelligence, assistive technology, disability inclusion, AI policy, algorithmic bias, Delphi study, accessibility, STEM workforce

Academia, Industry, and Policy: Data-Informed AI Practice and Policy Principles

Artificial intelligence (AI) is rapidly transforming numerous aspects of society, from transportation and healthcare to employment and accessibility and assistive technology (AT). Artificial intelligence (AI) systems have been defined as “machine-based systems that can make predictions, recommendations, or decisions influencing real or virtual environments” (U.S. Department of Justice Civil Rights Division, 2024). The potential benefits of AI touch most aspects of our economy, including improved efficiency, enhanced decision-making, and greater access to information and resources. However, the increasing reliance on AI also raises significant ethical and social concerns, especially regarding bias, fairness, and accountability.

Existing research demonstrates that AI systems can perpetuate and amplify existing societal biases, particularly against marginalized communities such as people with disabilities. For example, AI systems used in hiring processes have been shown to discriminate against individuals with disabilities due to biases inherent in the data they are trained on (Whittaker et al., 2019). This can result in a lack of opportunities and further marginalization for those already facing significant systemic barriers. Similarly, AI-powered assistive technologies that do not reflect the needs and preferences of the disability community risk being ineffective and unused (Moura, 2022).

Target Audience and Relevance

In this issue on *AT Innovations for Education, Employment, and Independent Living,* the important implications of AI across all domains must be at the forefront. Both AI-driven AT and general use cases for AI will affect education, employment, and independent living activities throughout the coming years, and all professionals and consumers will benefit from being proactive in learning about the intersections of AI and disability. Considering the diverse range of stakeholders within the AT ecosystem, the audience of Assistive Technology Outcomes and Benefits (ATOB) is key for disseminating policy recommendations around AI. Specifically, this article is relevant to key stakeholders such as AT manufacturers & developers, AI manufacturers and developers, service providers who will train in AT, AI, or self-advocacy, and agency leaders who will be charged with decisions about whether to procure software solutions with an AI component.

Literature Review

The field of AI ethics has grown substantially in recent years, addressing the need for frameworks, tools, and methodologies to ensure fair and responsible AI development and deployment (Mitchell et al., 2021). Much of the research in this area has focused on identifying and mitigating algorithmic bias, ensuring transparency and accountability, and promoting human-centered design approaches (Lewicki et al., 2023).

Several studies have highlighted the importance of including diverse perspectives in the design and evaluation of AI systems (Whittaker et al., 2019). For example, in the context of assistive technology, it is crucial to involve individuals with disabilities in the design process to ensure that the resulting technologies meet their specific needs and preferences (Anho et al., 2019; Moura, 2022). This is especially important because there is often a mismatch between the technologies that are developed by researchers and the needs of the end users, a contributor to low rates of adoption and efficacy (Gamage et al., 2023).

The goal of explainable and interpretable AI (XAI) is to make AI systems more understandable and transparent to humans. This is achieved through methods that provide explanations for AI decisions (Holzinger et al., 2022). For example, interpretable AI has been researched and designed to identify fake media (deepfakes), recommend news articles, and diagnose pathologies (Sanders, 2008). Disabled users are often not considered in XAI development, as many of the trust metrics used are displayed without accessible equivalent content.

Some areas of AI research show promising inclusion of the perspectives and needs of disabled users. For example, Human-Centered AI (HCAI) emphasizes incorporating human-computer interaction methods in the design and evaluation of AI systems to ensure that the technology is usable, accessible, and beneficial for all people (Degen & Ntoa, 2021). In another positive direction, algorithmic accountability has the potential to include people with disabilities. Algorithmic accountability includes the idea that those who create and deploy AI systems should be held responsible for their actions (Lewicki et al, 2023). This obligates owners to address issues of bias, fairness, and potential harm. Algorithmic accountability can be supported by data and model cards, which document data origin and the limitations of the model, as well as the assumptions and trade-offs that were made in model development (Arnold et al., 2019).

Despite the growth of research in AI ethics, many challenges still remain. There is a need for more data-driven, actionable policy recommendations that can effectively address the ethical and social implications of AI (NAIAC, 2023). Existing ethical frameworks and guidelines often lack the specificity needed to translate into concrete actions and are often looking in the rearview mirror at how past decisions affected or were driven by past policies. Furthermore, there is a need for a more thorough investigation into the risks and harms associated with AI systems, especially in the context of marginalized populations.

While previous studies have provided valuable insights into the ethical and social implications of AI, and while many organizations have developed guidelines and recommendations for responsible AI design and deployment, there remains a significant gap in research that addresses the following critical areas. The development of data-driven policy recommendations remains a critical challenge due to the scarcity of evidence-based proposals that effectively translate general ethical principles into concrete actions. To bridge this gap, policy recommendations must be informed by a comprehensive analysis of available data and a nuanced understanding of the needs of affected communities. Additionally, research must extend beyond identifying the risks and harms of AI systems to exploring actionable oversight strategies that can prevent adverse outcomes. Within this broader framework, all organizations need to examine AI applications in specific contexts, such as hiring practices and assistive technology compatibility, to assess their implications for people with disabilities. Furthermore, research must address the diverse and evolving needs of individuals with a wide range of disabilities to ensure that AI-driven solutions are equitable and inclusive.

Purpose Statement

To address this research gap, the current study by the American Foundation for the Blind (AFB) takes a critical look at current and future evolutions of AI and creates policy guidelines proactively to inform coming developments. By highlighting these challenges, this AI Delphi study provides data points for policy recommendations on how to ensure that AI powered assistive technologies are designed to be effective and meet the needs of the community they serve. These data can be used to inform a wider discussion about how to ensure that AI development and deployment includes people with disabilities in an authentic way from the start of the research process. Additionally, the study points to key developments in AI so that policymakers can be proactive in their planning and development.

Methods

This study employed a Delphi methodology to establish expert consensus across industry, policy, and academia. The Delphi process, an iterative research method, systematically refines expert input through structured data collection and analysis rounds (Falzarano & Zipp, 2013). This methodology is particularly suited for exploring emerging trends and complex issues where diverse expert opinions are valuable. The study involved a panel of 32 experts from various sectors, including industry, policy analysis, academia, and government. Experts had knowledge of a wide range of AI applications and implications, as shown in Table 1. These experts were chosen for their experience and knowledge of both AI and disability, specifically in relation to blindness and low vision. Experts were balanced in gender as shown in Table 2, but predominately white with other races underrepresented as shown in Table 3. Three rounds were conducted: a qualitative phase with semi-structured interviews, followed by two web-based quantitative surveys. The study received Institutional Review Board (IRB) approval, and all participants provided informed consent.

Table 1: *Area of Expertise*

Expertise Area	Count
Generative AI	21
Large language models (LLM)	17
AI use in school settings	9
Education of students with disabilities in K-12 or postsecondary settings	12
Employment issues affecting people with disabilities	13
AI in the workplace	17
Autonomous vehicles	6
Transportation policy	6
AI used for visual descriptions (image/video descriptions) or visual interpretation	18
Algorithmic decision making in healthcare settings	9
AI use for determining benefits eligibility	3
Policy issues around regulation of AI technologies	13
Other	4

In the first round, semi-structured interviews identified key themes and issues. Experts were selected based on their expertise in industry, policy, and academia, ensuring diverse perspectives. Each interview lasted approximately one hour and was transcribed verbatim, with real-time notes taken for accuracy. Thematic analysis of the interviews informed the development of survey questions for the subsequent rounds. Items where the researchers could not foresee a clear policy implication were frequently excluded to reduce survey length.

Table 2: *Gender Demographics*

Gender	Count
Cisgender female/woman	13
Cisgender male/man	15
Genderqueer, gender-nonbinary, or gender fluid	3
I prefer not to provide this information	1

The second and third rounds used web-based surveys administered via Qualtrics, with data analysis performed in R version 4.3.2. The second-round survey quantified expert agreement using seven-point scales and included open-ended fields for justifications. The third round incorporated aggregated results from the second round, including mean Likert scores and anonymized justifications, allowing participants to reconsider their responses. Items that approached consensus, defined as a standard deviation (SD) of 1.0 or less, were re-evaluated.

Table 3: *Racial Demographics*

Race	Count
Asian/Asian American	7
Black/African American	2
I prefer not to provide this information	3
Middle Eastern/North African (ME/NA)	1
White non-Hispanic	19

The study maintained participant anonymity to encourage candid responses. Experts were informed of study goals and processes at each stage, ensuring voluntary participation. By integrating qualitative interviews with quantitative survey rounds, this Delphi study effectively captured expert perspectives, refined ideas iteratively, and identified areas of consensus, contributing to actionable policy recommendations. After determining the statements that experts across the panel could agree on, policy experts and researchers worked together to draft guiding principles for policy, which are rooted in this dataset.

Results

The agreement of expert opinions from the Delphi study revealed several key findings regarding the intersection of AI and blindness. The list below shows the 15 most strongly agreed upon statements.

Experts Agree:

- A human in the loop is necessary for candidate screening.
- The tech industry needs more diversity among its own employees to be able to spot and guard against the many types of bias that AI can generate.
- AI auditing must account for anti-disabled biases in addition to racial and gender biases.
- AI needs to focus on expanding access and inclusion; it is not enough to only avoid harm to people with disabilities (PWD).
- AI should be a partner, not a replacer, in writing Individualized Education Plans (IEPs) for students with disabilities.
- There should be strong privacy laws at the federal level that are informed by the disabled community.
- Automation bias (belief that if it comes from the algorithm, it must be true and unbiased) leads to an overreliance of AI for tasks that it is not particularly accurate for.
- Balancing privacy standards with accessibility needs is critical in AI development for PWD.
- Regulation needs to ensure that individuals with disabilities are proactively considered in AI development.
- AI used in resume screeners or hiring decisions needs to be disclosed to all applicants.

- AI should not replace interactions with human educators.
- PWD should be involved at every stage of creating, procuring and deploying algorithmic decision-making.
- Skills like curiosity, empathy, and critical thinking will remain the most relevant after AI adoption.
- Training methods for AI literacy, such as drag-and-drop interfaces, pose barriers for people with disabilities.
- Reactionary regulation, where actions are taken only after something bad happens, is common with AI.

Policy Guidelines

Working from statements such as those above, the following policy guidelines were developed (Silverman et al., 2025). These guiding principles for policy development address users' needs and implementation strategies, as well as policy development.

- AI has the potential to increase access to assistive technology by automating services, like captioning, image description, and wayfinding, and integrating those technologies into mainstream devices and software that are widely available to the general public.
- Investments in AI research and development should maximize the capabilities of human users to provide opportunities and services to people with disabilities such as in educational and transportation settings, rather than replacing human professionals altogether.
- Some uses of AI demand greater scrutiny. When AI has a significant impact on people's civil rights, health, safety, freedom, or opportunity, both deployers and developers have a greater obligation to ensure that the AI models in use are not discriminatory either by intent or happenstance.
- AI systems should be designed and audited to ensure that they do not amplify harmful stigmas about people with disabilities. The outcomes should be measured for specific negative effects against people with disabilities.
- In order to be representative of people with disabilities, the data used to train AI models should be sufficiently diverse to be representative of people with a range of disability types and with other characteristics, including gender, age, race, and income.
- Producers of AI training datasets should evaluate whether their datasets represent a sufficiently diverse representation of people with disabilities or incorporate stigmas, modify the datasets as needed, and provide transparent information to guide data users and researchers to understand the limitations of the dataset.
- AI chatbots, especially those used in customer service settings, should be provided training information and resources to answer questions relevant to people with disabilities and their unique accessibility needs.
- Investments in AI research and development, including grants from government agencies, should incentivize and prioritize research into AI that is representative of and produces fair outcomes for people with disabilities.

- Additional resources should be invested in producing validation and auditing practices that ensure that people with disabilities are accurately and sufficiently represented by AI models and that decisions produced or influenced by algorithms are fair and appropriately attuned to the experiences of people with disabilities.
- The principles are to guide developers, deployers, users, and policymakers in crafting beneficial AI for people who are blind, have low vision, or have other disabilities.
- People with disabilities should have equal access to STEM education and careers. Improving the accessibility of K–12 and higher education STEM curricula as well as career training programs should be a priority to create pathways for students with disabilities to be able to enter careers creating and using AI technologies.
- AI developers should actively recruit people with disabilities and ensure that workplaces are accessible.
- Development tools used to program and train AI models should be accessible to and usable by people with disabilities.
- Training courses designed to prepare existing workers to develop AI skills should be fully accessible to people with disabilities, including by incorporating accessible interfaces, captions, audio description, plain language, and alternative formats of graphical information where appropriate.
- AI literacy and skills training should prepare people with and without disabilities to understand automation bias as well as potential sources of disability bias and how to correct for it. Deployers of AI should provide employees with ample agency, training, and time to question the results of AI decision-making tools and identify whether they present bias against people with disabilities.
- Developers of software that incorporates AI models should provide transparent information about the extent to which the software has been tested for representativeness, bias, and accessibility for people with disabilities.
- Developers of AI models should consider creating technical manuals that guide users and deployers of those models in understanding the limitations of the model and how to correct for biases that may be discovered after the fact, such as by incorporating human oversight into decision-making processes supported by AI.
- Training should be made available to guide users in understanding prompt creation for generative AI that produces results that are accurate and representative of people with disabilities.
- Software that incorporates AI may discriminate against people with disabilities if people with disabilities cannot use all aspects of the software interface, including with assistive technology like screen readers. AI software should be designed to fully conform with international accessibility standards, such as the Web Content Accessibility Guidelines 2.2, Level A and AA.
- The use of AI in software and decision-making tools should be clearly disclosed to users. Particularly in cases where the use of AI could screen out people with disabilities, users should understand how to request reasonable accommodations or how to appeal decisions to a human reviewer.

- Deployers of AI in employment and educational screening should carefully consider whether the AI model may explicitly or implicitly discriminate against people with disabilities, for example by discarding applications with employment gaps or judging candidate videos for certain eye movements or speech patterns. To the greatest extent possible, human reviewers should have access to all applications and should confirm that the screening tool appropriately recommended qualified candidates, including those with disabilities.
- In general, educational technology, regardless of whether it incorporates AI, should be fully accessible to and usable by students with disabilities. The U.S. Department of Justice has issued regulations for public schools and universities requiring educational websites and mobile applications to be accessible to both students and parents with disabilities.
- When used in educational technology, AI agents and chatbots should be designed to provide information in accessible formats and to produce pedagogical outputs and means of instruction that are appropriate for students with disabilities. Trained educators of students with disabilities, including teachers of students who are blind or have low vision, as well as students themselves, should be consulted in validating the appropriateness of these educational tools.
- AI may support teachers in reducing planning, documentation, and paperwork burdens, but it should not entirely replace human educators when delivering instruction or developing educational plans for students with disabilities.
- AI used in software to surveil employee and student performance as well as productivity should not disproportionately affect people with disabilities.
- Students and employees with disabilities should be able to have access to AI as an assistive technology that supports their educational and employment opportunities. School administrators and employers should consult with people with disabilities in developing appropriate policies and procedures for the use of AI in employment and educational settings, including as a reasonable accommodation.
- Employers and educational institutions should carefully evaluate whether such tools may discriminate, such as by flagging employees who need breaks for personal needs or to care for a service animal or by categorizing certain involuntary eye movements as cheating or inattention.
- Collaboration between the assistive technology industry, AI developers, and the disability community could result in more accurate and neutral representations of individuals in image descriptions that balance privacy, concerns about bias, and accuracy of the image descriptions.
- To the extent that AI powers assistive technology for people with disabilities, it may be given greater access to more personal information than a nondisabled user would provide. Access to assistive technology uses of AI should not be contingent upon people with disabilities relinquishing either their privacy or data security, especially in situations where people without disabilities do not have to exchange privacy for access.
- To enable people with disabilities to use AI in sensitive situations, such as reading mail, users should be able to choose where user data is stored and to what extent it is shared with an AI developer. When data must be uploaded to the cloud to provide greater processing power, users should be able to control whether that data is stored and accessible by companies using the data.

- Terms of agreement should offer users the choice of whether to allow companies to access and use the images that are uploaded to assistive technology tools.

Outcomes and Benefits

The synthesis of expert opinions emphasizes the importance of responsible AI development that includes the specific needs of people with disabilities. The findings show that AI technologies have the power to transform accessibility, but only if they are developed ethically, and with a commitment to fairness, inclusion, and nondiscrimination. The identified guiding principles should be integrated into all stages of AI research, development, and implementation to mitigate the risks while harnessing the benefits of AI for people who are blind or have low vision. If these guiding principles consistently informed internal organizational policies, assistive technology users would have equal access to the opportunities offered by AI platforms. Development of policies that align with these guiding principles would minimize bias against people with disabilities that AI tools generate. Developers and decision-makers can immediately benefit by aligning the policies they manage with these principles.

Discussion

The results of the Delphi study highlight the dual nature of AI's impact on people with disabilities. On one hand, AI offers growing potential to enhance accessibility and inclusion, and on the other hand it may create risks of discrimination. The importance of ethical considerations and responsible development is highlighted by the experts from their variety of backgrounds.

The guiding principles provide a framework for developers, deployers, managers, users, and policymakers to navigate the complexities of AI and disability. The emphasis on consultation with people with disabilities is critical and underscores the importance of "nothing about us without us." Furthermore, by understanding the limitations of AI, developing inclusive policies, and minimizing discrimination through oversight protocols, the harmful aspects of AI might be avoided.

It is critical to evaluate the decisions and outputs of AI systems to determine if they are meeting the stated goals. The experts also underscore the need to protect personal information, which is a particular concern when dealing with AI systems that collect and process data from vulnerable populations.

Strengths and Limitations

A major strength of this study was the consistent participation of the same expert panel across all three rounds. Retaining the same group facilitated continuity and enabled progress toward consensus as participants considered feedback and justifications. Furthermore, the study's integration of both qualitative and quantitative methods at each stage provided a well-rounded approach that capitalized on the advantages of both data types.

While the Delphi study provided valuable insights, there are some limitations to acknowledge. Delphi studies provide insight, not generalizability. That is to say that though a pool of leading experts agreed that human oversight is needed, this does not imply that all decision makers will automatically hold the same view. Additionally, AI is a dynamic and rapidly evolving technology area, so conclusions may be most relevant at the time of the study.

Despite these limitations, this paper provides a crucial starting point for promoting responsible and inclusive AI development for people with disabilities. Further research should build upon these findings, exploring individual statements for what social and economic forces can create meaningful change, ensuring that diverse perspectives are always included in shaping the future of AI.

Declarations

This content is solely the responsibility of the author(s) and does not necessarily represent the official views of ATIA. No financial disclosures and no non-financial disclosures were reported by the author(s) of this paper.

References

Guo, A., Kamar, E., Vaughan, J. W., Wallach, H., & Morris, M. R. (2020). Toward fairness in AI for people with disabilities SBG@a research roadmap. *ACM SIGACCESS Accessibility and Computing*, *125*, 1–1. https://doi.org/10.1145/3386296.3386298

Arnold, M., Bellamy, R., Hind, M., Houde, S., Mehta, S., Mojsilović, A., Nair, R., Ramamurthy, K. N., Olteanu, A., & Piorkowski, D. (2019). FactSheets: Increasing trust in AI services through supplier's declarations of conformity. *IBM Journal of Research and Development*, *63*(4/5), 6–1. https://arxiv.org/abs/1808.07261

Degen, H., & Ntoa, S. (2021). From a workshop to a framework for human-centered artificial intelligence. In *International Conference on Human-Computer Interaction* (pp. 166–184). Springer, Cham. https://link.springer.com/conference/hcii

Falzarano, M., & Zipp, G.P. (2013). Seeking consensus through the use of the Delphi technique in health sciences research. *Journal of Allied Health, 42*(2), 99-105. https://pubmed.ncbi.nlm.nih.gov/23752237/

Gamage, B., Do, T.-T., Price, N. S. C., Lowery, A., & Marriott, K. (2023). What do Blind and Low-Vision People Really Want from Assistive Smart Devices? Comparison of the Literature with a Focus Study. *Proceedings of the 25th International ACM SIGACCESS Conference on Computers and Accessibility*, 1–21. https://doi.org/10.1145/3597638.3608955

Holzinger, A., Dehmer, M., Emmert-Streib, F., Cucchiara, R., Augenstein, I., Del Ser, J., Samek, W., Jurisica, I., & Díaz-Rodríguez, N. (2022). Information fusion as an integrative cross-cutting enabler to achieve robust, explainable, and trustworthy medical artificial intelligence. *Information Fusion*, *79*, 263–278. https://doi.org/10.1016/j.inffus.2021.10.007

Lewicki, K., Seng Ah Lee, M., Cobbe, J., & Singh, J. (2023). Out of context: Investigating the bias and fairness concerns of “artificial intelligence as a service”. In *CHI Conference on Human Factors in Computing Systems* (pp. 1–17). https://doi.org/10.48550/arXiv.2302.01448

Mitchell, S., Potash, E., Barocas, S., D’Amour, A., & Lum, K. (2021). Algorithmic fairness: Choices, assumptions, and definitions. *Annual Review of Statistics and Its Application*, *8*(1), 141–163. https://doi.org/10.1146/annurev-statistics-042720-125902

Moura, I. (2022). *Addressing disability & ableist bias in autonomous vehicles: Ensuring safety, equity & accessibility in detection, collision algorithms & data collection*. Disability Rights Education & Defense Fund.

National Artificial Intelligence Advisory Committee. (2023). In *The federal register / FIND* (Vol. 88, Number 166, p. 59508). Federal Information & News Dispatch, LLC.

U.S. Department of Justice Civil Rights Division. (2024, October 1). *Artificial intelligence and civil rights.* https://www.justice.gov/crt/ai

Sanders, L. (2008). ON MODELINGAn evolving map of design practice and design research. *Interactions*, *15*(6), 13–17. https://doi.org/10.1145/1409040.1409043

Silverman, A. M., Baguhn, S. J., Vader, M.-L., Romero, E. M., & So, C. H. P. (2025). *Empowering or excluding: Expert insights on inclusive artificial intelligence for people with disabilities* [White paper]. American Foundation for the Blind. http://www.afb.org/AIResearch

Whittaker, M., Alper, M., Olin College, Kaziunas, L., & Morris, M. R. (2019). *Disability, bias, and AI*. AI Now Institute at NYU. https://ainowinstitute.org/publication/disabilitybiasai-2019

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Voices from Academia

Developing Artificial Intelligence Applications for Human Conversation: Perspectives, Tools, Exploratory Analyses

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Abstract

This paper evaluates the performance of conversational artificial intelligence (CAI)-enhanced speech-generating devices (SGDs) through the lens of social interaction. It involves a review of conversational principles, the dynamics of augmented speaker interaction, and the critical components and underlying processes of CAI in SGDs. Several evaluation tools are proposed to assess interaction performance in the context of CAI; this assessment is then applied to evaluate a prototype. Additionally, the paper explores the feasibility of integrating existing CAI technologies into SGDs, offering insights into how these technologies can be improved to enhance communication for users relying on augmented communication methods for conversation purposes.

Keywords: augmentative and alternative communication (AAC), artificial intelligence (AI), conversation, interaction

Developing Artificial Intelligence Applications for Human Conversation: Perspectives, Tools, Exploratory Analyses

Conversational artificial intelligence (CAI) encompasses a range of technologies designed to facilitate dialogue between users and AI systems, simulating human-like conversation. At its core, CAI aims to generate responses that are not only contextually appropriate but also rich in nuance—incorporating elements such as emotion, shared history, empathy, and adherence to social norms. This capability presents a transformative opportunity for augmentative and alternative communication (AAC), particularly in enhancing speech-generating devices (SGDs) used by individuals with communication disabilities.

For this discussion, we define CAI in a more specialized sense—focusing specifically on its integration within SGDs to support and enhance real-time conversational interaction. The effectiveness of CAI in this domain will be determined by its ability to address the inherent limitations of current SGDs, enabling users to participate more fluidly in conversations. A key challenge is ensuring that CAI-driven SGDs can meet the temporal demands of natural dialogue, ultimately empowering users to engage in more meaningful interactions within the time-sensitive framework of conversational practice.

Purpose

This paper investigates methods for evaluating CAI performance from a social interaction perspective. It examines the principles of conversation, the challenges that augmented speakers encounter, and the key components and processes underlying CAI. Additionally, we apply our proposed assessment techniques in two pilot studies to explore the feasibility of integrating current CAI technologies into SGDs.

Target Audience and Relevance

CAI can potentially revolutionize SGDs, yet its full impact remains uncertain. Despite its promise, many individuals—including researchers, academics, clinicians, and consumers—still lack a clear understanding of its components and how it operates. This article builds on Hackbarth's (2024) work on AI in AAC by examining current CAI-SGDs' components and performance characteristics. A conversational perspective is crucial for designing and evaluating CAI-SGDs' ability to facilitate social interactions. The conversational perspective, evaluation tools, and performance data presented here are highly relevant to the above stakeholders.

What is Conversation?

Conversation is a collaborative and temporally-bound social activity that has fundamentally shaped our interactive language use throughout human evolution (Dediu & Levinson, 2013; Levinson, 2016). It is the cornerstone of our daily social interactions, underpinning communication structure and coordinated social actions, even those facilitated by everyday communication technologies (Clark, 1996; Enfield, 2013; Seale et al., 2020).

Effective conversation hinges on the cooperative principle, that is, the ability of participants to work collaboratively to achieve mutual understanding and move the exchange forward (Clark, 1996; Grice, 1975). This means that participants need to coordinate their spoken and non-spoken actions (e.g., head nods/shakes, gestures) with one another towards the shared goal of progressivity, the continuous forward movement of the conversation (Schegloff, 1979; Schegloff & Sacks, 1973; Stivers & Robinson, 2006). Among typically abled persons, progressivity is accomplished through turn-taking. Participants shape their contributions to match their recipient's perceived communication needs. The recipient, in turn, evaluates the previous utterance's content, relevance, and manner before responding, typically with little temporal gap. Research in social interaction suggests that this gap averages around 250 milliseconds, with comparable findings across multiple languages. Delays of half a second or more are often deemed problematic, as turn delays often signal reluctance in responding or problems in understanding (Levinson, 2016). Consequently, the drive for progressivity frequently takes precedence over grammaticality, brevity, and precision (Stivers & Robinson, 2006).

Due to design limitations in SGDs, individuals relying on SGDs for face-to-face conversations often struggle to engage effectively in the natural flow of dialogue, as these technologies require the augmented speaker to compose their utterance in text before delivering it via synthesized speech. Seale et al. (2020) suggest that this is problematic because the delayed SGD utterance production typically occurs in conversation with an oral-speaking partner who adheres to the temporal norms of spoken interaction and expects their augmented partner to do the same.

Higginbotham et al. (2016) proposed a conversation delay taxonomy along three categories (see Enfield's [2014] framework for studying language and Hackbarth's [2024] temporal model of human activity for additional information):

- *Now-Time* extends from zero to a few seconds and covers the operative timeframe for conversational turn-taking. Embodied forms of expression, such as face and limb gestures and vocalizations, are commonly used by augmented speakers to respond to their partner's utterances or to make interjections within the Now-Time interval. Single selections are sometimes operative within this timeframe.
- *Near-Time* extends from 2 to 10 seconds, providing time for a few single-letter selections or stored messages in utterance-based systems.
- *Delayed-Time* communication ranges from 10 seconds to several minutes and is the category where most augmented speakers compose their sentences, except those who type with both

hands without physical impairment. As previously mentioned, the pragmatic effects of intonation and the content of the utterance change as the delay lengthens.

Due to technological constraints related to message composition delay, it is difficult for many SGD users to approximate Now-Time or Near-Time interactions (Rayman et al., 2023). CAI provides an attractive approach to addressing these problems but must achieve specific conversational criteria.

Research by Koroschetz et al. (n.d) on conversations between SGD speakers with ALS and their oral-speaking partners has shown that SGD users' response delays frequently disrupt the flow of conversation. Oral-speaking partners employ various strategies to deal with these disruptions and fill the time, including continuing to talk or addressing the problematic nature of the delay itself ("Are you using your word predictor?"). During these message construction delays, conversation partners may forget the original conversation topic or attempt to repair the misunderstanding.

Both Waller (2006, 2019) and Hackbarth (2024) note that the temporal delays associated with SGDs make it difficult to have social conversations, often restricting interactions to transactional exchanges.

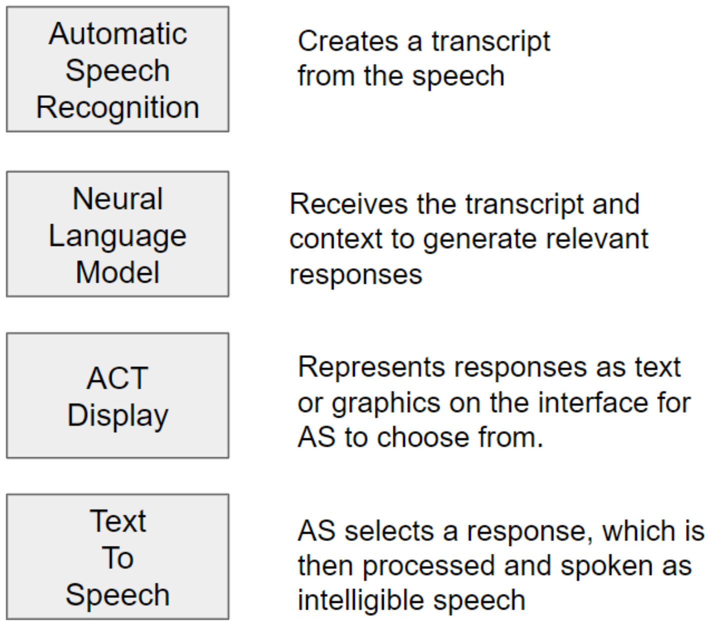
Conversational Artificial Intelligence

1. CAI is a type of artificial intelligence (AI) that simulates human conversation. Current CAI systems, including chatbots and virtual assistants, leverage various AI-related technologies, such as natural language processing (NLP), neural language models (NLMs), automated speech recognition (ASR), and text-to-speech (TTS), to perceive, understand, and produce comprehensible and appropriate responses, and to learn from human language input. Generative AI powers the CAI under discussion and utilizes various technologies to process inputs and deliver outputs through speech and written text. CAI aims to facilitate seamless and intuitive human-computer interactions, providing users with efficient and contextually relevant responses. A simple flowchart illustrating the processing sequence of CAI is shown in Figure 1.The first component of CAI is ASR, which processes the partner’s speech, transforming it into text. Advanced ASR systems may also segment speech into utterances identifying the speaker, collectively termed diarization. It may also analyze the content of the speech in terms of its emotional qualities (e.g., negative, neutral, positive), known as sentiment analysis. Diarization and sentiment analysis can be used to inform other parts of the CAI.
2. NLMs use machine learning to understand the relationships between words in natural language texts. Given specific instructions or prompts, these models can use the input from ASR to generate appropriate responses.
3. Information from the NLMs is sent to the SGD, which then displays the generated utterances on its interface for the augmented speaker (AS) to select. The AS can choose one of the provided options to speak or prompt the NLM to reanalyze and generate more choices tailored

to convey specific emotions (e.g., happiness, anger, fear) or intended communication acts (e.g., request, question, comment).

4. TTS systems vary significantly in quality. The more advanced ones use neural networks to produce more natural and human-like speech from text.

Figure 1: *Flowchart of Processing Sequences for a Conversational AI-enhanced ACT*



Issues About CAI Posed by Augmented Speaker

There has been little documentation of the potential benefits or downsides of using CAI by or regarding people who use SGDs. At the Future of AAC Research Summit (Communication First, 2024), several individuals using SGDs spoke about their research priorities for the field. Yoosun Chung, an academic with cerebral palsy, talked about her hopes for the transformative impact of CAI on SGDs and its ability to incorporate location information, speaking partner, physical environment, current activities, social dynamics, and conversational history into generating topically relevant contributions (p. 8, Communication First, 2024). A contrasting view was presented by individuals who were part of a brain-computer interface (BCI) study (Fried-Oken et al., 2023). Their concerns focused mainly on communication accuracy and correct interpretation of their utterances. There was a general orientation towards error-free communication, citing concrete harms that could come from inaccurate interactions during conversations with healthcare providers, and to relationships in general.

There were also concerns about BCIs' slow speeds, as Fried-Oken et al. (2023) write, "One person noted that it is already 'a battle to be engaged in the world' and 'that by giving up speed you risk not being involved in the conversation'" (p. 7). Another participant noted that "[if the prediction] is conveying basically what I want to say, even if it's not totally precise, I'll go ahead out of convenience sake and just select that one" (p. 6).

Current Examples of CAI for Augmentative Communication

Currently, CAI is absent from commercially available SGDs, but two prototypes are exploring its potential. The first, a CAI prototype, Speech-Macros, was developed by Valencia et al. (2023) to demonstrate the capabilities of a large language model (LLM) in providing diverse choices, utilizing background information, and changing pragmatic utterance choice characteristics. Speech Macros refer to predefined or custom LLM prompts that SGD users can quickly use with short user inputs to produce different phrases based on the ongoing conversational context (partner's speech) and a keyword of their choice. The second prototype by Avaz, Inc. is SwiftSpeak® for the iPhone and iPad. This prototype uses generative AI to produce contextually appropriate responses by integrating cues such as partner talk, tone of communication (e.g., anger, disappointment, humor), user personality, and user input (Figures 2 & 3).

Figure 2: *Speech-Macros Prototype (From Valencia, et al., 2024)*

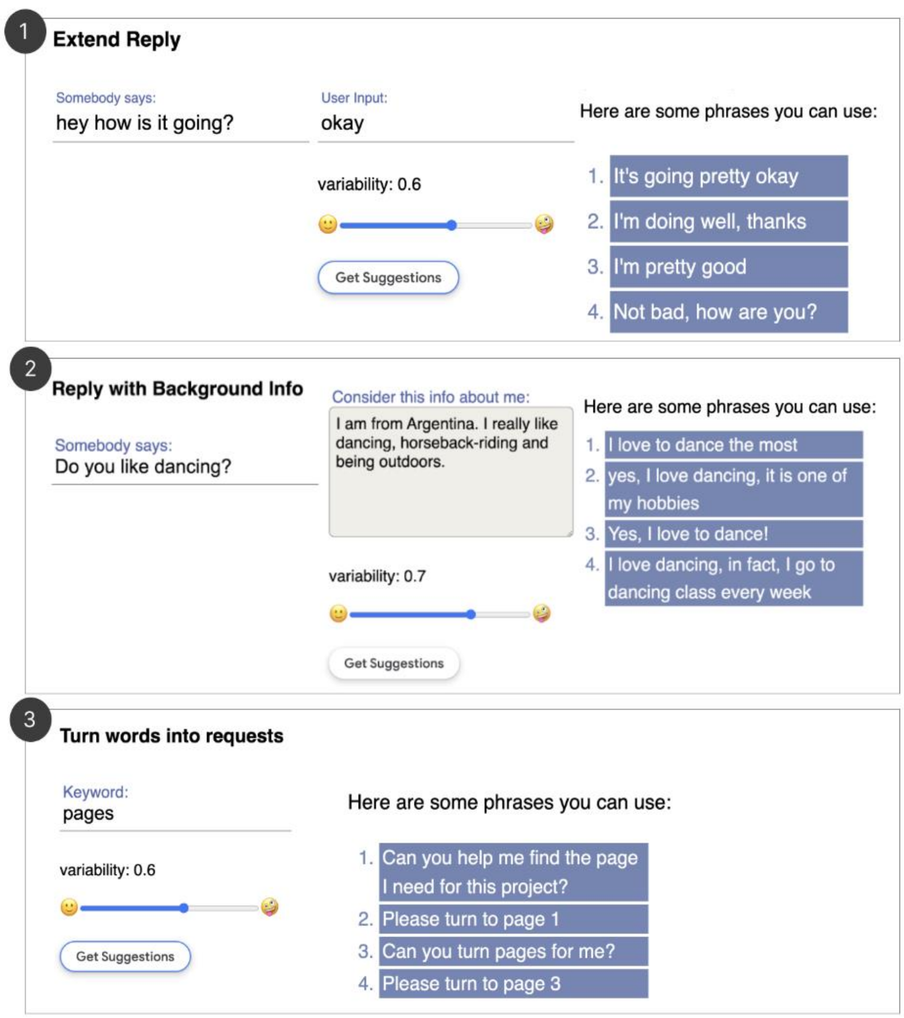
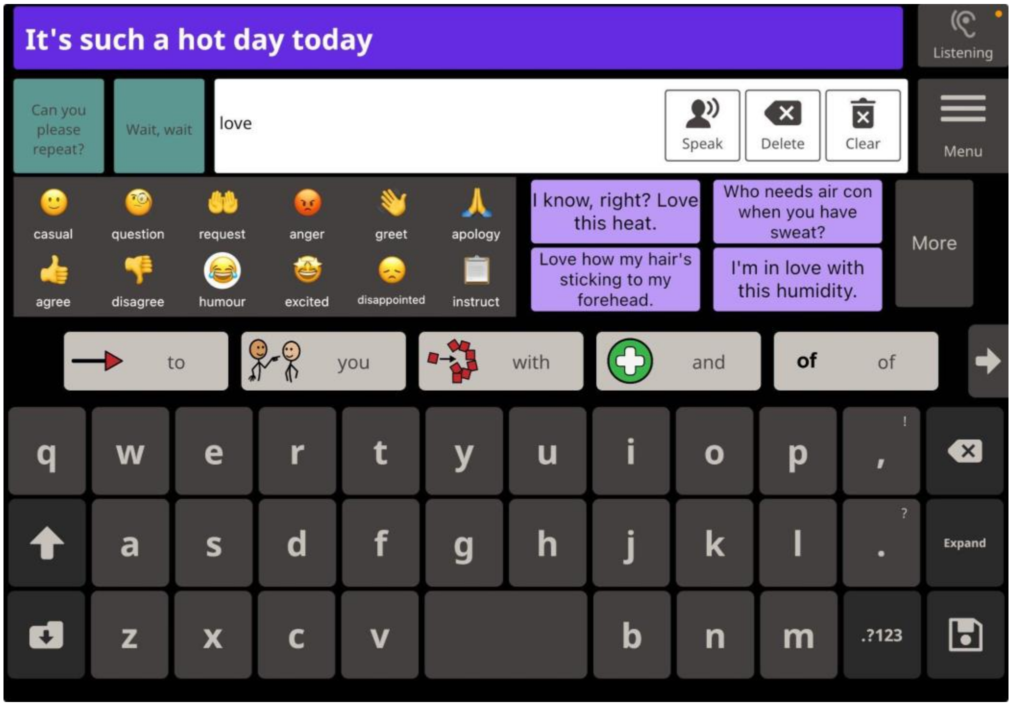


Figure 3: *SwiftSpeak® CAI prototype From Avaz, Inc.*



Requirements for CAI to Meet Talk-in-Interaction Needs

Below, we provide a broad set of interaction criteria to guide our assessment of CAI in real-time conversations. These criteria for evaluating chatbots and other interactive technologies are based on principles of effective communication (Grice, 1975) and the costs incurred when communication fails (Clark, 1996; Clark & Brennan, 1991). They reframe the essential social interaction requirements for successful turn-taking and conversation. They are purposefully general and descriptive so that they can be brought to bear on assessing aspects of CAI performance.

Criterion #1: Sufficiency and Sincerity. In spoken conversation, the speaker provides as much information as the partner needs but avoids being too lengthy or overly wordy. The speaker also designs their utterances to be perceived as being truthful and factually correct. For their part, the listener assumes the speaker's words to be truthful. To meet this criterion, contributions generated by CAI need to align with the AS's assumptions about the comprehension needs of their interaction partner. This may include meeting the AS's expectations about length, grammatical complexity, coordination of shared knowledge, factualness, and referential specificity.

Criterion #2: Timing and Sequencing. The speaker initiates the conversation without problem or delay, and the participants can maintain an active and engaged relationship when taking conversational turns without problems. Each turn of talk is connected to the preceding one and simultaneously sets the context for the following turn. To meet this criterion, the conversational AI (CAI) should respond within seconds of the partner finishing their speaking turn. This quick response is crucial for starting conversations or new topics, maintaining coherence between turns (ensuring the user understands that the CAI's response relates to what they just said), and handling time-sensitive communication acts, such as initiating repairs (e.g., clarifying misunderstandings).

Criterion #3: Content and Manner. Conversants can say what they want in their chosen manner. In spoken conversation, these criteria include grammatical and dialectical choices, the performative aspects of identity, and the subjective representation of self through interaction style and intonation. To meet these criteria, the CAI should provide utterances, materials, and controls that support the AS's views about themselves and what they want to disclose to others at a given moment and within the conversational context (i.e., relevance to the topic, grammatically appropriate as a response).

The Initial Design and Testing of the System

DEAN (Dynamic, Expressive, Augmented Narrator) is our SGD prototype which uses a personalized CAI to respond to spoken input from communication partners. It was developed by the University at Buffalo, departments of Computer Science and Engineering and Communicative Disorders and Sciences (e.g., NLMs, web servers, and prompts) and the Center for Literacy and Disability, University of North Carolina – Chapel Hill (i.e., Open Source Design and Programmer Interface [OS-DPI; Project Open Design Community, 2020]). Our research aims to evaluate DEAN's potential to enhance interactive communication for SGD users. In this section, we will present a short history of the DEAN project, describe its system architecture, and present two studies addressing critical questions regarding DEAN's performance. First, how long does DEAN take to issue a set of responses after a partner speaks an utterance? Second, how effectively does DEAN generate appropriate and usable responses to the ongoing discourse?

Project History

Initial discussions about the development of DEAN among the coauthors began in the fall of 2022. By the spring of 2023, the initial research and development team had started working on the first version of the CAI-SGD interface. We conducted our first DEAN interface test using an off-the-shelf LLM during this period. The summer of 2023 was dedicated to integrating the OS-DPI into DEAN's architecture. One of our co-researchers, Todd Hutchinson, a lifelong SGD user, had just completed a book about his life. He consented to have his book used for our research and to participate in evaluating DEAN's performance.

After acquiring a dedicated training server, we fine-tuned the language model in the fall of 2023, which led to a second evaluation of DEAN in the spring of 2024. Some of our initial findings are reported below. We also developed our prototype based on the architecture described in this paper during this time. Throughout the summer, we enhanced DEAN's world knowledge capabilities and incorporated emotion analysis of partner talk for future use. Additionally, we enabled the AS to initiate conversations through composition.

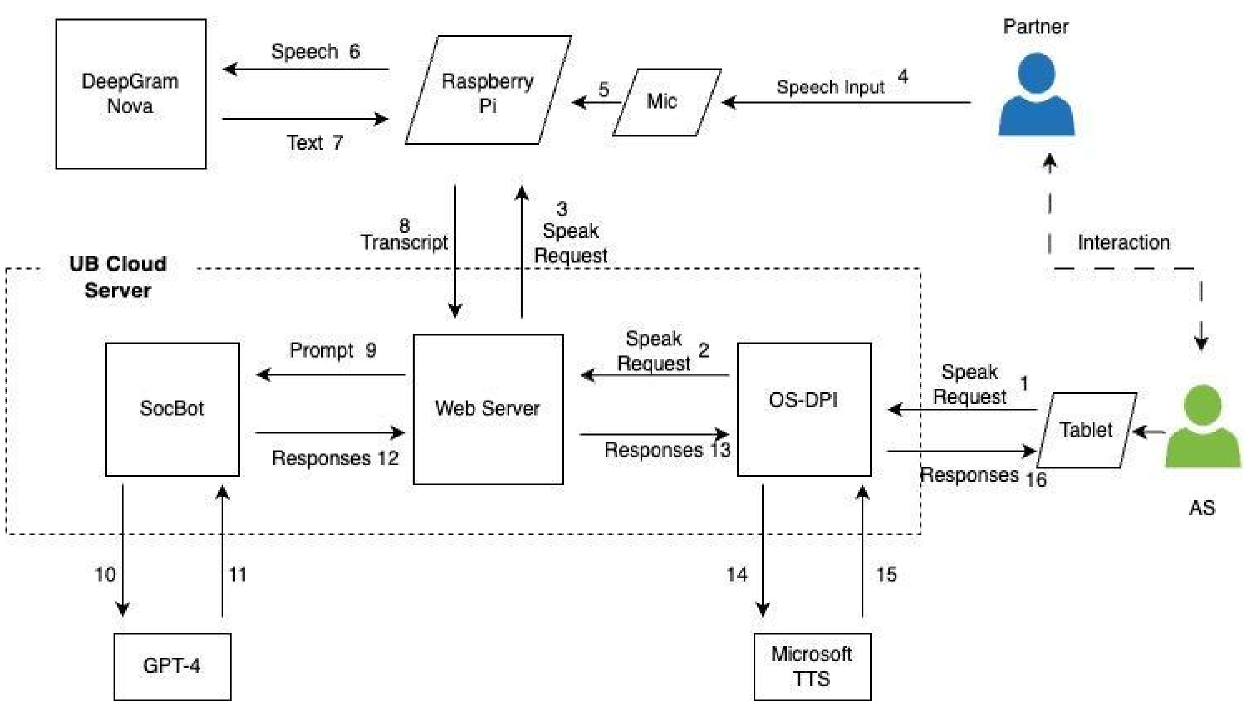
Fine-Tuning a Language Model for DEAN: Methodology and Implementation

As noted above, we integrated a book into DEAN through a fine-tuning approach. Once the model establishes this broad linguistic and conceptual foundation through a pre-training process, *fine-tuning* is employed to adapt it for specialized tasks or domains, such as answering subject-specific queries. In this study, we utilized pre-trained models, including Flan-T5 and GPT-4, refining them further with a specific text—an autobiography by Todd Hutchinson (Hutchinson, 2024). We transformed the book into a structured dataset composed of dialogues to optimize the model's ability to generate contextually appropriate and natural responses. These models were further trained on this dataset to enable the model to internalize conversational patterns and produce responses that were more nuanced, relevant, and aligned with Todd's experiences.

Architecture

DEAN's architecture is shown in Figure 4. This particular component configuration allowed us to test and study the performance and impact of the latest AI technologies on conversation. The architecture was designed to be portable, enabling study participants to use DEAN in their homes. A description of each of DEAN's components and their interrelationships is graphically depicted in Figure 4.

Figure 4: *DEAN's System Architecture*



First, The AS prompts the partner to speak by sending a request through their tablet device, which goes through the OS-DPI interface to the web server and then to the Raspberry Pi (RP). This is depicted from steps 1 to 3 in Figure 4. The RP is a compact single-board computer that captures the conversation partner's speech and manages the information flow between various DEAN components via a cellular hotspot. After the RP is prompted to listen, the partner begins speaking, and the RP captures the input, as indicated by steps 4 and 5 in Figure 4.

Second, the RP sends the captured speech input to the Deepgram ASR model called Nova (Deepgram, 2023). Nova is an advanced system designed to rapidly transcribe spoken language into written text using state-of-the-art machine-learning algorithms and acoustic modeling. Steps 6 and 7 depict this process.

Third, the ASR output is sent via the RP and web server to the NLM for conversational processing. The NLM is hosted on the UB Cloud Server. Steps 8 and 9 depict this flow.

Fourth, GPT-4 rephrases the response generated by the NLM using a linguistic style associated with the tone-of-voice prompts previously selected by the AS, as depicted with steps 10 and 11.

Fifth, the multiple responses generated by the NLM are sent to the OS-DPI through the web server, after which the AS can choose their response. They can also prompt the TTS to add a particular tone of voice (e.g., happy, angry, sad, terrified) or whether the speech should be spoken at an average volume, whispered, or shouted before the utterance is produced. This process is shown in steps 12 and 13.

Finally, the AS’s chosen response is sent to Microsoft TTS (Microsoft, 2024) via the OS-DPI, which converts the TTS output. Microsoft Azure TTS is an advanced AI system that converts text into high-quality, human-like speech through deep neural networks, which can be modified through prompting. This is depicted with steps 14, 15, and 16. The above process is reinitiated after the partner responds to the spoken output.

Study 1: Measuring DEAN’s Component Latencies

In-person conversation is inherently time-sensitive, requiring participants to take turns with little to no gap between spoken contributions. This temporal constraint limits the time between a partner's utterance and the selection of DEAN’s response by the AS if the response is to be perceived as part of a typical speaking turn. Each component in DEAN’s system introduces a delay, which can diminish the quality of social interaction if the delays become excessive, especially if the cumulative delays move the AS’s response into the Delayed-Time category described earlier in this paper. Therefore, evaluating the delays associated with each component is crucial, allowing for documentation and targeted efforts to reduce these latencies.

Methods

To assess DEAN's delays, we measured each technical component's timings under experimental conditions at the Communication and Assistive Device Laboratory, University at Buffalo.

We selected ten sentences from the 131 partner utterances generated in Study 2, with a median length of 10.3 words (range: 4 to 16 words). One of the coauthors (JH) recorded the sentence stimuli and then measured the latencies associated with the various processing stages. The results of this test are presented in Table 1.

Table 1: *Average Latency Measures (Seconds) Associated with Dean-CAI Processing Stages for Ten Utterances*

DEAN-CAI Component Latency	Median IQR (s)	Range min - max(s)
Initiate recording process	0.16 (0.04)	0.40 (0.11 - 0.51)
ASR transcription	5.05 (1.20)	2.30 (3.30 - 5.60)
Transcript back to server	0.12 (0.02)	0.04 (0.11 - 0.15)
socBot response generation	5.98 (2.29)	3.93 (3.66 - 7.59)
TTS response generation*	<0.5	

* Estimate

Results

As shown in Table 1, the largest latencies are associated with the ASR transcription (5.05s) and the NLM's response generation (5.98s), both NLMs. These two delays alone add up to approximately 11 seconds, which already places the response time into Higginbotham et al.'s Delayed-Time category, even without considering the amount of time it takes to read the choices and make a response. If we estimate the AS response time, then with our current version of DEAN, we expect it to take between 15 and 20 seconds from the time the partner has finished speaking to the point at which the selected utterance is spoken. When we evaluate this data using the three social interaction performance criteria presented earlier, it is apparent that the extent of the delays associated with DEAN directly violates the timing component of Criterion #3 (the CAI provides utterances within a few seconds of the partner finishing their speaking turn). At this level of delay, ensuring sustained partner attention is difficult at best, putting the AS at risk of being misunderstood and unable to share in the direction of the conversation.

Study 2: Testing the Acceptability of DEAN's Dialogue Generation

In this study, we evaluated the ability of the DEAN's language model to produce conversational utterances by having the AS use it to answer questions about his past and present posed by a partner familiar with his history. The AS and partner engaged in 25 conversations, encompassing 47 total turn exchanges. Our analysis used forty randomly sampled individual turn contributions generated by CAI (e.g., question-answer).

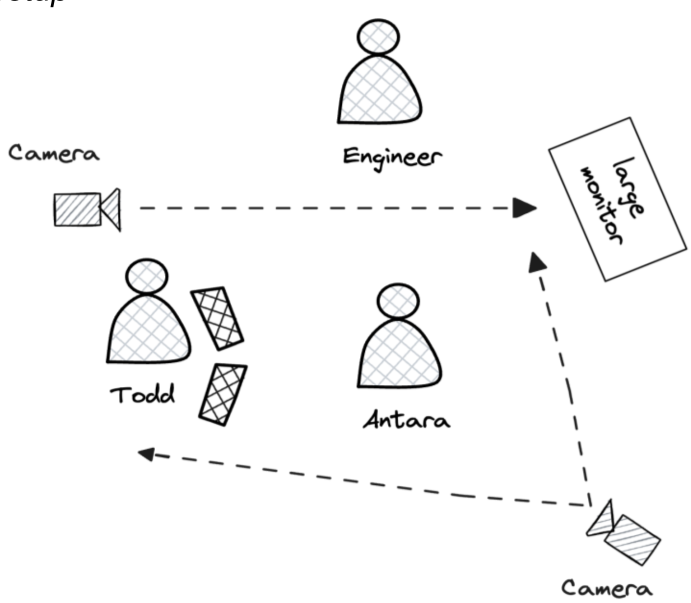
Methods

Participants

Todd (coauthor) is an adult with cerebral palsy who has used Minspeak SGDs for 38 years and worked with us to evaluate DEAN. He participated in our study by making his autobiographical text available to fine-tune our language model, serving as the AS in the experiment, sharing his experiences using DEAN, and providing input on its development. Antara (coauthor) is a typically-abled adult, doctoral student, and research scientist in our lab who participated as Todd's conversational partner in this study.

Todd's SGD setup included a Prentke Romich 1400 and Unicorn keyboard connected to his M2 MacBook Air. His computer screen was displayed on a 56-inch monitor. Typically, Todd types into a Microsoft Word document when interacting with others at home. During the testing of DEAN, Todd made his selections using the OS-DPI interface shown on his monitor. Depending on the context, the experiments were recorded using cameras positioned in various ways. A typical experimental setup is illustrated in Figure 5.

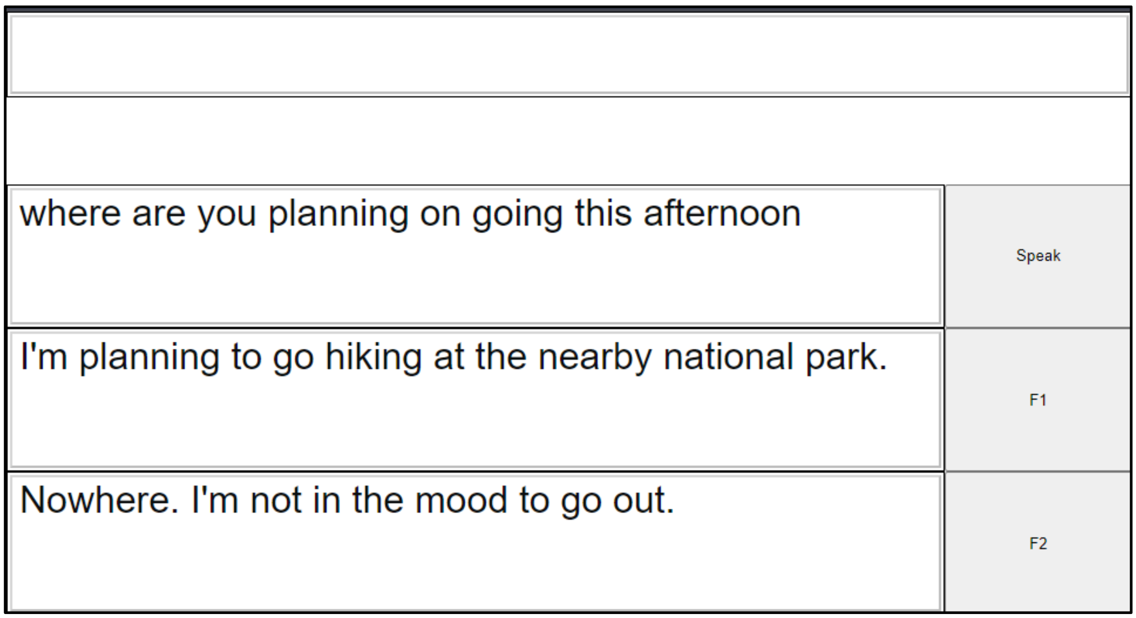
Figure 5: *Experimental Setup*



Experimental Context

In this experiment, the OS-DPI interface incorporated several key elements including a field displaying the partner’s speech, two fields showing the NLM’s responses, and additional interactive features (Figure 6). The interface was presented on a wall-mounted monitor. Each interaction began when the researcher activated the microphone by pressing Todd’s Unicorn keyboard button. After the researcher asked a question or commented, the spoken text appeared on the interface, followed by two responses generated by the NLM. Todd then used his Unicorn keyboard to select the most appropriate response, which was voiced aloud.

Figure 6: *Open Source Design and Programmers Interface (OS-DPI)*



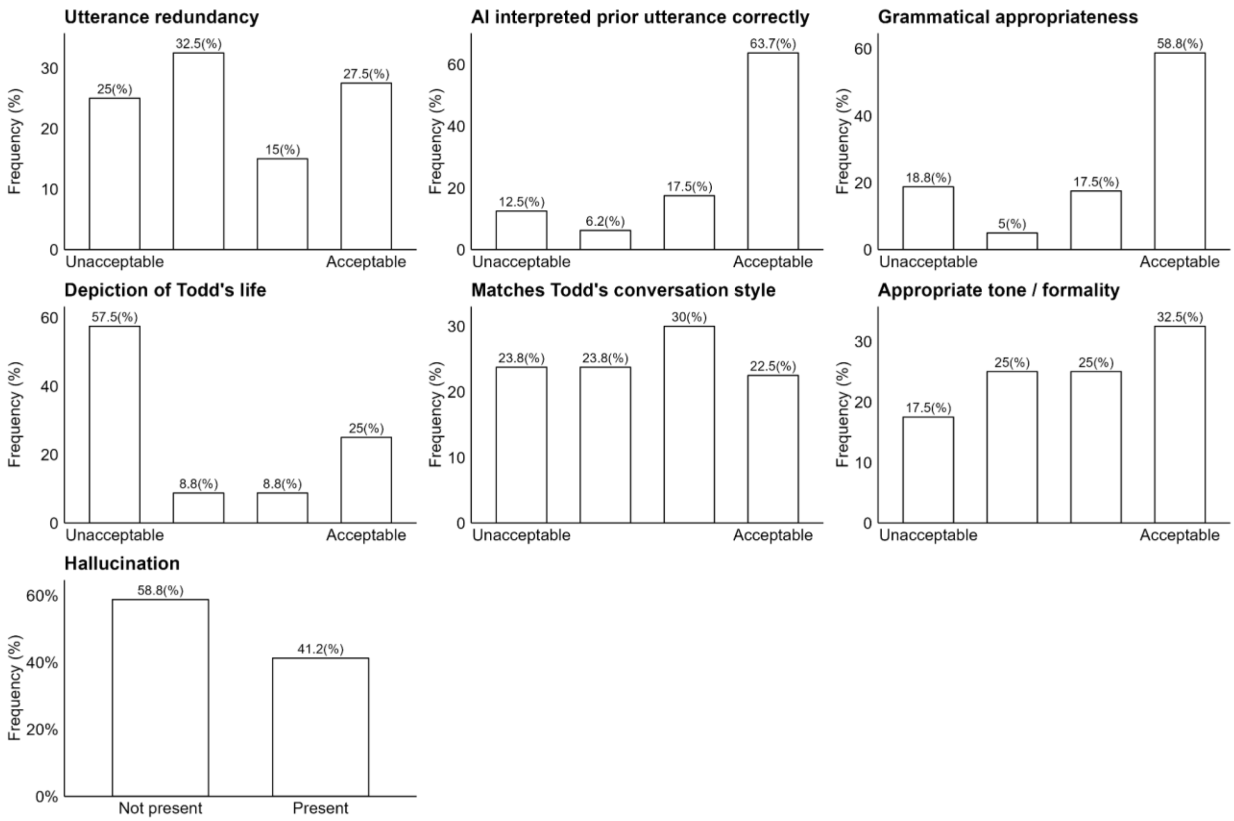
The experiment involved recording 25 multi-turn conversations for 133 total turn exchanges. After each exchange, Todd assessed the acceptability of his chosen response through typing or gestures by entering an “A” or “X” (i.e., Acceptable or Unacceptable) into his Minspeak device. One of the researchers recorded these data after each conversation. An analysis of Todd’s acceptability rating indicated that Todd's acceptance rating for responses selected at the time of the experiment (N = 113) was just 47% (n = 53), while he disapproved of 53% (n = 60). Based on these data, we then undertook a follow-up evaluation of DEAN's communication performance.

Following the experiment, Todd and the primary researcher collaborated to develop a rating scale addressing seven problematic aspects of DEAN’s response options. Items recorded the acceptability of responses in terms of DEAN’s ability to provide response choices that minimize redundancy, correctly interpret the partner’s prior utterance, address the previous utterance’s grammar and syntax, accurately depict Todd’s life, match Todd’s conversational style, have an appropriate overall tone and formality, and eliminate hallucinations (i.e., inaccurate or misleading information). Todd used these ratings to evaluate 40 CAI-generated utterances, 20 randomly selected from each of two conversational conditions (i.e., personal history, general topics), with 10 representing items he had deemed acceptable at the time of the study and 10 he had deemed unacceptable.

Results

Todd's ratings of DEAN's performance are illustrated in Figure 7.

Figure 7: *Todd's Ratings of the Problematic Aspects of DEAN's Performance*



To facilitate comprehension and comparison, we combined the "Unacceptable" category with its adjacent "Partially Unacceptable" category, then combined the "Acceptable" category with its corresponding "Partially Acceptable" category. For three out of the seven items, Depiction of Todd's Life, Hallucination, and Utterance Redundancy, all of which fell under the criteria of Sincerity and Sufficiency, more than 50% of Todd's ratings fell into the "Unacceptable" or "Partially Acceptable" range. The four remaining items, all of which addressed the Content and Manner criterion, had combined "Acceptable" and "Partially Acceptable" scores of over 50%.

The items with the highest combined "Unacceptable" ratings were Accuracy at Depicting Todd's Life (66.3%), Redundancy (57.5%), and Hallucinations (58.8%). The highest-rated "Acceptable" categories were Grammatical Appropriateness (76.3%), Correct Interpretation of the

Partner's Prior Utterance (81.2%), Matching Todd's Communication Style (52.5%), and Overall Tone and Formality (57.5%).

These data indicate that although DEAN demonstrated some success in addressing the areas evaluated by Todd, the unacceptable scores for even the most successful areas ranged from 18.7% to 47.6%. This level of performance needs to be significantly improved to maintain sustained, non-problematic conversational interactions. Additionally, it is important to note that even if a particular CAI utterance scored high in one category, it may still have received an "Unacceptable" score in one or more other categories, suggesting that most turn exchanges were problematic somehow. The most problematic items appear to map directly to the Sincerity and Sufficiency criterion, while the least problematic items address the area of Manner and Content. It's unsurprising that while DEAN performed better in areas reliant on grammar and language structure, it did not fare as well in representing the AS's perspective.

Outcomes and Benefits

This article provides a background perspective and tools for understanding and evaluating the use of CAI for SGDs. Conversation interaction presents unique challenges to an augmented speaker, particularly in terms of being able to say what you want to say within the narrow normative timeframe of conversation. Based on our evaluations of DEAN, current CAI-enhanced SGDs may need more speed and sophistication to support face-to-face conversation at this time. This work should alert researchers, practitioners, and end users to develop a critical, informed perspective on current and future advances in this area.

To carry out our research we developed several tools that researchers and practitioners can adapt when assessing CAI from a social interaction perspective. First, we proposed three interaction-based criteria that can be used to evaluate the ability of CAI—or any communication technology—to facilitate in-person interaction effectively. Second, we identified key components of CAI and provided initial latency estimates for each process, offering a method to determine whether the temporal characteristics of a given CAI system are sufficient for real-time conversation. Finally, we developed two approaches for assessing the quality of CAI responses: an approve/disapprove test and a rating system designed to evaluate various communication and informational parameters critical to the user's experience with CAI technology. We encourage all SGD stakeholders, including users, clinicians, manufacturers, and researchers, to review, adapt, or reinvent these tools to suit their specific goals and perspectives, as we will do in our future research. It is important to note that these tools are still in the prototype stage and should be regarded as preliminary resources rather than finalized evaluation methods. We hope the evaluation tools provided in this article can serve as the basis for future empirical efforts to assess CAI-enhanced SGDs and their ability to facilitate conversational interaction.

Discussion and Conclusions

In this article, we outlined an initial framework for describing and evaluating the performance of CAI-enhanced SGDs, focusing on the requirements necessary for these devices to support fluent, interactive conversations between augmented speakers and their communication partners. Adopting an interaction-focused perspective is essential for advancing CAI in ways that genuinely enhance the conversational experiences of SGD users.

Our initial evaluation of DEAN demonstrated that CAI failed in several ways to achieve even the minimum performance levels needed to sustain non-problematic interactions. The latency analysis depicted significant response delays related to ASR and NLM processing, which move the augmented speaker's responses beyond the conventional temporal boundaries of conversational interaction.

In addition, both of Todd's evaluations portray undesirable levels of acceptability related to the content generated by DEAN's fine-tuned language model. Although trained on a considerable amount of text, the model failed to respond to Todd's life appropriately and in his preferred communication style. It also offered redundant selections (e.g., duplicated utterances) and hallucinations (e.g., incorrect utterances). It's hard to imagine using a CAI-enhanced system that performs this way.

As CAI-enhanced SGDs emerge in the commercial market, it is crucial to move beyond the initial novelty of interacting with such SGDs and focus on their ability to maintain conversational time with an AS. We should be mindful of past practices where technological innovations were prematurely labeled as solutions to existing communication challenges, such as word prediction, which was touted as a rate-enhancement technique but later discovered to have the opposite impact (Koester & Levine, 1994, 1996). Where do the solutions lie? There are several approaches we can take to address the current challenges. Utilizing more powerful systems could achieve faster response times associated with ASR and NLMs. Integrating both of these directly into SGDs has the potential to enhance response times significantly. However, it remains uncertain whether investing in more advanced technologies will allow augmented speakers to communicate within the temporal constraints of typical conversational interaction, specifically within Now-Time and Near-Time boundaries.

In our current prototype, DEAN was only responsive to the communication produced by the partner. In our next iteration, we plan to integrate CAI into the AS's message composition process, allowing the AS to guide the CAI by typing an initial phrase or keyword and selecting prompts (e.g., tone of voice, communication act) to generate more appropriate and effective utterances.

Our research highlights critical limitations in integrating personal content into CAI for SGDs. Fine-tuning our NLM using Todd's book proved to be both effortful and time-consuming, and given that most SGD users lack access to extensive amounts of personalized text, this approach is impractical. Even with fine-tuning, the NLM did not meet our performance expectations. A fundamental issue lies in CAI's inability to receive, store, and integrate personal information—such as an individual's life details, conversational histories, or data from journals, text messages, and emails—into an SGD's knowledge base. Moreover, fine-tuning, regardless of its potential benefits, demands more data than most users can provide and remains too complex and time-intensive for practical SGD use. One possible solution involves processing smaller amounts of text as prompts, which could be applied globally during interactions or selected to achieve specific conversational goals. We have recently explored alternative methods for integrating personal information into CAI, such as Retrieval-Augmented Generation (RAG), which shows promise in addressing these challenges. However, further research and development are needed to fully evaluate its potential (Graves, 2024; Higginbotham et al., 2025).

Declarations

This content is solely the responsibility of the author(s) and does not necessarily represent the official views of ATIA. This work was supported by the Engelke Family Foundation and the National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR grant number 90DPCP0007).

References

Chung, H. W., Hou, L., Longpre, S., Zoph, B., Tay, Y., Fedus, W., Li, E., Wang, X., Dehghani, M., Brahma, S., Webson, A., Gu, S. S., Dai, Z., Suzgun, M., Chen, X., Chowdhery, A., Narang, S., Mishra, G., Yu, A,…Wei, J. (2022). Scaling instruction-finetuned language models. *arXiv*. https://doi.org/10.48550/arxiv.2210.11416

Clark, H. (1996). *Using Language*. Cambridge University Press.

Clark, H., & Brennan, S. E. (1991). Grounding in communication. In L. G. Resnick, J. M. Levine, & S. D. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 127–149). American Psychological Association. https://doi.org/10.1037/10096-006

Communication First. (2024). AAC Research Summit: *13 AAC Users: Priorities for Future Research* [Video]. YouTube. https://youtu.be/abT7pnqeEHQ?si=p3TV-uzmB8Zv-oC8

Dediu, D., & Levinson, S. C. (2013). On the antiquity of language: The reinterpretation of Neandertal linguistic capacities and its consequences. *Frontiers in Psychology*, 4. https://doi.org/10.3389/fpsyg.2013.00397

Deepgram. (2023). *Nova*: *The speech-to-text model.* https://deepgram.com/

Enfield, N. (2013). *Relationship thinking: Agency, enchrony, and human sociality*. Oxford University Press.

Enfield, N. J. (2014). *Natural causes of language: Frames, biases and cultural transmission*. *Conceptual foundations of language science 1*. Language Science Press.

Fried-Oken, M., Kinsella, M., Stevens, I., & Klein, E. (2023). What stakeholders with neurodegenerative conditions value about speed and accuracy in development of BCI systems for communication. *Brain-Computer Interfaces*, *11*(1–2), 21–32. https://doi.org/10.1080/2326263X.2023.2283345

Graves, B. (2024). *RAG-enhanced conversational AI: A comprehensive guide*. Forum One. https://www.forumone.com/insights/blog/rag-enhanced-conversational-ai-a-comprehensive-guide/

Grice, H. P. (1975). Logic and conversation. In *Syntax and Semantics*. Brill. https://doi.org/10.1163/9789004368811_003

Hackbarth, K. R. (2024). Revolutionizing augmentative and alternative communication with generative artificial intelligence. *Assistive Technology Outcomes & Benefits* (ATOB), *18, 100 – 123. https://www.atia.org/wp-content/uploads/2024/04/ATOB_V18_FINAL-1.pdf*

Higginbotham, J., Fulcher-Rood, K., & Seale, J. (2016). Time and timing in ALS in interactions involving individuals with ALS, their unimpaired partners and their speech generating devices. In M. Smith & J. Murry (Eds.), *The silent partner?: Language, interaction and aided communication* (pp. 201–229). J&R Publishers.

Higginbotham, J., Golleru, M., & Hutchinson, T. (2025, January 30-February 1). *Conversational artificial intelligence: Promises and current realities* [Paper presentation]. Assistive Technology Industry Association, Orlando.

Hutchinson, T. (2024). *My fateful dreams book one*. Self-published.

Koester, H. H., & Levine, S. (1996). Effect of a word prediction feature on user performance. *Augmentative and Alternative Communication*, *12*(3), 155–168. https://doi.org/10.1080/07434619612331277608

Koester, H. H., & Levine, S. P. (1994). Modeling the speed of text entry with a word prediction interface. *IEEE Transactions on Rehabilitation Engineering, 2*(3), 177–187. https://doi.org/10.1109/86.331567

Koroschetz, J., Possemato, F., & Higginbotham, J. (n.d.). Composition delay involving augmentative communication technologies: Sequential misalignment and intersubjective loss. Manuscript, University at Buffalo

Levinson, S. C. (2016). Turn-taking in human communication—origins and implications for language processing. *Trends in Cognitive Sciences,* 20(1), 6–14. https://doi.org/10.1016/j.tics.2015.10.010

Microsoft. (2024). *Neural Speech (Azure Text-to-Speech)*. https://azure.microsoft.com/services/cognitive-services/text-to-speech/

OpenAI. (2023, March 31). *ChatGPT*. https://chat.openai.com

Pal, S., Das, S., Srihari, R. K., Higginbotham, J., & Bizovi, J. (2024). Empowering AAC users: A systematic integration of personal narratives with conversational AI. *Proceedings of the 1st Workshop on Customizable NLP: Progress and Challenges in Customizing NLP for a Domain, Application, Group, or Individual (CustomNLP4U),* 12–25. https://doi.org/10.18653/v1/2024.customnlp4u-1.2

Project Open Design Community. (2020). *OS-DPI*. https://github.com/UNC-Project-Open-AAC/OS-DPI/wiki

Rayman, A. S., Satchidanand, A., & Higginbotham, J. (2023). Simulation of other-initiated repair using AAC. *Augmentative and Alternative Communication*, *40*(2), 115–124. https://doi.org/10.1080/07434618.2023.2271563

Schegloff, E., & Sacks, H. (1973). Opening up closings. *Semiotica*, *8*(4), 289–327. https://doi.org/10.1515/semi.1973.8.4.289

Schegloff, E. A. (1979). The relevance of repair to syntax-for-conversation. In *Syntax and Semantics*. Brill. https://doi.org/10.1163/9789004368897_012

Seale, J. M., Bisantz, A. M., & Higginbotham, J. (2020). Interaction symmetry: Assessing augmented speaker and oral speaker performances across four tasks. *Augmentative and Alternative Communication*, *36*(2), 82–94. https://doi.org/10.1080/07434618.2020.1782987

Stivers, T., & Robinson, J. D. (2006). A preference for progressivity in interaction. *Language in Society*, *35*(3), 367–392. https://doi.org/10.1017/S0047404506060179

Valencia, S., Cave, R., Kallarackal, K., Seaver, K., Terry, M., & Kane, S. K. (2023). "The less I type, the better": How AI language models can enhance or impede communication for AAC users. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (CHI '23),* 1–14). Association for Computing Machinery. https://doi.org/10.1145/3544548.3581560

Waller, A. (2006). Communication access to conversational narrative. *Topics in Language Disorders, 26*(3), 221–239. https://doi.org/10.1097/00011363-200607000-00006

Waller, A. (2019). Telling tales: Unlocking the potential of AAC technologies. *International Journal of Language & Communication Disorders, 54*(2), 159–169. https://doi.org/10.1111/1460-6984.12449

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Voices from Academia

Increasing Water Access for Individuals Living with Spinal Cord Injury Using an Innovative Smart Faucet

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Abstract

This project aimed to assess the functionality of an innovative fountain faucet, called the Access-H2O™ faucet, to enable and empower individuals living with spinal cord injury (SCI) to gain water access independently for activities of daily living (ADLs). The faucet integrates electromechanical controls, software programs, and remote sensors to control the water arch stream. Eighteen SCI subjects were recruited to test the faucet's functionality by using eye gaze, voice, and motion sensors to activate fountain mode, washing mode, and grooming mode for three ADLs: drinking, rinsing, and grooming. The SCI subjects achieved an average success rate of 100% in activating the three types of sensors for the three faucet modes. They achieved 100% success rates for drinking and rinsing, and 88.9% for grooming using the eye-gaze sensor. Using the voice sensor, they achieved a 100% success rate across all three ADLs. With the motion sensor, they achieved a 94.4% success rate for all three ADLs. The average System Usability Scale score reported by SCI subjects was 85 for voice, motion, and eye-gaze, indicating excellent usability of the faucet. This study provided preliminary insight into the potential for this innovative faucet to empower independent drinking, rinsing, and grooming in individuals living with SCI.

Keywords: activities of daily living, assistive technology, spinal cord injury

Increasing Water Access for Individuals Living with Spinal Cord Injury Using an Innovative Smart Faucet

Spinal cord injury (SCI) affects more than 300,000 individuals in the U.S., with 18,000 new cases annually (World Health Organization, 2024). SCI affects the somatic and autonomic nervous systems, often resulting in motor paralysis and sensory impairment below the level of the SCI. Injuries in the cervical region often result in paralysis of the arms, trunk, legs, and organs. In contrast, lower-level injuries in thoracic or lumber regions typically lead to paralysis of the trunk, legs, and organs. Occupational therapists help patients learn skills and assistive strategies to increase independence with activities of daily living (ADL), such as eating, drinking, grooming, functional bathing, dressing, and toileting. Patients with low-level cervical SCI may be able to gain independence in many ADLs; however, patients with higher-level injuries require assistance with personal care and special devices or environmental controls to complete ADLs (Goosey-Tolfrey et al., 2016).

Accessing water can be difficult for individuals with SCI due to limitations in mobility. That can make self-care tasks like drinking water and grooming challenging or impossible, particularly for those high-level injuries affecting hand function (Hetz et al., 2009). That could lead to inadequate hydration, which could be associated with other health issues, such as kidney issues, constipation, or the occurrence of urinary tract or bladder infections (Han et al., 2013).

Conventional bathroom faucets typically feature hot and cold-water knobs to control water flow, commonly used for hand washing, face washing, and rinsing after brushing teeth. However, individuals with SCI face significant challenges accessing water from traditional faucets due to limited hand and upper trunk mobility. While some sensor-based or touch-activated faucets on the market allow users to turn the water on and off, adjust temperatures, and control flow rates, they do not provide the appropriate water flow and trajectory from the spout for individuals with SCI. These faucets still require users to bend over, making them impractical for individuals with physical limitations. As a result, these faucets are inadequate or limited to support the needs of individuals with SCI in performing ADL.

This study aimed to evaluate the functionality of the Access-H2O™ faucet, an innovative personal assistive device, developed by Nasoni Inc. Designed to support independent drinking and grooming for individuals with upper body limitations, such as those with SCI, the faucet builds on Nasoni Inc.'s original fountain-style design, inspired by the historic fountains of Rome, Italy. This unique feature allows users to access water more easily without bending their heads. Recognizing its potential to enhance independence for individuals with SCI, the company later integrated advanced smart sensors, transforming the faucet into a fully accessible smart bathroom fixture, now patented as the Access-H2O™ faucet.

Target Audience and Relevance

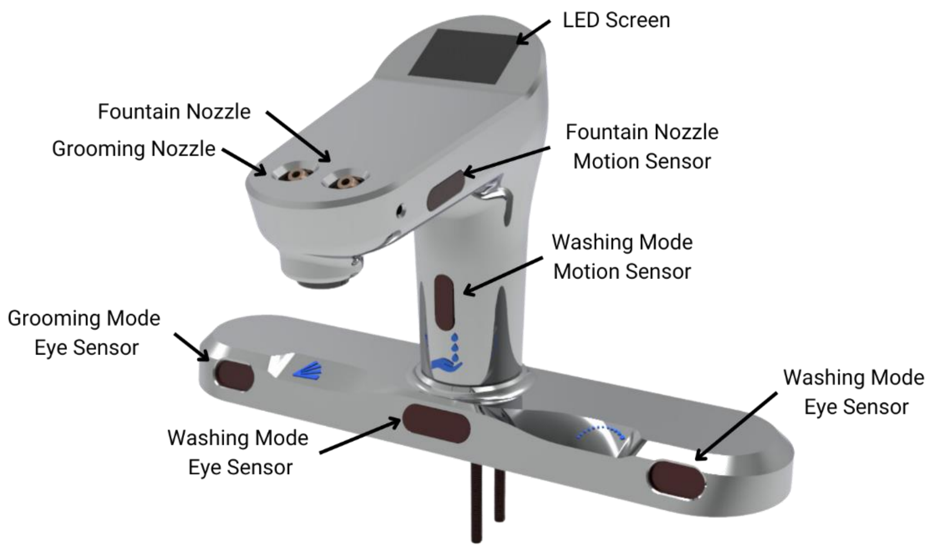
The target audience includes professionals in physical therapy, occupational therapy, health sciences, medicine, biomedicine, public health, and biophysics. The study has valuable and practical relevance in healthcare and public health. First, the Access-H2O™ faucet could enhance the quality of life for individuals living with SCI. Second, this faucet can empower individuals to access water for some ADLs with greater independence. Third, the faucet could reduce the burden on caregivers. Fifth, this faucet may help lower medical costs by preventing dehydration and associated health complications.

Methods

Access-H2O™ Faucet

The Access-H2O™ faucet includes the Nasoni dynamic fountain flow technology and the latest sensor technology, allowing individuals living with SCI to access water using multiple hands-free methods (Figure 1). The dynamic fountain flow technology allows the faucet to switch seamlessly between a traditional downward water flow and an upward fountain mode. A lever at the end of the spout is used to rotate a ceramic disc valve which stops the downward flow and re-routes the flow to an upper chamber, through a pressure-compensating flow regulator and secondary aerator (Figure 2) that generated water outputs different from those of traditional faucets.

Figure 1: *Access-H2O Faucet Prototype*

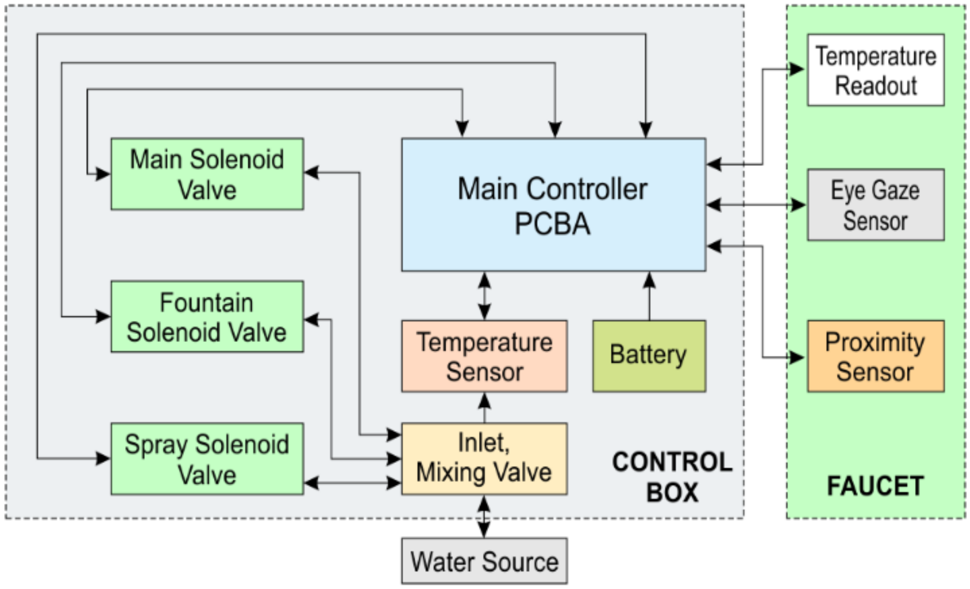


This system includes a control box with all electromechanical controls inside to regulate water temperature, faucet flow, spray patterns, spray angles, and operating pressures (Figure 3). At the base of the front, the faucet body incorporates a proximity sensor with a voice recognition function that can precisely dispense water at the desired temperature and volume and allow hands-free operation (Figure 1). Water temperature is controlled by an electromechanical mixing valve, which operates a plunger the same way a mechanical valve does. An electrical actuator is used to move the plunger, and a semiconductor temperature sensor in the outflow is used to measure the water temperature and balance the flow with a microcontroller. Cold and hot water supply lines connect to the control box, where they attach to the mixing valve. Inside the control box, the mixing valve combines the hot and cold water to achieve the desired temperature. The pre-mixed water is then directed to three solenoid valves, each controlling one of the three water outlets: fountain mode, washing mode, and grooming mode. When a user selects a mode, the corresponding solenoid valve opens, allowing water to flow to the designated outlet while keeping the others closed, ensuring precise temperature control and efficient water distribution.

Figure 2: *The Fountain Mode of Access-H2O™ Faucet Prototype*

The Access-H2O™ faucet was built on a robust software platform, designed to integrate seamlessly with three sensor controls—eye-gaze, motion, and voice control—accommodating diverse user needs (Figure 3). It features three distinct modes: fountain mode, which provides an upward fountain flow for drinking; washing mode, which delivers a traditional downward flow for hand washing and other cleaning tasks; and grooming mode, which utilizes a spray pattern for rinsing the face.

Figure 3: *Integration of The Access H2O™ Electromechanical Flow Control System With the Faucet Sensors and Temperature Readout*



For motion control, time-of-flight sensors enable users to activate washing mode by waving or placing a hand near the proximity-based motion sensor and then switch to fountain mode by waving again. Additionally, these sensors allow users to adjust water temperature. The software translates sensor data into actions based on three defined detection zones—hot, warm, and cold—determined by the proximity of the user's hand to the faucet. During setup, users can configure these distances to map specific ranges for hot, warm, or cold water. For example, placing a hand closest to the sensor activates hot water, while the farthest position activates cold water.

For eye-gaze control, the faucet was integrated with Tobii eye-tracking technology, combining both hardware and software. To maintain a compact design without making the faucet excessively wide, we engineered a removable escutcheon to house the eye-tracking sensors. This removable feature ensures versatility, allowing the smart faucet to be installed in both one-hole and three-hole sink configurations. The system enables users to activate and deactivate water flow by staring at specific sensor locations for a set duration. The sensor locations correspond to three faucet modes. A user can stare or hand wave at the right sensor to activate the fountain mode for fountain flow for drinking, the center sensor for washing mode, and the left sensor for grooming mode. The selected mode remains active until the user looks at the same sensor again to turn it off. To prevent accidental activations, the software measures fixation duration and incorporates error-handling protocols to account for distractions or environmental factors.

For voice control, users can activate three faucet modes through spoken commands. With Alexa or Google Assistant, they can turn the faucet on or off by saying, "*Alexa, turn on washing mode*." Additionally, users can select specific functions, such as "*Alexa, activate fountain mode*" to enable the fountain feature. To control flow duration, users can issue commands like "*Alexa, run water for 10 seconds*."

During setup, the system allowed for manual adjustments to the faucet's functions. Also, the system was designed to enable the faucet to automatically detect and adjust sensor sensitivity and dynamically adapt flow angles to ensure water reaches the user effectively. Furthermore, the system includes a diagnostic tool that reports the status of each time-of-flight sensor, allowing for real-time monitoring and troubleshooting.

Subject Recruitment and Selection

Subjects. A total of 18 subjects living with SCI (C2-C6), called SCI subjects, and 10 control subjects were recruited in an outpatient rehabilitation clinic. Controls without limitations in head, trunk, and arm movement were used to verify that all faucet functions operated correctly, and that water was accessible for drinking, rinsing, and grooming. This preliminary assessment by the controls was conducted after installing the Access-H2O™ faucet in the rehabilitation clinic and before SCI subjects' participation.

Before conducting this study, the investigators obtained approval from their university's Institutional Review Board. Informed consent was also obtained from each participant and control subject before data collection. A physical therapist reviewed medical records and screened individuals living with SCI to determine if they met the inclusion criteria for this study. Individuals with a SCI above C7, and the ability to swallow water safely, follow one-step verbal directions, move their eyes up, down, right, and left to activate the eye-gaze sensors, and move their heads up, down, right, and left to access the water stream, were recruited for the study. Individuals with cognitive deficits, serious mental health, or medical conditions that could compromise subject safety or accurate user feedback were excluded. Eighteen individuals living with SCI met the study criteria and volunteered to participate in the study.

Procedure

The study's procedures included interview on the use of current faucet methods for drinking, rinsing, and grooming, and feasibility testing on Access-H2O™ faucet. The feasibility testing served the purpose of 1) demonstrating that the device concept is viable for further development, 2) indicating how effective the device might be in meeting the needs of SCI subjects' performance of ADLs, and 3) informing the design and development process before commercialization. Both the interview and the feasibility study were conducted at the outpatient rehabilitation clinic.

Interview

The SCI subjects were interviewed by a physical therapist about the use of their current bathroom faucet to determine what their level of assistance was for drinking, rinsing, and grooming. Based on the participant's explanation of each activity, the physical therapist rated the participants' four levels of assistance: independent, modified independent, assistance needed, or dependent. The independent level is defined as an individual completing the tasks without needing physical assistance, additional time, or type of assistive device; the modified independent level as an individual completing the tasks without physical assistance, but requiring more than the typical amount of time, or needing an adaptive/assistive device (brace, splint, extended lever, etc.); the assistance needed level is defined as an individual needing physical assistance, but he or she can participate in completing the drinking, rinsing, and grooming tasks; the dependent is defined as an individual not being able to complete the tasks and a caregiver must do everything.

Feasibility Testing

Prior to the SCI subjects test the feasibility of the Access-H2O™ faucet, 10 controls tested the faucet's eye-gaze, voice, and motion sensors. They consistently showed that Access-H2O™ faucet was functioning properly. They could activate all the faucet sensors for fountain mode, washing mode, and grooming mode, and achieved a 100% success rate in drinking, rinsing, and grooming

The feasibility testing was conducted to test the faucet's eye-gaze, voice, and motion sensors for SCI subjects' ADLs: drinking, rinsing, and grooming. All SCI subjects who relied on wheelchairs were seated in their own manual or power wheelchairs. The wheelchairs were positioned in front of a sink equipped with the Access-H2O™ faucet. Sufficient space was provided to accommodate the subjects' legs under the sink. Then, the same physical therapist who conducted the interview provided scripted instructions to each participant on how to turn on the faucet for the faucet modes and then turn off the faucet. During setup, the system was tested and calibrated to ensure proper operation. If any function did not meet the standard, manual adjustments were made as needed. (For example, during setup, flow and spray angles for fountain mode and grooming mode can be customized by adjusting valve angles or water pressure to achieve the preferred water flow trajectory.)

Once the system was ready, each SCI subject was asked to place his or her hand by the motion sensor (motion control), use a speech speaker (voice control), and move their eyes up, down, left, and right to activate the eye-gaze sensor (eye-gaze control) to activate water output modes for drinking, rinsing, and grooming. For example, to test eye-gaze control, a subject looked at the right side of the eye-gaze sensor to activate fountain mode for drinking and looked at the left side of the sensor to activate grooming mode for spray pattern flow to wash a quarter-sized area of soap from the left or right cheek. For each ADL activity (drinking, rinsing, and grooming), the physical therapist rated and recorded their levels of assistance as 1) independent, 2) modified independent, 3) assistance required, or 4) dependent. Each participant performed the same activity (drinking, rinsing, or grooming) and sensor controls (voice, motion, or eye-gaze) three times. For example, a subject used the voice control to activate fountain mode for drinking and repeated the procedure three times. The total of tests for a subject was 27 (3 sensors x 3 modes x 3 repetitions).

We sought answers to the following questions: 1) Can the test participants get the water from the fountain mode to their mouth to drink/hydrate? 2) Can the test participants use the fountain mode to rinse their mouths? and 3) Can the test participants use the fountain spray to rinse a quarter-sized area of soap partially or fully from their left or right cheek? The physical therapist evaluated whether they were fully successful, partially successful, or unable to complete each drinking, rinsing, and grooming activity. The investigators also recorded the time it took for each subject to complete each activity.

After completing the feasibility testing procedures, each SCI subject completed the System Usability Scale (SUS) to help the investigators gain a better understanding of users' perceptions of the Access-H2O™ faucet's effectiveness, efficiency, and ease of use (Bangor et al., 2008). The detailed procedures for determining a SUS score are described in Bangor et al. (2008). Briefly, each subject rated 10 survey questions on a scale from "strongly agree" to "strongly disagree." Each response was converted to a numerical value from 1 to 5, and the SUS score was calculated using the formula (X+Y) x 2.5, where X = Sum of the points for all odd-numbered questions -5, and Y = 25 - Sum of the points for all even-numbered questions. SUS scores are interpreted based on their potential range (0–100). Higher scores indicate better usability, with scores above 68 generally considered above average or good, scores above 85 considered excellent, and scores over 90 regarded as the best imaginable (Bangor et al, 2008; Bangor et al., 2009).

Statistical Analysis

The means and standard deviations of three times on the testing variables-assistance level, completion of the activity, and time required for activity completion on three faucet modes were calculated. The feasibility testing commonly doesn't require a full statistical power analysis since it primarily focuses on gathering preliminary data used to further enhance the faucet's functionality before commercialization and does not aim to draw definitive statistical conclusions.

Results

Subjects

Table 1 summarizes the demographics and physical complexity of SCI subjects. The distribution of SCI subjects' complexities spans the four degrees of functional limitations—no limitations, low complexity, medium complexity, and high complexity—based on head, neck, trunk, or upper limb movements, as described in Table 1.

Table 1: *Demographics and Physical Complexity of Subjects*

	SCI Subjects *N* = 18
Race (%)	
Caucasian	15 (83%)
African American	3 (17%)
Hispanic and Latino Americans	0
Asian	0
Gender (%)	
Female	1 (6%)
Male	17 (94%)
Age (%)	
18-30	3 (17%)
31-50	7 (39%)
51-80	7 (39%)
>80	1 (5%)
Complexity (%)*	
No limitations	4 (22%)
Low	6 (33%)
Medium	4 (22%)
High	4 (22%)

Access-H2O™ Faucet Feasibility Testing

Table 2 tabulates the outcomes on SCI subjects using the Access-H2O™ faucet for drinking, rinsing, and grooming. The subjects successfully activated three sensors for the fountain mode, washing mode and grooming mode. When using the voice sensor, they achieved an average success rate of 100% for drinking, rinsing, and grooming. When using the eye-gaze sensor, they achieved an average success rate of 100% for drinking and rinsing and an average success rate of 88.9% for grooming. When using the motion sensor, subjects with SCI achieved an average success rate of 94.4% across the three ADLs: drinking, rinsing, and grooming. A subject was unable to extend either hand or arm within the required proximity to activate the sensor, preventing them from performing these activities.

Table 2: *SCI Subjects Using Access-H2O™ Faucet for Drinking, Rinsing, and Grooming*

Activation Sensor	ADL activity	Performance Outcome	Subject %	Time for Completion (sec) Mean ± *SD*
Eye-Gaze	Drinking	Successful	18 (100%)	14.0 ± 4.32
		Partially successful	0	
		Not completed	0	
	Rinsing	Successful	18 (100%)	13.6 ± 3.62
		Partially successful	0	
		Not completed	0	
	Grooming	Successful	16 (88.9%)	20.6 ± 4.90
		Partially successful	0	
		Not completed	2 (11.1%)	
Voice	Drinking	Successful	18 (100%)	20.4 ± 5.26
		Partially successful	0	
		Not completed	0	
	Rinsing	Successful	18 (100%)	18.9 ± 3.15
		Partially successful	0	
		Not completed	0	
	Grooming	Successful	18 (100%)	28.6 ± 5.42
		Partially successful	0	
		Not completed	0	
Motion	Drinking	Successful	17 (94.4%)	12.3 ± 5.34
		Partially successful	0	
		Not completed	1 (5.6%)	
	Rinsing	Successful	17 (94.4%)	10.9 ± 3.93
		Partially successful	0	
		Not completed	1 (5.6%)	
	Grooming	Successful	17 (94.4%)	11.3 ± 2.84
		Partially successful	0	
		Not completed	1 (5.6%)	

Successful = completion of all tasks (turned the faucet on, completed the task, and turn off the faucet)

The SCI subjects rated the Access-H2O™ faucet with an average SUS score of 85 (*SD* = 8.3), indicating excellent usability. This represents a significant improvement from the SUS score of 57 (*SD* = 4.6) given to traditional faucets.

Self-Reported Levels of Independence for Drinking, Rinsing, and Grooming

When using the Access H2O™ faucet, SCI subjects demonstrated 100% independence on both drinking and rinsing tasks (Table 3). Additionally, SCI subjects demonstrated 91.3% independence on grooming activity, while 8.7% of SCI subjects required some assistance in washing their faces. When comparing the levels of assistance needed between the use of a traditional faucet and the Access-H2O™ faucet, SCI subjects reported elevated independence for drinking, rinsing, and grooming activities when using the Access-H2O™ faucet compared to their traditional faucets. Noticeably, SCI subjects reported 100% independence without assistance for drinking and rinsing.

Table 3: *Level of Assistance Using Traditional Bathroom Faucet and Access-H2O™ Faucet for Drinking, Rinsing, and Grooming*

ADL Activity	Assistance Level	Traditional Bathroom Faucet %	Access-H2O™ Faucet %
Drinking	Independent	25	100
	Modified independent	50	0
	Assistance Required	25	0
	Dependent	0	0
Rinsing	Independent	25	100
	Modified independent	50	0
	Assistance Required	16.7	0
	Dependent	8.3	0
Grooming	Independent	25	91.3
	Modified independent	50	0
	Assistance Required	8.3	0
	Dependent	16.7	8.7

Outcomes and Benefits

Throughout the study, participants made several spontaneous comments regarding their satisfaction with the faucet such as 1) “The urge to be independent was very strong after I was paralyzed. This faucet would have given me more peace of mind if I had it when I couldn’t use my arms or hands.” 2) “This is better than the way I do it at home because I can do it myself.” 3) “It’s nice and sanitary.” 4) “It was easy to use.” 5) “It gives me more independence.” 6) “I liked the hands-free features in general, even though I can use my arms.” 7) “This faucet would make it easier for me to wash my face without taking a shower.”

Overall, subjects living with SCI had a positive experience in using the innovative faucet as 100% of the participants could independently operate at least two of the three sensors (eye-gaze, voice, or motion) without assistance from caregivers. The Access-H2O™ faucet could benefit SCI subjects by improving their independence in accessing and using water for ADL that are typically performed at bathroom sinks.

Discussion/Conclusion

As most individuals with SCI live outside specialized care facilities, fostering independence while reducing caregiver burden is essential. Due to the wide variability in remaining innervation and levels of independence among individuals with SCI, personalizing strategies and obtaining assistive devices for their ADL present unique challenges. Currently, few—if any—assistive devices are available to enhance water access for individuals with SCI.

SCI subjects in the study consistently reported that traditional faucets, even those compliant with the Americans with Disabilities Act, posed challenges for performing ADLs. Many users expressed difficulty reaching the knobs or levers, adjusting water flow and temperature, and/or accessing water altogether for ADL. Compared to existing faucets, the Access-H2O™ faucet substantially improved usability and water accessibility. This faucet also enhanced subjects’ independence in water access for drinking, rinsing, and grooming, offering substantial improvement over traditional faucets.

The SUS score assessment demonstrates the excellent usability of the Access-H2O™ faucet, indicating that SCI subjects found it highly usable, easy to operate, and widely acceptable, with minimal usability concerns. The time required to complete the three ADLs further supported that the faucet was user-friendly and easy to operate. The feasibility testing results align with the outcome of the SUS assessment.

The Access-H2O™ faucet has several innovative features that benefit SCI subjects’ water access for ADL. This faucet utilizes specialized sensors to detect and activate different modes for ADLs, triggering the appropriate spray functions. Most notably, it represents a significant breakthrough in bathroom fixtures by integrating multiple sensors for a fully touch-free operation, enhancing accessibility. For example, pushing the boundaries of inclusivity, the Access H2O™ faucet has successfully integrated Alexa or Google voice command functionality. This feature affords hands-free operation, significantly broadening its accessibility, and making it an ideal solution for those with mobility issues or disabilities. Additionally, the faucet’s water flow angle and trajectory are designed to accommodate upper body, trunk, and arm limitations, improving water access. Most importantly, these features can be customized to create a personalized user experience. The overall improvement for individuals with SCI in performing personal daily activities may contribute to planning their rehabilitation and managing their long-term care.

While the Access-H2O™ faucet is a substantial improvement from traditional faucets, there are opportunities for further enhancements. During this study, we identified the need to 1) improve the Alexa voice integration to enhance the voice command capabilities, and 2) augment auditory feedback to inform users that a specific mode has been activated. Moreover, plans include incorporating a larger screen to improve the visibility and legibility of the digital readout, which would significantly enhance user interaction with the smart faucet. These proposed improvements aim to provide a more comfortable, eco-friendly, and efficient living environment, reinforcing the smart faucet's commitment to inclusive and sustainable design. Finally, the eye-gaze feature was particularly beneficial for SCI subjects with limited mobility or dexterity. Our feasibility testing showed that the eye-gaze mode was functional, and the SCI subjects could activate the innovative faucet and use it for ADL. At the same time, the study results also showed primary issues associated with the feature. First, the inclusion of a camera-based gaze system raised concerns about privacy and HIPAA compliance, particularly in a bathroom setting. Second, the integration of the eye-gaze technology significantly increased the overall cost of the faucet. This added expense made it impractical for widespread adoption, especially when compared to alternative control methods like smart motion sensors and voice commands. These insights have been instrumental in refining our future design approach to focus on practical, user-centered, and cost-efficient solutions that maintain user trust and privacy. The major limitation of this study was the small sample size which limits the generalizability of the results. Therefore, further research is needed to determine functionality with a larger sample and more diverse population.

The feasibility testing of the faucet didn't include a cost analysis. The final cost of the faucet would depend on further development, manufacturing optimization, and potential funding or reimbursement pathways. To ensure that the faucet remains accessible, several payment approaches have been explored, for example, Flexible Spending Account and Health Savings Account eligibility; Partnerships with VA hospitals, healthcare providers, and disability organizations; and user willingness to pay. The NIH I-Corps customer discovery program showed that a faucet enabling them to drink or groom independently would be life-changing, and users are willing to pay more for assistive technology if it helps them regain independence.

Declarations

This content is solely the responsibility of the author(s) and does not necessarily represent the official views of ATIA. No financial disclosures and no non-financial disclosures were reported by the author(s) of this paper.

References

Bangor, A., Kortum, P. T., & Miller, J. T. (2008). An empirical evaluation of the system usability scale. *International Journal of Human-Computer Interaction*, *24*(6), 574–594. https://doi.org/10.1080/10447310802205776

Banger, A., Kortum, P., Miller, J. (2009). Determining what individual SUS scores mean: Adding an adjective rating scale. *Journal of Usability Studies*, *4*(3), 114-123. https://uxpajournal.org/determining-what-individual-sus-scores-mean-adding-an-adjective-rating-scale/

Goosey-Tolfrey, V., Paulson, T., & Graham-Paulson, T. (2016). Practical considerations for fluid replacement for athletes with a spinal cord injury. *Fluid Balance, Hydration, and Athletic Performance,* 1st edition*,* CRC Press

Han, Z. A., Choi, J. Y., & Ko, Y. J. (2013). Dermatological problems following spinal cord injury in Korean patients. *The Journal of Spinal Cord Medicine*, *38*(1), 63–67. https://doi.org/10.1179/2045772313y.0000000154

Hetz, S. P., Latimer, A. E., & Martin Ginis, K. A. (2009). Activities of daily living performed by individuals with SCI: relationships with physical fitness and leisure time physical activity. *Spinal Cord, 47*(7), 550–554. https://doi.org/10.1038/sc.2008.160

Noreau, L., Noonan, V., Cobb, J., Leblond, J., & Dumont, F. (2014). Spinal cord injury community survey: A national, comprehensive study to portray the lives of Canadians with spinal cord injury. *Topics in Spinal Cord Injury Rehabilitation*, *20*(4), 249–264. https://doi.org/10.1310/sci2004-249

Wang, Y., Arora, C., Liu, X., Hoang, T., Malhotra, V., Cheng, B., & Grundy, J. (2024). Who uses personas in requirements engineering: The practitioners' perspective. *Information and Software Technology*, *178*, 107609. https://doi.org/10.1016/j.infsof.2024.107609

World Health Organization. (2024). *Spinal cord injury key facts*. https://www.who.int/news-room/fact-sheets/detail/spinal-cord-injury

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Voices from Academia

Assistive Technology Innovations: Perceptions, Adoption, and Desires

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Abstract

Assistive technology (AT) innovations for people who are blind or have low vision are occurring at a rapid pace, yet we know little about what this population thinks or knows about these innovations. This paper presents the results of a survey study with 329 employed people who are blind or have low vision regarding their perceptions about, adoption of, and desires for AT innovations. We found that many people were not aware of any recent technology advancements. A very small percentage of the participants adopted novel AT, as defined in the survey, during the 2-year period of the study, and only about one-third of the participants expressed an interest in adopting a novel AT. Key barriers to adopting new or novel AT were the high cost, the time required to learn the new technology, and the lack of training or support for learning and using the new technology.

Keywords: blind, low vision, assistive technology, adoption

Assistive Technology Innovations: Perceptions, Adoption, and Desires

There is much potential for new and emerging assistive technology (AT) to enhance independence for people who are blind or have low vision. There has been an explosion in assistive technology (AT) for this population in recent years (Bhowmick & Hazarika, 2017; Madake et al., 2023). This includes emerging technology, such as artificial intelligence (AI) and machine learning (ML), multi-line refreshable braille displays and tactile graphics, wayfinding technologies, and wearable technologies. However, research is needed to learn how people who are blind or have low vision perceive these innovative and novel technologies, their interest in adopting new technologies, and their desire for future technological advancements. The purpose of this study was to increase our knowledge about the lived experience of employed adults who are blind or have low vision with AT innovations, including their perceptions about, adoption of, and desires for these innovations.

Target Audience and Relevance

The target audiences for this paper are professionals who work with individuals who are blind or have low vision for AT-related assessments, training, and purchase requisitions, as well as manufacturers and vendors who develop accessible and assistive technologies for these same populations. The primary audience includes professionals who provide training, assessment, and purchasing decisions for AT, such as Certified Assistive Technology Instructional Specialists for Individuals with Visual Impairments (CATIS) and other AT instructors, Certified Vision Rehabilitation Therapists (CVRTs), Certified Low Vision Therapists (CLVTs), teachers of students who have visual impairments (TVIs), and Certified Rehabilitation Counselors (CRCs) and other professionals in vocational rehabilitation services. We believe this study's findings are relevant to all blindness-field professionals and manufacturers because they provide novel information about what employed people who are blind or have low vision perceive to be the best technology advancements, which new technologies they have adopted, their motivation for adopting new AT, and their interest in future AT innovations. This is especially pertinent to manufacturers and vendors as they continue to develop new and updated technologies. Additionally, it is relevant for CATIS, who must maintain knowledge within the core domain of exploration, which includes reviewing "…mainstream and AT hardware and software tools at every available opportunity…" (ACVREP, n.d.) to enable them to then teach these strategies.

Background

The increase in emerging technologies within the field of blindness and low vision has been apparent at recent AT conferences. More than half (25 of the 49) of the sessions in the Vision & Hearing Technologies Strand were labeled with the keyword "emerging technology" at the 2025 Assistive Technology Industry Association Conference (ATIA) (B. Williams, personal communication, February 11, 2025). Furthermore, at the 39th Annual California State University, Northridge (CSUN) Assistive Technology Conference in March 2024, 31.6% of the sessions (105 out of 332 sessions) included the topics of either "Artificial Intelligence & Machine Learning" or "Emerging Technologies" (CSUN 2024 sessions). This represents an increase of approximately 150% from CSUN 2022, when there were 42 sessions on these topics (CSUN 2022 sessions). Of the CSUN sessions on emerging technologies and AI/ML in 2024, one-third (35 sessions) included the topic of "Blind/Low Vision." This suggests an accelerating pace of AT innovation for those who are blind or have low vision in recent years.

Bhowmick and Hazarika (2017) determined that research and literature on AT for people who are blind or have visual impairments has been doubling every four years since the 1990s. They discussed some emerging technologies highlighted in research, such as mobile phones, wearable technologies, biomedical enhancements, and the capability to extract information from visual images. These researchers projected that the extraordinary growth in the field would continue. This study also documented that potential AT solutions for this population are being developed across many different professional disciplines. Since this publication, several other authors have conducted literature reviews on the topic of AT for people who are blind or have low vision.

Mashiata et al. (2022) conducted a literature review to explore the evolution of AT for people who are visually impaired and classified the types of AT into four primary categories (i.e., portability, navigation, detection, and smartphone assistance), then further divided them into sub-categories. Madake et al. (2023) reviewed 140 research articles from 1946 to 2022 that focused on orientation and mobility AT for people who are blind or have low vision. They evaluated the major types of mobility aids and provided a performance score for each major type. Muhsin et al. (2024) conducted a systematic review of 52 research articles and 18 literature reviews on AT for people with visual impairments published between 2018 to 2023. They determined that many technology advancements have not been developed in consultation with people with visual impairments, have poor usability or a high learning curve, and often focus on those with total blindness rather than those with partial sight.

Despite innovations and emerging technologies for people who are blind or have low vision, researchers have discussed the lack of adoption of innovative technologies, as well as themes relating to the adoption of new technologies. Through semi-structured interviews with 16 participants and a behavioral study that included 8 of those same participants, Turkstra et al. (2023) explored how blind adults use AT to perform instrumental activities of daily living and discovered that when participants could choose between low- or high-tech solutions, 75% chose a low-tech option. They reported that some participants would only use a digital aid if using their senses or tactile approaches did not work. Many demonstrated a preference for visual interpreting technologies, including those with integrated AI features (e.g., SeeingAI, Google Lookout); however, participants commented on issues with the accuracy of AI technologies. Barriers to the adoption of high-tech AT solutions identified by Turkstra et al. (2023) were a lack of awareness, including learning about newer technology; the amount of training and support needed to learn new AT; accessibility issues; and technical issues, including those related to compatibility with other technologies.

In a study of 20 older adults with visual impairments, Kim (2022) explored factors related to AT adoption, specifically the adoption of mobile apps. He reported the following themes: advance (whether the technology is better than other available technologies), compatibility (with participants' expectations, as well as with other technologies that they use), complexity (ease of use and need for training), observability of others who use the technology, and trialability. Comments within the "Trialability" theme indicated a desire for free and affordable technologies, as well as free trial versions. Similarly, participants in the Turkstra et al. (2023) study also discussed cost as a barrier to adopting new high-priced technologies.

While Turkstra et al. (2023) and Kim's (2022) studies provide valuable information about AT adoption and preferences, their conclusions are based on small samples. To increase our knowledge about blind and low vision adults' perceptions about, adoption of, and desires for AT innovations, we surveyed a large sample of employed adults living in the United States or Canada. This study was guided by the following research questions:

1. What do employed people who are blind or have low vision consider to be the best recent technology advancements?
2. What percentage of employed people who are blind or have low vision (a) have adopted new AT recently and (b) have adopted innovative AT?
3. What motivates people who are blind or have low vision to adopt a new AT?
4. What innovative AT are employed people who are blind or have low vision most interested in adopting and what factors influence whether they will adopt a novel AT?
5. What AT innovations do employed people who are blind or have low vision desire?

Method

Participants

Our sample consisted of 329 people who were participating in the National Research and Training Center on Blindness and Low Vision's longitudinal *AT in the Workplace Study*. This study was determined to be exempt from oversight by Mississippi State University's Institutional Review Board. Participants were recruited via a blindness participant research registry, invitations distributed by blindness organizations (e.g., National Federation of the Blind, American Council of the Blind, American Foundation for the Blind), and notifications posted in email lists and websites for people who are blind (e.g., Top Tech Tidbits, Blind Bargains) and joined the study in 2021 or 2022. All participants were blind or had low vision, were currently employed or had recently been employed, used AT for work, and resided in the U.S. (97.3%) or Canada (2.7%). Participants who resided in the U.S. came from 46 states. Demographic information about the participants is provided in Table 1. Surveys were completed either online (via Qualtrics) or by phone. We utilized participant responses from Survey 2 (conducted in 2022, N = 313) and Survey 3 (conducted in 2023, N = 246) for this study.

Table 1: *Participant Characteristics*

Characteristic	Survey 2 (*n*)	Survey 2 (%)	Survey 3 (*n*)	Survey 3 (%)
Gender				
Female	192	61.3	143	58.1
Male	121	38.7	103	41.9
Race				
American Indian or Alaska Native	1	0.3	1	0.4
Asian	18	5.8	11	4.5
Black or African American	16	5.1	13	5.3
Native Hawaiian or Other Pacific Islander	1	0.3	2	0.8
White	258	82.4	206	83.7
Other race or Mixed race	19	6.1	13	5.3
Hispanic Ethnicity				
Yes	25	8.0	20	8.1
No	288	92.0	226	91.9
Age Categories				
21-30	31	9.9	22	9.4
31-40	84	26.8	69	29.4
41-50	76	24.3	56	23.8
51-60	84	26.8	66	28.1
61 or older	38	12.1	22	9.4
Level of Vision				
Totally blind	190	60.7	143	60.9
Legally blind with minimal functional vision	65	20.8	50	21.3
Legally blind with some functional vision	47	15.0	33	14.0
Low vision, not legally blind	11	3.5	9	3.8
Vision Loss Onset				
Preschool	214	68.4	171	69.5
Kindergarten-12th grade	47	15.0	36	14.6
Post school	52	16.6	39	15.9
Highest Education Level				
Less than a Bachelor’s degree	56	17.9	45	18.3
Bachelor’s degree	118	37.7	89	37.9
Master’s degree	112	35.8	80	34.0
Professional or doctoral degree	27	8.6	21	8.9
Additional disability				
Yes	112	35.8	90	36.6
No	201	64.2	156	63.4

Note: Survey 2 *N*=313; Survey 3 *N*=246.

Variables

Data included multiple-choice and open-ended responses to the survey questions. *Best AT advancements* were determined by participant responses to the Survey 3 question "What is the best new technology advancement in the past year or two? This could be a new feature added to an existing product or a new AT." To determine *adoption of new AT*, we utilized responses to the question, included in both Survey 2 and 3, "Have you adopted any new AT since you completed the last survey in [month] of [year]?" with the participants' date of last survey completion included. Participants who answered yes specified what AT they had adopted, and they had the ability to report on up to three new AT adopted during the time frame. To determine *motivation for AT adoption*, we asked the participants who had adopted new AT to select from a list of eight options (e.g., Features of the AT appealed to me, Ease of use/convenience) as to their reason for adopting the AT ("What made you decide to begin using this AT?"). The eight multiple-choice options were developed based on participants' responses to an open-ended version of the same item in Survey 1. Once they selected all reasons that applied, they were asked to select the one reason that they considered their primary, or most important, reason for adopting that AT.

To determine *what influences innovative AT adoption*, all participants were asked in Survey 2 to rate the importance of six factors in their decision to adopt innovative, or novel, AT ("How do you decide whether to adopt a newly introduced, novel AT? Please rate the importance of the following factors."). See Table 4 for a list of the factors. Participants rated importance on a 5-point scale, with 5 labeled "Very important" and 1 labeled "Not at all important." In the survey, we defined novel AT as newly introduced technology that is commercially available but has not been widely adopted yet. Participants were asked to share any comments they had about deciding whether to adopt newly introduced, novel AT. Then participants indicated whether there were any novel AT they were interested in adopting, and if so, what that novel AT was. To determine *desired AT innovations*, we utilized participant responses to the question, asked in both Survey 2 and 3, "Is there something you wish your AT could do that it currently doesn't do (but conceivably could do)?"

Data Analysis

We utilized descriptive statistics (frequencies, percentages, and means) to analyze our quantitative data. Most analyses utilized number of respondents (people) as the denominator to determine the reported percentage, but number of AT was utilized as the denominator for the new AT adopted analyses. We also utilized frequencies and percentages with the themes determined through qualitative analyses (described below).

Two researchers utilized content analysis to analyze responses to the five open-ended questions in Survey 2 and Survey 3 regarding what participants considered to be the best new technology advancement, comments about deciding whether to adopt novel AT, novel AT they were interested in adopting, and wishes for new AT innovations. Content analysis is an iterative qualitative research strategy used to analyze how participants experience a phenomenon through a four-step process of decontextualization (familiarization with the data and initial coding), recontextualization (reviewing the data to determine if changes to coding are needed), categorization (creation of categories or themes and sub-themes), and compilation (analyzing the results and writing process; Bengtsson, 2016).

The researchers first reviewed the responses while making notes about potential codes before initial coding began. Inductive coding was used to develop an initial set of codes after thoroughly reviewing and engaging with the open-ended responses (Bengtsson, 2016; Braun et al., 2019; Elliott, 2018). Each researcher independently coded the comments for each set of responses. We followed an iterative process as described by Elliott (2018), in which the two researchers reviewed the data and associated codes for accuracy and agreement, while considering new codes and revisions to existing codes. Through this process, the codes were updated, and any necessary recoding based on the updated codes was completed independently. Next, the researchers compared their assigned codes for each comment and reviewed any codes that were not in agreement and made changes, if needed, independently. The researchers then met to discuss all codes for which they were not in agreement and came to a consensus on the final codes assigned to each comment. Prior to the final analysis and writing process for this study, the researchers revisited the codes to review any needed changes or updates, including the recognition of previous stand-alone themes as a better fit as sub-themes under existing codes.

Results

Best AT Advancements

All 246 Survey 3 participants responded to the question about AT advancements, but 53 (21.5%) either did not provide a substantive answer (e.g., wrote N/A) or indicated they didn't know of any AT advancements. For example, one participant's response was:

> Unfortunately, I am one of those people that does not keep up on the newest advances. I find that I simply don't have the time. I just need assistive technology that works to make things accessible for me in my job and home life.

Other participants provided one or more answers regarding their perceptions of the best AT advancements, and common response themes are provided in Table 2. The most common theme was related to AI, with 100 comments that named an AI-related AT advancement. In addition, we counted the number of people whose response was related to an AI advancement (even if AI was not named), and 102, or 41.5% of the sample, provided such a response. AI incorporated into remote sighted assistance, such as Be My AI, was the most commonly identified AT advancement (17.5%). For example, one person said,

> I love the Be My AI feature built into Be My Eyes. It is robust and provides a lot of description. I just saw today too that Seeing AI has built in a similar feature to their technology. The ability to ask questions and get AI clarification I think is invaluable and makes things easier and more efficient.

Twenty-one people (8.5%) commented on advancements in braille devices or features. For example, more than one respondent was excited about a soon-to-be-released braille device, as illustrated by this response:

> The upcoming Orbit Optimum Laptop is a game changer in notetakers being that it is a full Windows 11 device with 40 cell braille internal. It comes out first quarter of 2024, but I have worked with it, and it is game-changing.

Seventeen people (6.9%) indicated the addition of optical character recognition (OCR) or the availability of enhanced OCR in their AT was an important advancement. Twenty-seven people (11.0%) commented on improvements to specific AT or devices (only coded here if not captured in another code, such as OCR or AI), with several identifying new JAWS features or iPhone/iOS accessibility enhancements. Five people (2.0%) believed that the improved ability of AT to read handwriting was an advancement, with three specifically mentioning this feature in SeeingAI.

Many people (*n* = 43, 17.5%) provided AT-related comments that did not fit under the other codes. Some of these comments were related to mainstream accessibility features, such as: “Accessibility features being more and more mainstreamed into most devices, and with better quality (like dictation, or very natural-sounding voices for built-in screen readers)” and “Ease of use and implementation. If new things can be easily integrated into technology I already use then I'm much more likely to utilize them.” Other comments were related to specific AT, without an indication that the respondent was referring to updates to that AT (e.g., OrCam, SeeingAI). Of note is that very few people mentioned new AT products; most identified new features added to existing AT as the best advancements. Also of note is that one-quarter of all comments referred to AT or features of AT that have existed for more than two years, although some of those commonly mentioned, such as OrCam, had features that were consistently evolving.

New AT Adoption

In the time frame between the first and second survey (2021 to 2022), 26.8% of the 313 participants adopted a new AT. Most adopted one AT (21.1%), a few adopted two AT (5.1%), and two people (0.6%) adopted three AT, for a total of 104 new AT adopted. The most commonly adopted AT were braille devices, which were 20% of all new AT adopted. Different types of apps were the other commonly adopted AT (46.2% for all types combined), including orientation, navigation, and wayfinding apps (14.4%); OCR or OCR+ apps (14.4%); and remote sighted assistance apps (4.8%). Screen readers (7.7%) and electronic video magnifiers (6.7%) represented a smaller percentage of the adopted AT. A relatively small number (*n* = 12, 11.5%) of the adopted AT were novel AT (as we defined it in Survey 2), including Envision Glasses, OrCam device (adopted by two people), BrailleSense 6 (adopted by three people), and Soundscape (adopted by six people). Eleven people, or 3.5% of all participants, reported adopting novel AT between Survey 1 and 2.

Table 2: *Perceptions About Assistive Technology Advancements*

Advancement Themes	*n*	%
Artificial intelligence (AI) related		
AI incorporated into remote sighted assistance	43	17.5
AI that can describe images	25	10.2
Generative AI	24	9.8
AI improving accessibility	8	3.3
Braille device and feature advancements		
Braille devices	10	4.1
Multi-line braille displays or tactile displays	7	2.8
JAWS Split braille feature	4	1.6
OCR or enhanced OCR added to AT	17	6.9
Improvements to specific AT or devices (not captured in other codes)		
JAWS features/enhancements	9	3.7
iPhone/iOS accessibility enhancements	6	2.4
Updates/enhancements to other AT	12	4.9
Reading handwriting	5	2.0
Other AT-related comment	43	17.5
Not AT-related comment	15	6.1

Note: *N*=246. Data from Survey 3 (2023).

In the time frame between the second and third survey (2022 to 2023), 17.5% of the 246 participants adopted a new AT. Most adopted one AT (14.6%), a few adopted two AT (2.4%), and one person (0.4%) adopted three AT, for a total of 51 new AT adopted. Braille devices were again the most commonly adopted AT, representing 35.2% of all new AT adopted. Remote sighted assistance apps were the only other common category of AT adopted, with 15.7% adopting Be My Eyes or Be My AI. Again, a relatively small number (*n* = 7, 13.7%) of the adopted AT were considered novel, including braille devices (Monarch braille display, BrailleSense 6 mini, and BrailleNote Touch Plus – two people), Hable One (two people), and VoiceVista. Only seven people, or 2.8% of all respondents, reported adopting novel AT between Survey 2 and 3.

Motivation for Adopting New AT

Participants' reasons and their primary reason for adopting the new AT they obtained are provided in Table 3. The number of new AT adopted across the two surveys were combined and used as the denominator for these analyses (*N* = 155). Results indicated that appealing features of the AT was the most important reason for adopting new AT, followed by the need to use the AT to perform a specific task and the need to use the AT for their jobs. Although ease of use/convenience and affordability/low to no cost were two reasons commonly identified for adopting an AT, they were not as often selected as the primary reason for adopting an AT. Even though only 15.5% of people selected the need to use the AT while at work as their primary reason for adopting it, 65.8% of the new AT was used on the job.

Table 3: *Motivation for Adopting New Assistive Technology*

Reason	Select All (*n*)	Select All (%)	Primary (*n*)	Primary (%)
Features of the AT appealed to me	110	71.0	42	27.1
Ease of use/convenience	92	59.4	15	9.7
Needed it to perform a specific task	88	56.8	29	18.7
Needed it for work	75	48.4	24	15.5
Affordability/low or no cost	63	40.6	11	7.1
It was recommended/had positive reviews	59	38.1	10	6.5
Needed to upgrade/update an existing AT I used	27	17.4	11	7.1
Needed due to vision changes or other disability	26	16.8	4	2.6
Other	8	5.2	5	3.2

Note: Overall *N*=155 AT adopted across Survey 2 and 3.

Novel AT Adoption

Participants rated the importance of six factors that may be associated with deciding to adopt newly introduced, novel AT. Their ratings, with factors sorted in order from most to least important, are provided in Table 4. Functionality, defined as whether what the AT does would help more than the person's current AT options, was clearly the most important factor, with more than three-fourths of participants rating it as very important. Two other factors that were important to most participants were price/affordability and ease of use (whether it would be easier to use than the person's current AT). User reviews and whether friends or colleagues were using the novel AT were of moderate importance to most participants. Uniqueness of the AT (preference for being one of the first to try new products) was not an important factor for most people.

Table 4: *Importance of Factors Associated with Novel Assistive Technology Adoption*

Factor	5	4	3	2	1
Functionality (whether what it does would help me more than current AT options)	78.6	17.9	2.9	0.6	0.0
Price/Affordability	45.4	32.9	16.6	3.5	1.6
Ease of use (whether it would be easier to use than my current AT)	41.2	33.9	19.8	4.8	0.3
User reviews	12.5	27.5	34.5	19.5	6.1
Friends or colleagues are using it	10.9	28.4	30.0	16.6	14.1
Uniqueness of the AT - I like to be one of the first to try new products	4.8	7.7	15.3	24.0	48.2

Note: 5 was labeled as "Very important" and 1 was labeled as "Not at all important." All numbers are percentages. *N*=313. Data from Survey 2 (2022).

Participants were also given the opportunity to provide comments about their decision process regarding novel AT, and 174 of the 313 participants provided substantive comments. The most common themes identified in the responses (discussed by 4% or more of the total sample) are provided in Table 5. In accordance with the importance ratings, the most common theme was that the AT should be practical—useful in daily life, functional, or fill a need—as mentioned by 18.5% of the participants. A subgroup of these respondents (5.4%) specifically emphasized the importance of the usefulness of the AT: “It would need to really stand out in order for me to take the time to adopt, meaning extremely helpful/functional.” Relatedly, several participants (6.1%) noted that the novel AT would have to improve their productivity or efficiency to be of interest.

Table 5: *Themes Related to Novel Assistive Technology Adoption Decision Comments*

Theme	*n*	%
Must be useful in daily life, functional, or fill a need	58	18.5
Cost is a factor/novel AT is usually expensive	51	16.3
Likes to use, learn about, or is excited about novel AT	33	10.5
Must be easy to use and/or easy to learn	20	6.4
Needs to improve productivity or efficiency	19	6.1
Lack of interest in trying novel AT	18	5.8
Desire to try out/see a demonstration of novel AT before buying	16	5.1
Comments on time/energy it takes to adopt new AT; the big learning curve for new AT	15	4.8
Talks to other blind users about novel AT or waits for reviews from others	14	4.5
Considers whether the novel AT offers new features or is unique/has unique features	14	4.5

Note: *N*=313. Data from Survey 2 (2022).

The second most common theme was cost being an important factor, which included comments related to novel AT usually being prohibitively expensive (16.3%). As one participant commented, “There are always a lot of new and interesting products coming out, and adopting every one would be most costly and time-consuming. So, the decision about each specific product has to be made very carefully…” Another commented on the high cost not being justified when there is a short lifecycle for technology stating, “Most AT is ridiculously overpriced because it is for such a small market, and it seems that hardware will become obsolete quickly.”

More than 10% of participants indicated excitement about or interest in using or learning about novel AT. For example, one participant stated,

> I'm all about novel assistive tech, especially if it performs a new function I haven't previously been able to do without sighted assistance. Aira has been this novel AT in recent years, and I think the Braille/tactile tablet and/or the multi-line Braille display may represent the next revolutions.

Another participant indicated interest while taking a cautious approach: “I love new technologies but want to make sure they add value to me. Often new products are just enhanced versions of other applications or systems that are already available and that I'm familiar with.”

Conversely, some participants indicated a lack of interest in adopting novel AT (5.8%) for reasons such as not wanting to deal with potential bugs or use too many different technologies. Some indicated that their interest has waned with increasing age or career advancement. For example, one participant stated,

> The older I get, the less zealous I am to try something novel unless evidence from users of significant ROI [return on investment] is overwhelming. Perhaps, when I retire, I will have more of an appetite to try new things just for the ‘adventure’ or ‘possibility’ of the effort. For now, however, as a husband, father, and family head, the prospect of carving out time and energy to invest in a new prospect is far less appealing than it was earlier in life.

The time it takes to adopt new AT was a consideration for several participants, including some who indicated that novel AT must be easy to use, easy to learn, or both (6.4%) and some who specifically noted that there is often a big learning curve for new AT (4.8%). Lack of support for learning new AT appears to be an issue for some participants: “I have big fears about the learning curve. Adding to the issue of training that is made available through [the] AT provider is usually just an introduction and overview that I will forget shortly after.” Another participant explained his interest in novel AT, but lack of ability to typically integrate it into his daily life:

> I enjoy the evolution of technology to provide access to things otherwise unavailable to me, but I'm not very patient about learning how to use it. It always seems like the learning curve is high and requires a lot of trial and error to figure out. So, I learn about an app such as Soundscape, download and play around with it, but then don't usually implement it in daily use because I find it too cumbersome. If I had better access to learning these new apps, I'd probably use them more often.

Interest in Adopting Novel AT

Although few participants reported adopting new, novel AT during the study, about one-third (*n* = 101, 32.3%) expressed an interest in adopting a novel AT in Survey 2, and 20 people identified more than one novel AT they were interested in. The most common categories of AT that participants expressed interest in were wearable devices/glasses (28.7%) and orientation/navigation aids (28.7%). Novel braille and tactile displays were of interest to 23.8% of participants. About one-fifth of participants mentioned an AT that was not a novel AT as defined in the survey. For example, several people mentioned remote sighted assistance apps such as Aira, electronic magnifiers, or refreshable braille displays. While these technologies have been available for many years and are in common use (and thus were not considered novel), innovative features may have been added to the AT.

Desired AT Innovations

Although 31% of participants in each survey could not identify a wish, or desired innovation, for their AT, most participants expressed one or more desires for what they wanted their AT to be able to do. Their responses were categorized into common themes, and themes mentioned by 2% or more of participants in either Survey 2 or 3 are provided in Table 6. Perhaps not surprisingly, the most common desire was for their AT to function better or offer additional functions or features, with 43.1% of comments in Survey 2 and 39.0% of comments in Survey 3 in this area. Some participants had specific wishes about AT functionality, such as this person:

> I wish that screen readers, when in PowerPoint presentation mode, would only read the displayed content and not any that is displayed later by slide automation. For example, when presenting, some slides are designed to show partial content until the next click, where additional content is displayed. Screen readers currently read the whole slide at first transition.

Other participants expressed broad wishes, such as being easier to configure or improved navigation of websites.

Participants desired better functioning in several common areas, which are listed in Table 6 as subcategories below the general category of function better/add functions or features. The most common subtheme was to be able to access information in images or tables, followed by improve (or add) OCR ability. For example, one participant stated, "I wish my AT was better at reading/deciphering data visualizations like charts, graphs, and tables, which I often have to interact with in the course of my work." Another participant said,

> If Seeing AI could display tables, charts, and/or documents with multiple columns in such a way that things could be read in the manner in which they are meant to be read (e.g. a page from a book with two columns would read down the first column, then move to the second, rather than reading the page straight across thereby mixing the information from the two columns).

Some participants expressed a desire for their current AT to incorporate AI, and these comments were more common in Survey 3 (3.7%) than Survey 2 (2.2%). For example, several people wanted their screen readers to add AI features, as illustrated by this comment:

> I would like to see JAWS and the other screen readers utilizing AI, deep learning and similar technologies to recognize commonly-implemented inaccessible code patterns in apps and websites and then add the necessary code to make them accessible on the fly.

Another participant said, "Wish all screen readers built in AI capabilities [were] similar to Be My AI when encountering inaccessible digital products. This would greatly assist with understanding and completing the digital products." Other suggested incorporations of AI in existing AT were using AI to create scripts in JAWS, adding it to Blind Square to create better routes and improve navigation, and adding it to OCR software or apps to process text and resolve common OCR errors. A few participants commented on advanced uses of AI, not related to a specific AT, and again these comments were more common in Survey 3 (2.8%) than Survey 2 (0.6%). For example, one participant expressed their wish related to indoor navigation:

> I'd love to see AT that allows for a blind/visually impaired person to take an already existing map of a store, train station, airport, etc. and be able to put it in an app and have the app (using AI) guide the user to a specific location.

Another common theme was improving accessibility or usability of AT with software, websites, or digital elements (such as buttons or form controls), mentioned by 11.8% of participants in Survey 2 but only 6.9% of participants in Survey 3. For example, one participant stated,

> …I also wish JAWS worked more efficiently for advanced Microsoft Office tasks, and that commands were consistent from application to application (reviewing comments worked the same in Word, Excel, and PowerPoint). Learning different commands for every application starts to feel like learning another language.

Others wished that JAWS worked better or was accessible with specific software that they needed to utilize for work. A related theme was the lack of accessibility or usability of digital content, which some acknowledged was not the fault of the AT, mentioned by 3.5% of participants in Survey 2 and 4.5% in Survey 3. For example, one participant stated, “Most of the issues I normally find are external to the AT, for example inaccessible website or app; it would be great if all programmers/content designers were fully knowledgeable on WCAG guidelines.”

Other common themes were for AT to read handwritten material (6.1% in Survey 2; 5.7% in Survey 3) and provide improved navigation, orientation, and wayfinding solutions (4.8% in Survey 2; 5.3% in Survey 3). A few participants provided unique ideas for new technology or features (6.1% in Survey 2; 2.4% in Survey 3). For example, in Survey 2 one participant stated,

> We need to make it so screen readers can display on multiple braille displays in the same way computers already do to multiple monitors. It would also be nice to have multiple focus points displayed on the same braille display as if it was split screen…

Other participants wished for advances in magnification options, such as: “Smart glasses that magnify quickly like the iPhone/smartphone camera - 4x - 6x minimum, something to help fine-tune magnify [to] read music notes while playing piano from [a] music sheet.” Others wished their head-mounted devices or smart glasses would add unique features, such as:

> …add pictures of people on the fly…People I’d like to identify, like it should recognize that I am saying ‘hi’ to someone named Bill and then save a picture of that person for me to know

> that that person's name is Bill, or as I'm introducing myself to a client perhaps I could press a button on the device or do a hand gesture, which would let the device know that I am introducing myself or being introduced to a person. I would just like it to be more covert.
> and
>
> It would be great if you could teach it to locate a specific item. Example, I dropped my time clock fob, while trying to put it on my keyring. This item is not preprogrammed into Envision, but it would be nice if I could program it in myself.

Others wanted their AT to help them effectively utilize the AT, for example:

> Tell me when there is a better way for me to do something than what I am doing, so I can learn new things and continue to complete tasks. Occasionally, I have forgotten something if I haven't used it in a long time or if I rarely use a particular command or keystroke.

Table 6: *Desired Assistive Technology Innovations*

Theme	**Survey 2 (*n*)**	**Survey 2 (%)**	**Survey 3 (*n*)**	**Survey 3 (%)**
Function better or offer additional functions or features	42	13.4	33	13.4
Access information in pictures, photos, graphics, and/or tables	24	7.7	16	6.5
Improve (or add) OCR ability	22	7.0	15	6.1
Improve braille technology access and support	18	5.8	13	5.3
Formatting/layout	8	2.6	3	1.2
Improve the speed or process to complete tasks and access information	7	2.2	4	1.6
Improve image clarity and settings	7	2.2	3	1.2
Incorporate AI	7	2.2	9	3.7
Improve accessibility or usability with software, websites, or digital elements	37	11.8	17	6.9
Read handwritten material	19	6.1	14	5.7
Unique idea for new technology or features	19	6.1	6	2.4
Improved navigation, orientation, and wayfinding assistance and solutions	15	4.8	13	5.3
Mentions feature/technology that already exists	11	3.5	11	4.5
Lack of accessibility or usability of digital content (not the fault of the AT)	11	3.5	11	4.5
Need to reduce cost of AT	8	2.6	3	1.2
Color identification	3	1.0	8	3.3
Advanced AI solutions	2	0.6	7	2.8

Note: Survey 2 *N*=313 (2022); Survey 3 *N*=246 (2023).

Discussion

Technology innovations, including AT innovations for people who are blind or have low vision, are occurring at a rapid pace. Many people from multiple disciplines are working to improve the quality of life of people who are blind or have low vision through technological advancements. Yet we know little about what people who are blind or have low vision know or think about these innovations, or what additional innovations they desire. This is the first study to collect data on thoughts about, desires for, and actual uptake of AT innovations from a large sample of this population who are currently using AT in the workplace.

The availability of generative AI was a recent major technology innovation. Generative AI became widely available during data collection for this study, between Survey 2 and 3, with the release of ChatGPT, and awareness of generative AI is very high in the U.S. (Pandya, 2024). The incorporation of ChatGPT into Be My Eyes, becoming Be My AI, was considered game-changing by many people who are blind or have low vision (Costabel, 2023; McDonnall, 2024). Despite this innovation and many others, more than one-fifth of our participants could not identify any technology advancements in the past two years, and many people identified technology advancements that were older (and, in some cases, much older) than two years. Our findings suggest a potential lack of awareness by a portion of the blind/low vision population of the AT innovations that are being developed for them. Greater awareness of AT innovations may improve uptake and thus potentially improve efficiency, productivity, and even quality of life. Also of note regarding perceived AT advancements is that participants most often identified advancements within existing technologies (e.g., screen reader, mobile apps) rather than completely new or novel devices.

Very few participants actually adopted a novel AT during the more than two years of the study, and most indicated they were not interested in adopting a novel AT. Key barriers to adopting AT and particularly novel AT were the expense, time to learn the new technology, and lack of training or support, which coincides with findings from Turkstra et al. (2023) and Kim (2022). While AT innovations are exciting for some, many people are more interested in the practical aspects and the costs, both in terms of dollars and time and effort, of adopting new AT. The bottom line for most people in terms of adopting new AT (including novel AT) seems to be its features, functionality, and usefulness. Although ease of use/convenience and affordability were important considerations for most people, they were not primary reasons (or the most important reason) provided for actually adopting a new AT. However, price/affordability and ease of use were important or very important considerations for most participants when it came to deciding whether to adopt novel AT.

Innovation is needed to determine methods to lower the cost of novel AT, and one potential solution is to explore options, when feasible, to integrate into emerging mainstream technologies, which are often less costly than standalone AT products designed for those who are blind or have low vision. Examples of this are new head-mounted devices and smart glasses, which have varying features, such as cameras, built-in voice assistants and AI, and other accessibility features that can be enhanced by the integration of specific accessibility apps.

In terms of desired AT innovations, more than one-third of our sample could not or did not identify a wish for what their AT could do that it currently does not do. Most desires were specific to existing AT the person used and focused on (a) working with specific programs or elements, (b) functioning better, or (c) adding features, although a few participants did provide unique ideas for AT innovations they would like to see. Interestingly, some participants' desires for AT innovations have become available as of the time of this writing. For example, several people wished for their screen reader to recognize text embedded in images, and JAWS Picture Smart feature performs that function. Although Picture Smart was introduced in 2019, it is now much more robust with the incorporation of advanced AI through the enhanced Picture Smart AI feature (Freedom Scientific, 2024). One participant wished for a method for someone who is blind to remote into another computer to provide technical assistance. This wish became a reality in 2023: An updated version of Remote Incident Manager (RIM) made it possible to connect to and control Windows or macOS computers while using a screen reader on either Windows or a macOS computer (Pneuma Solutions, 2023). We anticipate that, given the rapid pace of technological advancements, more participant wishes will have been granted by the time of the publication of this paper.

While innovations such as these are fantastic and clearly meet a need, they are often initially introduced in only one brand. For example, JAWS is frequently a leader in screen reader innovations, and when a new feature is released, users of other screen readers may have to wait for it to be implemented in their software. Another potential challenge is lack of awareness and utilization of new features in current users' AT. While new and updated features are introduced regularly, with the expectation that even more will follow as AI is implemented in new ways, we do not know how many users are aware of and utilize the new features. Given the barriers of lack of time and training opportunities, fewer people may be benefiting from these technological innovations than the number that could. Finally, although there are a large number of new, novel AT being developed for people who are blind or have low vision, particularly new tools for orientation, navigation, or wayfinding, our findings suggest that encouraging the uptake of new devices such as these, particularly those that are not free, may be challenging for their developers.

Outcomes and Benefits

This study explored the lived experience of employed adults who are blind or have low vision to gain insight into their perceptions about, adoption of, and desires for AT innovations. This research is timely given the large number of AT advancements and innovations for this population in recent years. Considering the ongoing evolution of technologies, such as AI and ML, multi-line refreshable braille displays and tactile displays, head-mounted devices, and smart glasses, this growth is likely to continue at a rapid pace into the future.

There are several outcomes of this study that are beneficial for AT practitioners and manufacturers of mainstream technologies and AT. The relatively high number of participants who did not know of any recent AT advancements suggests that they are not keeping up to date with the latest technologies. It is vital that practitioners, such as CATIS, AT instructors, TVIs, CVRTs, and others, not only stay current with emerging and innovative technologies themselves, but also develop strategies to provide instruction to consumers on how to remain current with innovative AT, including new features added to their existing AT. CATIS Certification through ACVREP (n.d.) requires certified instructors to be skilled in instruction for updating existing technologies, as well as teaching general exploration skills as appropriate for each student.

One potential model to counter the lack of awareness of new and innovative AT is technology clubs for people who are blind or have low vision. Some community rehabilitation programs have computer or technology clubs designed to inform current or past students of updates in the field of AT, such as the Boot Up Club (founded in 2003) at the Lighthouse for the Blind of the Palm Beaches, and TechTime at the Conklin Davis Center for the Visually Impaired. Participants benefit from these technology clubs through ongoing collaboration with instructors and other participants to remain current with their existing technologies and to learn about innovative AT. Other agencies and AT instructors should consider how similar programs would be beneficial to current and former AT students.

AT manufacturers can benefit from the input by people who are blind or have low vision about barriers to innovative AT adoption (beyond lack of awareness) provided in this study, such as the high cost and time and effort it takes to adopt new AT. Having a product that is easy to learn, intuitive, and easy to use was of high importance to our participants. Many people cannot or do not want to take the time to learn to use a new product and will not adopt something that has a high learning curve. For most of our participants, new products need to function better than their current AT options to be considered. It is also vital that developers work to lower the high cost of specialized AT solutions. These high costs present a barrier for many people, which will result in limited uptake of new devices for which significant time and expense has been expended in development. In addition, specialized hardware can become outdated quickly, or even obsolete, with the rapid advancements in AI technology (e.g., Ctech, 2024). It would be beneficial for developers of high-cost AT to identify cost-reducing solutions or explore strategies to integrate their technology into existing or mainstream technologies.

Declarations

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References

ACVREP. (n.d.). *Certified Assistive Technology Instructional Specialist for Individuals with Visual Impairments (CATIS) scope of practice*. Retrieved August 13, 2024, from https://www.acvrep.org/certifications/catis-scope

Bengtsson, M. (2016). How to plan and perform a qualitative study using content analysis. *NursingPlus Open*, *2*, 8–14. https://doi.org/10.1016/J.NPLS.2016.01.001

Bhowmick, A., & Hazarika, S. M. (2017). An insight into assistive technology for the visually impaired and blind people: State-of-the-art and future trends. *Journal on Multimodal User Interfaces*, *11*(2), 149–172. https://doi.org/10.1007/s12193-016-0235-6

Braun, V., Clarke, V., Hayfield, N., & Terry, G. (2019). Thematic analysis. In P. Liamputtong (Ed.), *Handbook of Research Methods in Health Social Sciences* (pp. 843–860). Springer. https://doi.org/10.1007/978-981-10-5251-4_103

Costabel, M. (2023, October 11). I'm totally blind. Artificial intelligence is helping me rediscover the world. *Slate*. https://slate.com/technology/2023/10/ai-image-tools-blind-low-vision.html

Elliott, V. (2018). Thinking about the coding process in qualitative data analysis. *The Qualitative Report*, *23*(11), 2850–2861. https://doi.org/10.46743/2160-3715/2018.3560

Freedom Scientific. (2024). *What's new in JAWS 2024 screen reading software*. https://support.freedomscientific.com/Downloads/JAWS/JAWSWhatsNew

Kim, H. N. (2022). User experience of assistive apps among people with visual impairment. *Technology and Disability*, *34*(3), 165–174. https://doi.org/10.3233/TAD-220377

Madake, J., Bhatlawande, S., Solanke, A., & Shilaskar, S. (2023). A qualitative and quantitative analysis of research in mobility technologies for visually impaired people. *IEEE Access*, *11*, 82496–82520. IEEE Access. https://doi.org/10.1109/ACCESS.2023.3291074

Mashiata, M., Ali, T., Das, P., Tasneem, Z., Badal, Md. F. R., Sarker, S. K., Hasan, Md. M., Abhi, S. H., Islam, Md. R., Ali, Md. F., Ahamed, Md. H., Islam, Md. M., & Das, S. K. (2022). Towards assisting visually impaired individuals: A review on current status and future prospects. *Biosensors and Bioelectronics: X*, *12*, 100265. https://doi.org/10.1016/j.biosx.2022.100265

McDonnall, M. (2024, Fall). Remote sighted assistance app use and thoughts about “sighted” assistance from artificial intelligence. *The American Foundation for the Blind*. https://www.afb.org/aw/fall2024/ai-usage-research

Muhsin, Z. J., Qahwaji, R., Ghanchi, F., & Al-Taee, M. (2024). Review of substitutive assistive tools and technologies for people with visual impairments: Recent advancements and prospects. *Journal on Multimodal User Interfaces*, *18*(1), 135–156. https://doi.org/10.1007/s12193-023-00427-4

OrCam closing glasses department, cutting dozens of jobs in third round of layoffs this year. (2024, July 28). Ctech. https://www.calcalistech.com/ctechnews/article/hy0rv6qya

Pandya, V. (2024, April). *The age of generative AI: Over half of Americans have used generative AI and most believe it will help them be more creative*. https://blog.adobe.com/en/publish/2024/04/22/age-generative-ai-over-half-americans-have-used-generative-ai-most-believe-will-help-them-be-more-creative

Pneuma Solutions. (2023, June 8). *Remote Incident Manager for macOS Officially Released!* https://pneumasolutions.com/remote-incident-manager-for-macos-officially-released/

Turkstra, L. M., Van Os, A., Bhatia, T., & Beyeler, M. (2023). Information needs and technology use for daily living activities at home by people who are blind. *arXiv Preprint arXiv:2305.03019*. https://doi.org/10.48550/arXiv.2305.03019

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Voices from the Industry

The Use of Obi Robot for Self-Feeding with Individuals with Upper Extremity Limitations

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Abstract

Feeding is an essential activity of daily living. For individuals experiencing limitations in their upper extremities (UE) due to motor and/or processing difficulties, self-feeding becomes challenging, impacting their sense of autonomy and independence. Moreover, relying on others for feeding removes their ability to control the timing or the pace that food is placed into their mouths during feeding, leading to heightened hurdles in maintaining adequate nutritional and caloric intake. Their feeding schedule and pace also becomes contingent upon the skill and patience of their caregivers. This descriptive study examined the functional performance of self-feeding in 19 individuals with upper extremity limitations using Obi, a robotic self-feeding device. Participants ranged in age from 8 to 60 years and were observed across various environments, including homes, simulated-home setups, clinics, and schools. Using observational methods and secondary data analysis, participants' performance with Obi was evaluated. Results indicated that all participants successfully used Obi to independently feed themselves by activating switches connected to the device, with a 100% success rate in delivering food up to their mouths by the final trial session. The use of different types of switches, customized according to the participants' needs, allowed for personalized feeding experiences and increased their social interactions with family and friends. These findings suggest that Obi can significantly enhance feeding independence for individuals with UE limitations, promoting autonomy, nutritional intake, and social participation.

Keywords: self-feeder, Obi robot, independence

The Use of Obi Robot for Self-Feeding with Individuals with Upper Extremity Limitations

Feeding is an essential activity of daily living. For individuals experiencing limitations in their upper extremities (UE) due to motor and/or processing difficulties, self-feeding, which refers to the ability to bring food to the mouth independently, becomes challenging, impacting their sense of autonomy and independence. According to the International Classification of Functioning, Disability, and Health (ICF) by the World Health Organization (WHO), eating encompasses "the coordinated tasks and actions of consuming food that has been served, bringing it to the mouth, cutting or breaking food into pieces, opening bottles and cans, using eating implements, and consuming it in culturally acceptable ways, such as dining or feasting" (WHO, 2001, p. 123). When individuals are unable to feed themselves and rely on others for feeding—which involves the assistance of a caregiver to bring food to their mouth—it removes their ability to control the timing or pace of eating. This can create additional challenges in maintaining adequate nutritional and caloric intake. Their feeding schedule and pace also become contingent on the skill and patience of their caregivers. It disrupts their participation in the social and cultural dimensions of eating, which are integral to human connection and identity.

Culturally, mealtimes serve as important rituals in nearly all societies, symbolizing togetherness, celebration, and community. The inability to self-feed can isolate individuals from these communal experiences, contributing to feelings of dependency, exclusion, and diminished self-worth (Ji et al., 2019). Socially, eating is often a shared activity, and being able to eat independently allows individuals to participate fully in family gatherings, social outings, and cultural practices associated with food (Harte et al., 2019). Loss of this ability can have profound emotional effects, as individuals are forced to rely on caregivers not only for physical nourishment but also for navigating the timing and style of feeding, often leading to frustration or embarrassment (Cipriano-Crespo et al., 2020).

Healthcare professionals, including occupational therapy practitioners and speech-language pathologists, play vital roles in assessing and addressing feeding, eating, and swallowing difficulties across diverse populations with varying conditions (AOTA, 2007). Their specialized training allows them to assess individuals' motor, sensory, and cognitive abilities, as well as environmental factors that contribute to these challenges. Importantly, clinical evaluations are often conducted in various settings—such as homes, schools, and outpatient clinics—because different environments provide unique insights into an individual’s functional performance (Reiman & Manske, 2011). For instance, home-based assessments can reveal how an individual interacts with their familiar environment, including their access to utensils and the layout of their eating area, while clinic-based evaluations may provide a more controlled setting to analyze specific motor and cognitive skills related to self-feeding (Bole et at, 2015).

Moreover, the ability to assess individuals in multiple contexts allows clinicians to observe the influence of different social and cultural environments on feeding practices. For example, assessments in schools can shed light on how children with feeding difficulties manage during lunchtime, where peer interaction and social participation are critical (Peterson et al., 2022). Meanwhile, home-based assessments may highlight family dynamics, including the role of caregivers at mealtimes, and cultural practices related to food preparation and consumption. These settings offer valuable insights into the potential barriers to independence and opportunities for intervention, allowing clinicians to develop more comprehensive and culturally sensitive care plans.

One key aspect of the evaluation process involves determining the suitability of assistive technologies and adaptive equipment to support individuals in their environments. This assessment considers factors such as an individual's functional abilities, environmental constraints, and personal preferences to ensure the optimal selection and utilization of assistive devices. Through evidence-based practice and collaboration with interdisciplinary teams, they strive to enhance the independence, autonomy, and quality of life of individuals facing feeding challenges (Albarqi, 2024). Evidence-based practice and interdisciplinary collaboration are essential in this process, as clinicians work together to enhance the independence, autonomy, and quality of life of individuals facing feeding challenges.

Beyond the functional aspects, assistive technologies like Obi, a robotic system designed to help individuals with limited upper extremity mobility independently feed themselves, contribute to the reintegration of individuals into social and cultural practices surrounding mealtimes. By enabling individuals to self-feed, these technologies can reduce the social stigma associated with feeding disabilities, promote inclusion, and allow for greater participation in social dining experiences (Fardeau et al., 2023). As such, the adoption of robotic assistive technologies in feeding rehabilitation not only addresses physical limitations but also helps individuals reclaim their roles in the cultural and social rituals of eating.

In recent years, robotics has increasingly emerged as a pivotal component of assistive technologies in rehabilitation. Cutting-edge robotic systems are revolutionizing the landscape of rehabilitation by offering innovative solutions to enhance therapeutic interventions. Robotic assistive technologies are designed to provide personalized and targeted rehabilitation, catering to individual needs and specific conditions. Specialized robotics like self-feeders offer versatility, enabling therapists to customize therapeutic feeding regimens and adjust assistance levels according to individuals' progress, thereby optimizing function and independence (Nanavati, Alves-Oliveira, et al., 2023).

The purpose of this study was to evaluate the functional performance and independence of individuals with upper extremity limitations in self-feeding using Obi, a robotic assistive feeding device. By examining participants' ability to operate Obi independently, the study aimed to explore its potential to improve food intake, emotional satisfaction, and social participation, as well as its impact on caregiver burden.

Obi is designed, developed, manufactured, distributed and serviced in compliance with DESĪN, LLC’s ISO13485-certified medical device quality management system. It holds a medical device safety certification under the IEC60601-1 standard family and is listed with OSHA Nationally Recognized Test Lab, SGS North America, Inc. Obi’s innovative design in assistive technology has been honored with a Medical Design Excellence Award (Gold Winner) and a Research and Development (R&D) 100 Award.

Personal Statement and Disclaimer

Dr. Burgos has more than 30 years of multifaceted experience in clinical, administrative, and educational roles across various facilities and educational organizations. She is an accomplished professional with an extensive background in assessment and clinical interventions in occupational therapy and expertise in assistive technologies and durable medical equipment.

This study was originally created to classify and regulate Obi under the German statutory health insurance system and to ensure that the device is recognized and reimbursed by German health insurance providers (eligibility for financial reimbursement). The data and analysis in this study are based entirely on the examiner's own evaluation, without any input or influence from DESĪN, LLC or its employees. If you have any questions about the study, you can contact the examiner directly.

Target Audience and Relevance

The target audience for this article is indeed broad and encompasses a variety of healthcare and rehabilitation specialists, including occupational therapy practitioners, physical therapy professionals, speech-language pathologists, and nurses. Additionally, individuals with upper extremity limitations and their caregivers, assistive technology practitioners, engineers, researchers, and durable medical equipment vendors would also find the information relevant.

For occupational therapy practitioners, physical therapy professionals, and speech therapy pathologists, the article offers insights into innovative approaches to assistive technology in feeding rehabilitation, specifically focusing on the use of robotics like the Obi robot. Nurses involved in patient care may also benefit from understanding these advancements in assistive technology to better support their patients with feeding difficulties.

Users and caregivers of individuals with upper extremity limitations would find valuable information on available assistive technologies like the Obi robot, which could enhance their loved one's independence and quality of life. From a technological standpoint, Obi uniquely includes features such as 6 degrees of freedom, smart servo actuators, and capacitive touch sensors that allow caregivers to adjust the arm’s preferred feeding location or user preference. This means that the arm can be easily reprogrammed for varying dining locations (e.g., kitchen, bedroom, or even outdoor environments) without navigating complex menus and indexing quantitative setting parameters characteristic of older products. Moreover, Obi's adaptive feedback mechanisms enable real-time adjustments to the arm's movements, ensuring smoother operation in dynamic settings or environments with varying obstacles.

For vendors of durable medical equipment, Obi's inclusion in healthcare markets, particularly its certification under ISO13485 and compliance with medical device standards, highlights its safety, reliability, and scalability in terms of distribution. With Obi's potential for home-based, school-based, and clinic-based use, vendors can expect strong demand across different user groups. Obi's ease of use, coupled with its portable and lightweight design, positions it as a highly marketable product for families, caregivers, and healthcare providers seeking to enhance independence and improve quality of life for individuals with upper extremity limitations.
Assistive technology practitioners, engineers, and researchers would gain insights into the application of robotics in rehabilitation and may find opportunities for collaboration or further development of such technologies. Durable medical equipment vendors would be interested in understanding the demand for innovative assistive technologies like the Obi robot and how it could fit into their product offerings to meet the needs of healthcare professionals and their clients. Overall, the article serves as a resource for a diverse audience interested in leveraging innovative approaches to assistive technology in feeding rehabilitation.

Design

This descriptive research employed observational techniques and secondary data analysis to evaluate the functional performance of individuals with upper extremity limitations and their abilities to operate Obi for self-feeding.

Obi (see Figure 1) is a medical device intended to compensate for the function of a human arm during meals to restore functional eating performance (as defined by ICF). People 5 years and older living with severe/complete congenital or acquired neurological and/or physical impairment of the upper extremities are indicated for use. Obi uniquely contains 6 degrees of freedom (6 servo motors) which enable the device to have the following novelties: a large volume of possible ergonomic settings for food delivery location (height, width, and depth adjustments), smooth biomimetic motions (similar to the human arm during meals), and multi-directional food capture methodologies. A caregiver (family, friend, or clinician) cuts and inserts the food, adjusts the point of delivery (POD), then connects and positions the appropriate switch type. Following setup, the patient is empowered to independently eat with a safe and desirable pace. The device has two main user inputs: one for choosing which plate the food comes from, and another for activating the robotic arm to deliver the food to their mouth. These commands are each associated with a 3.5-mm switch receptacle which accommodates various off-the-shelf switch controls (pressure switches, pillow switches, sip-and-puff switches, etc.). This modular design of the robot's controls allows for adaptability, which can be tailored for different body movements and environmental contexts. Prior to use, the switches are placed in convenient locations based on the user's abilities (e.g., arm, foot, head).

The activation of the switches is momentary, meaning the user presses the switch briefly to initiate the action (like moving the arm or selecting food), rather than holding it down continuously. To use Obi, the user activates the desired switch (e.g. pressure switch, plate switch, sip-and-puff switch, pillow switch) once to select the desired food item from one of four compartments on the plate, then presses another switch to activate the robotic arm and bring the food to a position just in front of their mouth.

Figure 1: *Obi, A Robotic Assistive Feeding Device*

Figure 1a: *Obi A Robotic Assistive Feeding Device*

The study employed clinical observations, as well as semi-structured and informal interviews. The Observation of Use Form was developed using the Occupational Therapy Practice Framework (OTPF) Domain and Process which is a framework that has been developed for uniform description and outlining the domains of occupational therapy (AOTA, 2020). Domain and Process was used (OTPF) as a framework to collect essential functional information about individuals. The OTPF was developed for uniform description and outlining the domains of occupational therapy (AOTA, 2020).

The qualitative data from the letter of medical necessity reports was examined via content analysis utilizing spreadsheets to identify similar collective information from the Observation of Use Form like demographics, medical history, cognitive status, general performance, type of switch(es), type of food, environment, observations during trials with Obi, and performance skills.

Methods

Participants

Out of the initial cohort of 25 individuals screened, 19 were accepted into the study, resulting in an acceptance rate of 76%. The selection was based on the completion of required observations, as well as the availability of comprehensive data necessary from the examiners' evaluations. The remaining participants were excluded due to not having all the required data documented in their evaluations, which was essential for meaningful analysis.

Recruitment and Screening

Participants were recruited through a combination of outreach efforts, including referrals from healthcare providers from schools and hospitals, and advertisement from Obi personnel with individuals with upper extremity limitations and caregivers that were already familiar with Obi.

For confidentiality matters, the participants' names were not displayed. The participants resided in four U.S. states and met the following criteria:

- Cognitive ability to operate a simple machine or electronic device.
- Ability to chew and swallow without assistance.
- Ability to make decisions about food selection and consumption.
- Presence of upper extremity limitations that impaired the ability to self-feed, determined through a combination of self-reported difficulties and clinical assessments conducted by licensed occupational therapists. The clinical assessments were based on standardized measures commonly used in occupational therapy practice, such as Range of Motion (ROM) Testing, and Manual Muscle Testing (MMT), which assessed motor control, strength, and range of motion of the upper extremities.

Participants who reported or demonstrated limitations in upper extremity motor control, coordination, or strength that prevented the use of traditional utensils were considered eligible for the study. This determination was either made during the screening process or confirmed by reviewing existing clinical documentation provided by their healthcare providers.
The participants' demographics are displayed in Table 1, including gender, race, age group and diagnoses.

The participants consisted of a total of nineteen individuals (32% females, 68% males) between the ages of 8 and 60 years with a variety of conditions and upper extremity limitations that affected self-feeding.

Attrition

There was no attrition during the study, as all accepted participants completed the required sessions and assessments.

Participant Experience

Among the 19 participants, some were trying Obi for the first time, while others had been using it for varying durations prior to the study. Specifically, 13 participants were first-time users, while six had been using Obi for an average of 6 months (range: 1–12 months) before the study commenced.

Table 1: *Demographics of Participants*

	Demographics	*n*	%
Gender	Male	13	68%
	Female	6	32%
Race	White/Caucasian	10	53%
	African American	1	5%
	Hispanic	2	10%
	Unknown	6	32%
Age group	5 –14 years	6	32%
	15 – 20 years	7	37%
	21 – 39 years	1	5%
	41 years or older	5	26%
Diagnosis	Amyotrophic Lateral Sclerosis	1	5%
	Arthrogryposis	1	5%
	Cerebral Palsy	4	21%
	Chromosome duplication	1	5%
	Congenital anomalies	2	11%
	Duchenne Muscular Dystrophy (DMD)	1	5%
	Multiple Sclerosis	1	5%
	Spinal Muscular Atrophy (SMA)	1	5%
	Septic Shock/Organ failure	1	5%
	Spinal Cord Injury	5	26%
	Traumatic Brain Injury (TBI)	1	5%

Training on Obi Usage

Participants received training on how to use Obi effectively, focusing on several key areas:

- Device Familiarization: Participants were introduced to the components of Obi and how to activate it using different types of switches.
- Food Preparation: Training included guidance on preparing appropriate foods for use with Obi, including size and texture considerations to facilitate successful feeding.
- Switch Operation: Participants practiced using the switch activation system, learning to select food items and control the delivery of food to their mouths.
- Positioning and Safety: Training emphasized the importance of proper positioning while using Obi to enhance ease of use and ensure safety during meals.
- Feedback Mechanisms: Participants were encouraged to provide feedback during training sessions to optimize their experience and adjust settings based on individual preferences and needs.

Data Collection

The data collection involved a variety of observational methods and interviews:

- Observations: Clinical observations were conducted in naturalistic settings (homes, clinics, schools) to assess participants' interactions with Obi during self-feeding tasks. The naturalistic settings were homes (57%), simulated homes (11%), schools (11%), and outpatient clinics (21%).
    - Settings and Duration: The decision on where to observe each user was based on their personal preferences and comfort, as well as practical considerations such as the availability of caregivers. Each participant was observed in their selected environment for a minimum of 30 minutes, during which they engaged in a meal using Obi. This duration was chosen to capture a representative sample of their feeding behavior and interaction with the device.
- Interviews: Semi-structured interviews were carried out with participants and caregivers to gather qualitative insights on their experiences, satisfaction, and perceived benefits of using Obi.
- Performance Assessments: The Observation of Use Form was developed using the Occupational Therapy Practice Framework (OTPF) to collect essential functional information about the individuals, including motor control, range of motion, switch activation and social interactions.
- Supplementary Data: Secondary data from archived clinical documents and video recordings of participants using Obi in previous trials were also analyzed to triangulate findings and gain a comprehensive understanding of the participants' performance and experiences.

Examiners

The examiners were all clinical practitioners with professional credentials, registration, and licenses in occupational therapy (OT) with extensive experience in clinical assessment. They were all previously trained on how to conduct MMT and ROM assessments, and how to conduct clinical observations as part of their professional training. The OTs that conducted the in-person trials underwent training sessions focused on the use of the Observation of Use Form to promote inter-rater reliability. This included instruction on the criteria for evaluation and examples of various scenarios to ensure consistent scoring across different evaluators.

All examiners were also trained on how to use and program Obi, and how to activate it by using different types of switches.

Data Analysis

Content analysis was performed on the qualitative data collected from interviews, observational notes, and clinical documents. The analysis process involved the following steps:

- Multiple Reviewers: A team of two licensed occupational therapists conducted the content analysis independently to ensure a comprehensive review of the data. Each reviewer was trained in qualitative analysis methods and familiar with the specific aims of the study.

- Coding Process: The reviewers developed a coding scheme based on initial readings of the data. They identified themes related to user experiences, effectiveness of the Obi robot, challenges faced, and overall satisfaction with the self-feeding process. Each reviewer coded a portion of the data, and discrepancies were discussed to achieve a consensus on theme identification.
- Consensus Building: Regular meetings were held to discuss findings and resolve any differences in coding. The final thematic framework was developed through collaborative discussion, ensuring that the insights captured were reflective of the participants' experiences.
- Triangulation of Data: The findings from the interviews and observations were triangulated with secondary data sources to enhance the validity of the results. This approach ensured a more robust understanding of the participants' experiences with Obi and its impact on their self-feeding capabilities.

Findings

All 19 participants independently activated switches connected to the Obi Robot to select food from different bowls and deliver it close to their mouths, achieving a 100% success rate during their final trial session. Success was defined as the ability to activate the switches and self-feed without assistance. This means that all participants successfully activated the switches independently during self-feeding tasks in their final observation at the end of the trial sessions.

Trial Sessions

Participants engaged in multiple trials to familiarize themselves with the Obi device. For some participants, these trials represented their first introduction to Obi, while others had prior experience with the device. The total number of trials varied among participants based on their individual learning curves and adaptation to using Obi effectively. The standard trial sessions were conducted over a two-week period, with an average of two sessions needed for participants to achieve 100% independence with Obi. Two of the participants required additional sessions to explore the use of different switches and test various activation locations, which helped enhance their performance in activating the device.

The delivery location or area where the self-feeding robot, Obi, delivers food to the user, was previously set by a caregiver or therapists. The caregivers and therapists also prepared the food and cut it as needed per the individuals’ needs. Caregivers were also trained to adjust the arm position according to the dining location (e.g., bedroom, kitchen).

Three different types of activation (switches) were required by the participants (see Table 2). The pushbutton switch (84%) was the most used during the performance sessions. The pushbutton is also called the Buddy Button, which is the one that is included with the Obi kit. Two participants with severe upper extremity limitations used pillow switches (11%). Pillow switches are often utilized with individuals with severe extremity limitations as they are typically larger and softer, making them easier to press and activate. One participant utilized a sip-and-puff switch (5%) that was activated by using his mouth since he had no upper extremity function. He was already familiar with this type of switch from its use on his power wheelchair. Most of the participants (75%) used their hands to activate the switches while others used their heads, mouths, elbows, shoulders, and feet.

Table 2: *Type of Activation (Switches) and Location*

		n	%
Type of activation system	Sip & Puff	1	5%
	Pushbutton switch	16	84%
	Pillow switch	2	11%
Body part used to activate switch	Head	1	5%
	Hand	14	75%
	Mouth	1	5%
	Elbow	1	5%
	Shoulder	1	5%
	Foot	1	5%

The following is a summary of the performance of the participants in the different environments.

Virtual Live Observations (Home; n = 4)

The primary examiner scheduled appointments with four individuals who were Obi owners. They became Obi owners between November 2018 and November 2020. However, they were not familiar with The Observation of Use Form to examine performance skills (motor skills, process skills, and social interactions skills) related to self-feeding. All observations were performed synchronous (live) at their homes via Zoom or Google Meet with the participants and at least one caregiver. Each session lasted approximately 30 minutes. During this time, each participant ate a meal with Obi at their home and engaged in a conversation with the examiner. The conversations that occurred during the sessions were simultaneous to the participants eating their meals. This interaction provided a context for qualitative insights regarding their experiences using Obi for the analysis of social interactions skills (communication and interaction with others) as part of The Observation Use Form. Sessions were recorded, and qualitative data were obtained through audio recordings that were subsequently transcribed for analysis.

All four participants (100%) were completely independent in the activation of switches to select food and to bring food to their mouths. Two of the four participants were wheelchair users and two were able to walk but all presented upper extremity limitations that prevented the use of utensils and required others to feed them. All four participants used pushbutton switches to activate Obi but used different body locations. They relied on caregivers for the setup of Obi, switches, and food preparation.

All expressed that Obi has been life-changing, as it has provided a level of independence and social liberty. They shared that not only do they use Obi at home, but most take it everywhere they go, including family gatherings, restaurants, schools, and even on cruises during family vacations. As an example, one of the participants (a 10-year-old girl) stated that after using Obi at school, she could enjoy lunchtime and was able to be transitioned to eating at the regular school cafeteria with her peers and friends. This change also allowed her to be part of social clubs at school, as they usually meet during lunchtime. She could self-feed while socializing with members of the book club, like other students. All participants and caregivers reported that Obi has transformed their lives and mealtime experiences as a family, allowing them to enjoy meals together without the worry of cold food or rushing to eat while feeding others.

As the participants in this group were all Obi owners, it only took them one trial session to demonstrate independence in the use of Obi for self-feeding. The observations and additional information related to social interactions were documented and coded.

Video Observations (Home – Archived; n = 6)

Video footage used during a design validation test, completed in 2015, was examined. The video analysis was focused on the activation of selected switches (two-plate switch, sip-and-puff switch, and pillow switch) to complete the task of self-feeding during mealtimes. Participants used Obi for the first time during a trial period of two weeks (2–3 sessions). The performance summary of the six participants (50% females, 50% males) between the ages of 15 and 50 years with upper extremity limitations preventing the use of utensils was analyzed. All participants were able to use Obi independently at the culmination of their trial period at their homes. The training sessions for the use of Obi were provided by trained Obi staff who focused exclusively on the mechanical and functional use of Obi. The observations were performed by the examiners (occupational therapists).

In-Person Trials (Hospital and Home; n = 3)

The in-person observations and trials were scheduled at a local children's hospital in Central Florida (n = 2). One of the participants completed two trial sessions and another completed three trial sessions. Both participants were completely independent in the use of Obi for self-feeding by the second session, but an additional session was performed for one participant to evaluate if the number of food spillages could decrease with an additional trial session. The participant demonstrated a decrease in food spillage from 10+ on the first session to 3 to 5 on the second session and 1 to 2 on third and last session.

The third in-person trial was scheduled at a participant's home in South Florida (n = 1). The Observation of Use form was also used during this session. The participant only completed one trial session, as she was able to use the pushbutton switch independently to feed herself on the first session with minimal food spillage. Training and observations were also performed by examiners (occupational therapists). Observations and additional information related to social interactions were documented and coded.

Clinical Documents (Outpatient Clinics and Schools; n = 6)

A compilation of clinical documents written by five different occupational therapists was examined (one therapist wrote two clinical documents). All the occupational therapists were board-certified and licensed. These clinical documents were written with the intention of submitting them to the participants' insurance (for the approval of Obi to be used at home and at school as needed). The clinical documents included general information about patients' function, mobility, and trial sessions using Obi. Four therapists (21%) performed the trial sessions at occupational therapy outpatient clinics and two (11%) conducted the trials at the participants' schools. These six documents represented medical evaluation of certified and licensed occupational therapists, confirming that the six participants were able to activate the switches by themselves to have Obi scoop food from the plates and bring it to their mouths. This way, the six participants were able to use Obi to independently self-feed without the help of caregivers.

Outcomes and Benefits

The utilization of Obi can be deemed crucial as medically necessary equipment, particularly for individuals unable to self-feed, as inadequate food intake could jeopardize their health. It is imperative for individuals with disabilities to have the autonomy to make decisions about their activities of daily living (ADLs). The concept of occupational justice emphasizes the right of individuals to engage in meaningful occupations, including daily activities, that promote well-being and enhance quality of life.

Research highlights that self-determination is a critical aspect of occupational justice. According to Wehmeyer et al. (2018), individuals with disabilities who have control over their choices report higher levels of satisfaction and well-being. Allowing them to decide how to perform their ADLs—whether independently or with assistance—respects their autonomy and supports their identity. Occupational justice also advocates for equitable access to resources, including assistive technology (AT) and support services. A systematic study by van Dam et al. (2023) found that when individuals with disabilities have access to appropriate AT, they can significantly enhance their independence in performing ADLs. This access should not be limited by socioeconomic status or geographical location.

Moreover, individuals with disabilities often face barriers that limit their participation in everyday life. According to the World Health Organization (2011), facilitating access to decision-making around ADLs fosters social inclusion. When individuals can choose how they engage in their daily activities, it enhances their social participation and integration within their communities. Empowerment is also a fundamental principle of occupational justice. A qualitative study by Vahdat et al. (2014) revealed that individuals who actively participate in decisions about their care report a greater sense of empowerment and ownership over their lives. This empowerment leads to improved mental health outcomes and a stronger sense of belonging. Finally, encouraging individuals with disabilities to make decisions about their ADLs can improve the dynamic between them and their caregivers. When caregivers support the choices of those they assist, it fosters a more collaborative relationship that respects the individual's preferences and promotes their autonomy (Sedig, 2016).

The findings of this study have several implications for occupational therapy practice for individuals with upper extremity limitations. Obi, as a self-feeding robot, intends to compensate for the function of a human arm during mealtime to restore a person's functional eating status. The intended clinical benefit of Obi is to alleviate or ameliorate the disability caused by medical diseases or conditions that completely or severely impair upper extremity function. By fulfilling its intended use, Obi has the potential clinical benefit to improve quality of life and to alleviate or prevent medical issues known to be associated with impaired functional eating, including but not limited to gastroesophageal reflux disease (GERD), aspiration, aspiration pneumonia, malnutrition, and dehydration, as well as psychological and social health impairments.

There is strong advocacy for the ongoing promotion and justification of assistive technologies like Obi to foster independence, thereby unlocking the potential of individuals facing physical challenges.

Discussion

The results of this study demonstrated that all 19 participants with various upper extremity limitations were able to effectively utilize Obi for self-feeding. For many, this was their first attempt at self-feeding after injury or motor skill loss. All participants (100%) were able to independently operate Obi, activating its switches, selecting food from the plate compartments, and directing food to their mouths.

Psychological theories, such as Maslow's Hierarchy of Needs, emphasize that self-actualization, which is realizing one's potential and exercising autonomy, is a crucial aspect of fulfillment. Studies show that individuals who feel a sense of control over their lives tend to experience better mental health outcomes (Wehmeyer et al., 2018). Independence fosters empowerment, personal efficacy, and self-esteem. However, cultural differences significantly influence attitudes toward independence and caregiving. For instance, collectivist cultures may view caregiving as an honor and part of familial duty, reducing the emphasis on individual autonomy, while Western societies often promote independence as a marker of personal achievement and freedom. These cultural differences must be acknowledged, as they affect how self-feeding technologies like Obi are perceived and adopted across various regions.

In this study, all participants achieved independence in self-feeding, eating meals at home or in simulated environments without the assistance of caregivers. This independence also contributed to an increase in food intake, as reported by both participants and caregivers, even though no empirical measures of food intake were taken. The literature supports the notion that inadequate food intake can lead to immune system complications and malnutrition, which are associated with increased mortality and longer hospital stays (Childs et al., 2019; Stratton, 2007). Moreover, forced or hurried feeding by caregivers is linked to aspiration pneumonia, gastroesophageal reflux disease (GERD), malnutrition, and dehydration, all of which have significant health consequences (Simpson et al., 2023).

In addition to increasing food intake, using Obi conferred psychological and social benefits. Caregivers and participants reported emotional satisfaction and enhanced social participation. This finding aligns with research indicating that providing control over food selection, a basic aspect of daily life, enhances emotional well-being (Smeets et al., 2012b). Eating has profound social and cultural significance, and self-feeding enables individuals to participate more fully in mealtimes, which are often central to family bonding, celebrations, and community rituals. Individuals who rely on assistance for feeding may feel isolated or marginalized during such gatherings, affecting their social interactions and sense of belonging. By promoting self-feeding, Obi facilitates social inclusion and reduces caregiver burden, fostering healthier relationships.

Limitations

Despite its benefits, there are practical considerations regarding the use of Obi. Caregivers still need to connect the switches, set the food delivery position, pre-slice food, and load meals onto the plate, which suggests that users may require some level of supervision or setup assistance before and during meals. While the independence provided by Obi is significant, future iterations of the technology could aim to reduce these dependency points further, such as enabling the user to power the device on and off independently.

Furthermore, individuals who may not be suitable candidates for using Obi include those with severe cognitive impairments, significant sensory deficits that hinder effective interaction with the device, or those unable to comprehend its operational process. Nonetheless, a treatment plan that incorporates occupational therapy could benefit individuals who possess the basic potential to meet the minimal usage criteria. Occupational therapy can enhance their functional capabilities and provide strategies for gradually improving their ability to use Obi for self-feeding.

For engineers and researchers, Obi's design offers many opportunities for further exploration and development. Obi currently functions as a 6-degree of freedom robotic feeding assistant that integrates precision servos, electronic controllers, and 3.5-mm barrel jack connections. Engineers will appreciate the simplicity of Obi's standardized 3.5-mm control inputs to accommodate many off-the-shelf options, while also recognizing the room for integration of more advanced input devices such as eye-gaze systems, electromyographic switches, and brain computer interfaces, allowing those with even more severe disabilities to operate the device. Furthermore, many remaining severe upper extremity mobility impaired individuals (spastic cerebral palsy, late-stage ALS) unfortunately do not possess a sufficient level of consistent precise functional control (in particular, cervical extension, flexion, and rotation) to accurately and reliably move their head forward ~ 30–50 mm to obtain food from the Obi spoon that delivers food to just in front of their lips. This limitation creates new research and development opportunities to expand Obi's patient population by leveraging increased autonomy using 3D vision artificial intelligence systems. Such a system could autonomously locate the patient's mouth position (even in the case of positional shifting during meals), make safe and effective decisions as to when the patient is ready to have the utensil inserted into their mouth, and make subsequent decisions about retraction from the mouth.

Future studies could address these gaps by empirically measuring food intake and comparing outcomes across different feeding methods, including caregiver-assisted feeding and traditional utensils.

Conclusion

The use of Obi aligns with the definition of medically necessary services, as it provides essential assistance in feeding, a basic need, thereby preventing malnutrition and its associated health risks (Healthcare, 2021). Moreover, the device enhances social participation, a critical factor in maintaining physical, mental, and emotional well-being (Venna et al., 2014). Advocacy for assistive technologies like Obi is vital for promoting inclusion and independence in individuals with disabilities, fostering better mental health outcomes and reducing caregiver stress.

In conclusion, promoting the use of assistive technologies such as Obi is highly encouraged. These technologies empower individuals with physical limitations to achieve independence in self-feeding, promoting social participation, emotional satisfaction, and better health outcomes. Furthermore, they reduce the burden on caregivers and enhance family dynamics, contributing to healthier, more sustainable caregiving relationships. Future research is recommended to explore these benefits further, including a systematic study of food intake and its impact on health and well-being across different feeding modalities.

Declarations

This content is solely the responsibility of the author(s) and does not necessarily represent the official views of ATIA. No financial disclosures and no non-financial disclosures were reported by the author(s) of this paper.

References

Albarqi, M. N. (2024). Assessing the impact of multidisciplinary collaboration on quality of life in older patients receiving primary care: Cross sectional study. *Healthcare*, *12*(13), 1258. https://doi.org/10.3390/healthcare12131258

American Occupational Therapy Association. (2007). The practice of occupational therapy in feeding, eating, and swallowing. *American Journal of Occupational Therapy, 71* Supplement_2, https://doi.org/10.5014/ajot.2017.716S04

American Occupational Therapy Association. (2010). Specialized knowledge and skills in technology and environmental interventions for occupational therapy practice. *American Journal of Occupational Therapy, 64*, S44–S56. https://doi.org/10.5014/ajot.2010.64S44

American Occupational Therapy Association. (2020). Occupational therapy practice framework: Domain and process (4th ed.). *American Journal of Occupational Therapy, 74*(Supplement 2), S1–S87. https://doi.org/10.5014/ajot.2020.74S2001

Bole, R. E., Burdell, A., Johnson, S. L., Gavin, W. J., Davies, P. L., & Bellows, L. L. (2015). Home food and activity assessment. Development and validation of an instrument for diverse facilities of young children. *Appetite, 80*(1), 23-27. https://doi.org/10.1016/j.appet.2014.04.026

Childs, C. E., Calder, P. C., & Miles, E. A. (2019). Diet and immune function. *Nutrients, 11*(8), 1933. https://doi.org/10.3390/nu11081933

Cipriano-Crespo, C., Rodríguez-Hernández, M., Cantero-Garlito P., & Mariano-Juárez L. (2020). Eating experiences of people with disabilities: A qualitative study in Spain. *Healthcare (Basel), 8*(4), 512. https://doi.org/10.3390/healthcare8040512

Fardeau, E., Senghor, A. S., & Racine, E. (2023). The impact of socially assistive robots on human flourishing in the context of dementia: A scoping review. *International Journal Social Robotics, 15*, 1025-1075. https://doi.org/10.1007/s12369-023-00980-8

Harte, S., Theobald, M., & Trost, S. G. (2019). Culture and community: observation of mealtime enactment in early childhood education and care settings. *International Journal of Behavioral Nutrition and Physical Activity, 16* (69). https://doi.org/10.1186/s12966-019-0838-x

Healthcare. (2021). *Medically necessary.* https://www.healthcare.gov/glossary/medically-Necessary/

Ji, Y., Rana, C., Shi, C., & Zhong, Y. (2019). Self-esteem mediates the relationships between social support, subjective well-being, and perceived discrimination in Chinese people with physical disability. *Frontiers in Psychology, 10*, 2230. https://doi.org/10.3389/fpsyg.2019.02230

Maslow, A. H. (1943). A theory of human motivation. *Psychological Review*, *50*(4), 370–396. https://doi.org/10.1037/h0054346

Nanavati, A., Alves-Oliveira, P., Schrenk, T., Gordon, E. K., Cakmak, M., & Srinivasa, S. S. (2023). Design principles for robot-assisted feeding in social contexts. In *Proceedings of the 2023 ACM/IEEE International Conference on Human-Robot Interaction (HRI '23)*, pp. 24–33. Association for Computing Machinery. https://doi.org/10.1145/3568162.3576988

Reiman, M. P., & Manske, R. C. (2011). The assessment of function: How is it measured? A clinical perspective. *Journal of Manual & Manipulative Therapy, 19*(2), 91-99. https://doi.org/10.1179/106698111X12973307659546

Sedig, L. (2016). What's the role of autonomy in patient- and family centered care when patients and family members don't agree? *AMA Journal of Ethics,18*(1), 12-17. https://doi.org/10.1001/journalofethics.2017.18.1.ecas2-1601

Simpson, A. J., Allen, J.- L., Chatwin, M., Crawford, H., Elverson, J., Ewan, V., Forton, J., McMullan, R., Plevris, J., Renton, K., Tedd, H., Thomas, R., & Legg, J. (2023). BTS clinical statement on aspiration pneumonia. *Thorax*, *78*(suppl 1), 3–21. https://doi.org/10.1136/thorax-2022-219699

Smeets, P. A., Charbonnier, L., van Meer, F., van der Laan, L. N., & Spetter, M. S. (2012a). Food-induced brain responses and eating behavior. *Proceedings of the Nutrition Society, 71*, 511–520. https://doi.org/10.1017/S0029665112000808

Smeets, P. A., Charbonnier, L., van Meer, F., van der Laan, L. N., & Spetter, M. S. (2012b). Food choices and reward mechanisms in the brain: Insights from neuroimaging. *Appetite, 59*(1), 1–8. https://doi.org/10.1016/j.appet.2012.05.003

Stratton, R. J. (2007). Malnutrition: another health inequality? *Proceedings of the Nutrition Society, 66*, 522–529. https://doi.org/10.1017/S0029665107005848

Vahdat, S., Hamzehgardeshi, L., Hessam, S., & Hamzehgardeshi, Z. (2014). Patient involvement in health care decision making: a review. *Iran Red Crescent Medical Journal. 16*(1). https://pmc.ncbi.nlm.nih.gov/articles/PMC3964421/pdf/ircmj-16-12454.pdf

van Dam, K., Gielissen, M., Bles, R., van der Poel, A., & Boon, B. (2023). The impact of assistive living technology on perceived independence of people with a physical disability in executing daily activities: a systematic literature review. *Disability and Rehabilitation: Assistive Technology*, *19*(4), 1262–1271. https://doi.org/10.1080/17483107.2022.2162614

Venna, V. R., Xu, Y., Doran, S. J., Patrizz, A., & McCullough, L. D. (2014). Social Interaction plays a critical role in neurogenesis and recovery after stroke. *Translational Psychiatry, 4,* e351. https://doi.org/10.1038/tp.2013.128

Wehmeyer, M. L., Shogren, K. A., & Pompa, L. (2018). Self-determination and individuals with disabilities: What do we know and where do we go? *Intellectual and Developmental Disabilities*, *56*(1), 3–14. https://meridian.allenpress.com/idd

World Health Organization. (2011). *World report on disability*. World Health Organization. https://www.who.int/publications/i/item/9789241564182

World Health Organization. (2001). *International classification of functioning, disability and health (ICF)*. World Health Organization. https://www.who.int/standards/classifications/international-classification-of-functioning-disability-and-health

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Voices from Industry

Eyewear with Obstacle Detection: Design of a Novel Travel Aid

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Abstract

This paper summarizes ideation, initial design interviews, and prototype testing by the company, Lighthouse Tech SA, in the process of the creation of a novel wearable assistive technology device for people who have visual impairments ranging from moderate visual impairment to blindness. The company's aim is to implement a commercially available eyewear device with sensors that are effective at detecting and communicating obstacles in the upper-body zone, an area left unprotected by the traditional long cane. This paper describes the main outcomes and benefits of the initial design and testing process, including increased understanding of user needs in a wearable mobility device, and the methods employed, involving creation of an artificial obstacle maze that allowed for rapid comprehension of the device's functionality by testers and opportunities for discussion and feedback.

Keywords: visual impairment, blind and low vision, wearable technology, smart eyeglasses, mobility

Eyewear with Obstacle Detection: Design of a Novel Travel Aid

Lighthouse Tech is a company founded in 2020 with the mission of providing novel assistive technology for people who are blind or who have low vision. The company founders brought career-long experience in the fashion eyewear industry. They perceived an unmet need for assistive technology devices that combined elegance and style with function.

In 2019, the founders held a series of workshop-style meetings with blind associations in Switzerland and Italy. They encountered enthusiasm for the proposition of a stylish wearable from volunteer participants at informal workshops organized by blind associations for people who have a range of visual impairments from moderate and severe to blindness (no usable vision with the exception of light perception). These workshops collected initial observations on navigational challenges and gaps in existing solutions and provided strong motivation to work towards a novel technological solution to protect the upper body from dangerous collisions that could not be reliably solved by long cane use and orientation and mobility (O&M) skills. The consequent aim of the company was to provide a commercially available device that integrates meaningfully with the O&M needs of its users.

Problem Definition

Visual impairment, encompassing moderate to severe visual impairment and blindness, is associated with difficulties in daily life involving travel in indoor and outdoor spaces. These difficulties affect ability to travel independently and participate in social activities, impacting quality of life and well-being. Essential O&M skills can be developed for travel in the case of reduced or absent visual information, but these skills are qualitatively different from those employed by people navigating with sight (Pogrund & Griffin-Shirley, 2018).

Orientation is the ability to recognise the environment and establish position in relation to the environment, while mobility is the physical ability to move in an orderly, efficient, and safe manner through the environment. “Orientation and mobility” is “the teaching of the concepts, skills, and techniques necessary for a person with a visual impairment to travel safely, efficiently, and gracefully through any environment and under all environmental conditions and situations” (Jacobson, 2013, p. 3). Travel aids, such as the long cane, guide dog, global positioning system (GPS), and electronic assistive technologies including apps or software, are typically introduced to address O&M challenges (Chang et al., 2020; van Nispen et al., 2020). A combination of such tools, O&M techniques, and training are needed to acquire independence.

Exposure to serious life events, including serious accidents, is significantly higher for people with visual impairment than the general population (Brunes & Heir, 2021; Lundälv & Thodelius, 2021). Serious consequences of mobility restrictions associated with visual impairments include injury or fear of injury due to falling or collision, as well as higher incidence of mortality, social isolation, and psychological consequences (Brunes et al., 2019; de Boer et al., 2004; Riazi et al., 2016; Zijlstra et al., 2009).

The long cane is completely ineffective at detecting obstacles located in the upper body zone (e.g., tree branches, signs). Guide dogs may, if properly trained, route the traveler around such obstacles, but otherwise may not always alert the user to their presence (Smith & Penrod, 2010). A survey in Bamdad et al. (2022) reported head-level obstacles as representing the biggest challenge in collision avoidance, consistent with significance placed on head injuries in Lighthouse Tech's workshops. Manduchi and Kurniawan (2011) found no difference between mobility aid used (guide dog or long cane) in reducing head-level accidents. Head-level and fall accidents often require medical attention. These types of accidents reduce confidence and cause people to change their mobility habits (Chanana et al., 2017).

The study by Manduchi and Kurniawan (2011) found somewhat shockingly that 13% of participants experienced head-level accidents at least once a month. Medical attention was needed in 23% of these cases. Further, fear of injury resulted in changes in walking habits in 43% of cases and had negative impacts on confidence for independent travelers (26%). An overwhelming majority of head-level accidents happened outdoors due to tree branches, poles, signs, construction equipment, and trucks, although indoor accidents were reported for doors and cabinets left open, as well as shelves, tables, and walls.

Although risk of injury appears to provide ample motivation for people to look for solutions for independent travel, electronic travel aids (ETAs) that commonly use ultrasound or laser energy to sense objects in the environment and return information to the user via tactile-haptic or audio feedback (Penrod et al., 2010) have not enjoyed widespread uptake, though such devices have been available on the market for many decades. Barriers to adoption, including training requirements, cost, complexity, and suitability for a person's specific needs, can influence user acceptance of technology, which contributes to satisfaction, engaged use, and reduced risk of product abandonment (dos Santos et al., 2022). An important adoption barrier is stigma and social awkwardness, associated with device aesthetic, social acceptance, feelings of exposure, and fear of facing barriers (Faucett et al., 2017). Negatively experienced visibility of assistive devices has been associated with the risk of making a disability more visible (Faucett et al., 2017). Though social awkwardness sits among other barriers to a device's adoption, it was a core aspect that informed the design of the device prototype that we report on in this paper.

We have become aware that many attempts to design innovative devices have not made it to market because of lack of knowledge concerning mobility, and lack of research and field testing (Smith & Penrod, 2010). A prototype testing procedure, incorporating use of artificial head-level obstacles, was designed to evaluate effectiveness at assisting testers to avoid obstacles in the upper-body zone and elicit feedback to help refine the design. This paper reports on eyewear device design considerations and prototype tests, and discusses testing methods, outcomes, and perceived benefits, challenges, and potential drawbacks of the design.

Target Audience and Relevance

This article describes the process of assistive technology ideation and development and describes the testing and consultation approach to assess a novel device for people who are blind or who have low vision. Vision rehabilitation, O&M specialists, and specialists in accessible technology devices may find the results interesting because they relate to features and characteristics of design and present a novel approach to an ETA in an eyewear frame. The frame can accept prescription lenses for people with low vision; results may thus be of interest both for people who are blind and for people who have remaining functional vision requiring correction. The rapid assessment methods proposed may be of interest for designers of accessible technology, as they can be employed to capture valuable insights for validation of concepts and prototypes from testers during technology demonstrations while respecting their time and availability.

Methods

Idea Validation and Design Interviews

Initial exploratory workshops and interviews aimed at understanding the possibilities and challenges of eyewear as a platform for assistive technology for people who are blind or who have low vision. Workshops were organized with local blind association members to identify and evaluate assistive technology gaps that could be feasibly addressed in smart eyewear form. Results of the workshops were elaborated in further conversations with potential customers, including people with visual impairments, professionals in vision rehabilitation, and representatives of companies specializing in selling assistive technology devices. Transcripts and notes taken during these events were analyzed qualitatively to identify the main themes for device design implications. This analysis helped to identify primary requirements for creation of the first eyewear prototypes.

Prototype Testing Procedure: Prototype Characterization

Three iterations of the hardware prototypes were produced during the device design phase, comprising different components, configurations, and levels of miniaturization. Results that we report in this paper were obtained with a prototype created and tested in 2023. This prototype consisted of an eyewear frame that integrated forward-facing, near infrared time-of-flight obstacle sensors. These sensors were selected for validation activities due to their characteristics that allowed for rapid prototyping with low engineering cost. They had a maximum detection range of 4 m depending on the size, shape, and material composition of the obstacle. This range was sufficiently long in comparison to other ETAs available for similar mobility tasks (Smith & Penrod, 2010). These sensors had severe limitations under bright sunlight; thus, demonstrations and tests were conducted indoors or under cloudy and low-light outdoor conditions.

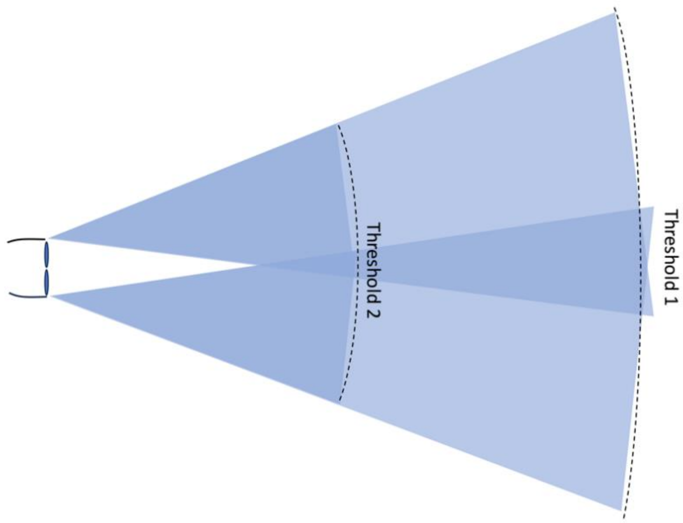
The sensor field of view was up to 50° (horizontally and vertically). The device, comprising two sensors, one on each eyewear arm, had a total horizontal field of view of approximately 80°. This angle of aperture was sufficient to create an overlapping central detection area where sensors on each side of the eyewear overlap. Simple vibration motors were embedded in each eyewear arm, connected to a microcontroller that elaborated distance data from the sensors. When obstacle distance fell within a threshold distance from the device, the motors were programmed to vibrate. Prototypes used for testing incorporated a normal eyewear front in two sizes with sun lenses and had a total weight of approximately 80 g. The prototype is illustrated in Figure 1.

Figure 1: *Eyewear Device Prototype*

Vibration of the eyewear arms was used to communicate presence of obstacles within the sensors' field of view. Vibrations on either or both arms provided information on the obstacle position in the horizontal field. For instance, if an obstacle is positioned centrally in front of the user, both eyewear arms signal its presence through vibration. If the user turns to the left, they will feel the presence of the obstacle on their right-hand side via the vibrating right arm. Turning further, the user can find a safe path around the obstacle as the vibration stops altogether.

Initial tests were performed with 11 people using a distance threshold of 1.2 or 1.3 m and a single vibration intensity. If an object was detected within the threshold range, the vibration motors provided feedback. Subsequently, two distance thresholds were implemented with software, corresponding to two distinct vibration intensities. A lower-intensity, pulsing vibration was used to warn the user of the presence of obstacles at higher distance thresholds (default values from 90 cm to 180 cm), whereas a more intense, pulsing vibration was used to warn users of imminent danger of collision (default: at an obstacle distance of 90 cm or shorter). These feedback threshold distances could be quickly changed from the defaults during tests using software if a participant wished to try different values. Figure 2 illustrates sensor field-of-view and range of the two distance thresholds.

Figure 2: *Obstacle Sensor Coverage and Vibration Intensity Zones on the Horizontal Plane*



Prototype Testing Procedure

Participation

The purpose of testing was to evaluate the usability of the prototype's sensing and tactile-haptic feedback system in a safe, supervised setting. Members of blind associations and O&M specialists were asked to participate in a series of testing events organized with blind associations and rehabilitation services. Tests were organized beginning in spring and ending in December 2023. Tests were conducted in Switzerland where the company is based, and during trips to Italy, France, USA, and Japan. Due to the commercial scope of Lighthouse Tech's activities, much testing was performed under the auspices of device prototype demonstrations and little time was often available for interaction with testers; thus, it was impossible to consistently gather information from testers regarding proficiency with travel aids and individual histories including years lived with vision loss, degree of visual function affected, and history of O&M training and assistive technology use. Testing and feedback sessions were performed with small groups of up to 6 people and lasted at most several hours.

Testers were found and engaged through blind associations and low-vision rehabilitation services, and at shows and events that gave space to demonstration of assistive technologies. Contact persons in organizations were asked to bring testers to meetings where the device could be demonstrated and tried. Testers were all capable of independent mobility and no testers had postural deviations or required use of assistive mobility devices like walking supports or wheelchairs.

Testers were asked whether they had usable vision, with or without optical correction (low vision), or if they did not have any usable vision (blind). Testers using corrective lenses were asked to remove their eyeglasses during testing and replace them with the prototype, though we noted to these testers that the device was designed to accept prescription lenses if desired. It is acknowledged that due to the impossibility of providing corrective lenses on the eyewear prototype during tests, these few testers were disadvantaged because they were unable to use some or all the advantages provided by their functional vision. As visual impairments are highly diverse, future exploration is required to better identify the people who would derive the largest benefit from the device.

A total of 56 people volunteered to test and give feedback on the prototype. Thirty-five people were blind, 17 had low vision, and four were sighted O&M specialists who tested the device with their eyes occluded. The mobility aid or aids used at the time of testing were recorded. Five people used a guide dog, three used both the guide dog and long cane, and 46 were long cane users. Only two testers reported use of ETAs (one long cane with laser ranging and one wrist-mounted, ultrasonic device). Two testers with low vision did not use any type of mobility aid. Although properly trained guide dogs can help their owners navigate around obstacles at head height, we included these testers because of their interest in testing the device. We noted that none of the guide dogs in the tests helped users avoid the head-height obstacles in the maze.

Each participant’s age group was recorded as young adulthood (19–34), middle adulthood (35–49), older adulthood (50–64) and retirement age (65+; see Table 1).

Table 1*: Title: Age Demographics of Testers.*

Age Range (years)	Number of Participants
19-34	14
35-49	13
50-64	21
65+	7
ND	1
Total participants	56

Explanation of test and potential risks were explained to participants as a group before testing and consent for participation was obtained orally in each case before tests were performed. In some, but not all cases, individual compensation was offered in the form of a gift voucher or cash. In some cases, refreshments or lunch was offered to participants.

Testing Methods

Testing followed two different approaches. The first involved ad-hoc accompanied free walks of up to 200 m in a space, such as an open area in a building or an outdoor area with urban obstacles. During these walks, naturally occurring obstacles and barriers were used when available. Accompanying people, on occasion, held up their arms or an object like a book or piece of cardboard to simulate an obstacle in the upper body zone.

The second approach involved short accompanied or unaccompanied walks in an artificial obstacle maze. Obstacles that specifically impact the upper body zone were not always easily found in the facilities where prototype demonstrations were conducted. Artificial obstacles were fabricated from soft foam and cardboard, providing a safe way to assess the ability of testers to understand and respond to obstacles using the device, and elicit tester feedback on their experience.

The maze elements were transported or replicated in locations in Switzerland, Italy, and Japan. The maze simulated a challenging environment for mobility on foot. It consisted of obstacles positioned in the zone above the testers' waists. Lower-body zone obstacles, such as a chair or box, were also placed in the obstacle maze. Artificial obstacles of fixed size and soft, lightweight materials were constructed for the safety of testers. For 17 of the testers, the free walk method was employed because of circumstance (difficulty of maze transport to events), while for the remaining 39 testers, a maze was used.

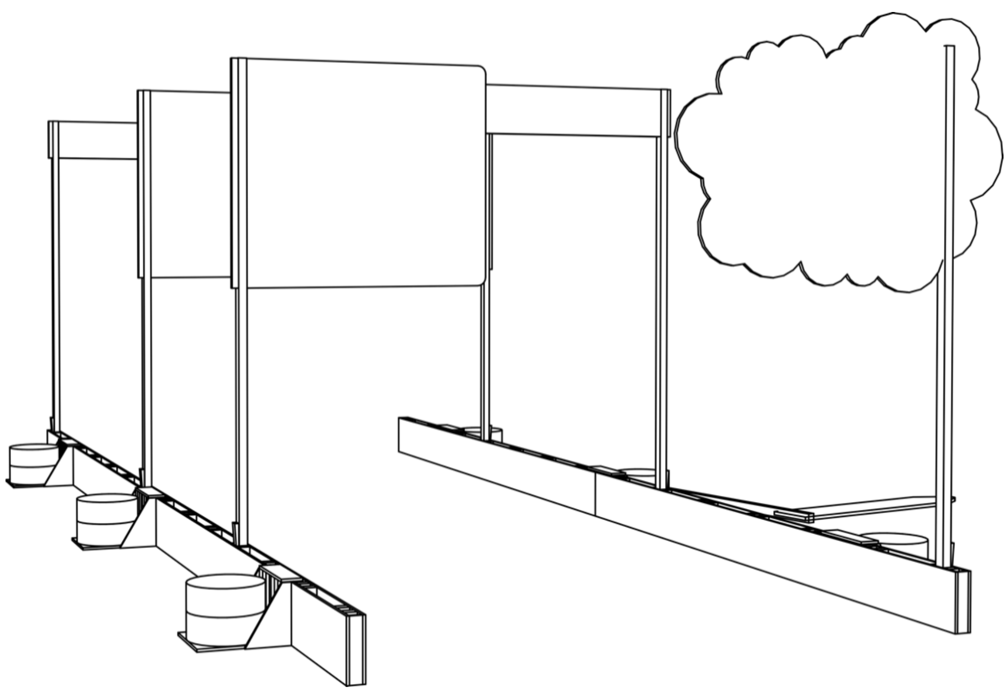
Mobility courses to evaluate technology for vision impairment have been employed for studies focused on completion of mobility tasks and measures of functional ability (Chang et al., 2020; Dernayka et al., 2021; Pundlik et al., 2018; Roentgen et al., 2012). The maze was designed and tested following a review of studies using artificial mobility courses (Chang et al., 2020; Dernayka et al., 2021). We employed an artificial maze as part of a strategy to collect design-relevant feedback on characteristics of device operation and obstacle avoidance performance for a broad group of participants.

Chang et al. (2020) compared mobility outcome measures across 32 studies using mobility courses, where obstacle contacts and avoidance were most frequently measured outcomes (23 counts). Accordingly, we noted all occasions when users experienced an error resulting in collision with an obstacle in the maze. We also asked for the person's own evaluation of the error when not evident. We recorded observations of other aspects of user behavior with the prototype, including confusion about distance to obstacles or location of obstacles in the user's path, and confirmed these situations through dialogue with testers following maze walks. During participants' walks, we observed their behavior and gathered feedback on difficulty in detecting obstacles and the testers' levels of confidence while using the device. For each participant, we noted their qualitative evaluation of their ability to detect obstacles with the device (1-poor, 5-excellent) and their evaluation of level of confidence (1-not confident, 5-very confident). In Japan, a translated questionnaire was used to gather these responses from participants. As with testers who performed accompanied free walks, follow-up interviews with maze testers aimed to identify issues relevant to device design, feedback on potential use cases for the prototype in everyday life situations, and their interest in follow-up.

Obstacle mazes were assembled in both indoor and outdoor settings where space and appropriate light levels were available. Light levels were not controlled, but lights were turned on in indoor situations to assist testers with usable vision. We constructed two slightly different versions of the maze in Switzerland and Japan. A test with five participants in Italy was performed with a preliminary setup that did not allow for obstacle positions to be interchanged. In Japan, the testing situation was qualitatively different because maze testing was integrated into an assistive technology demonstration event and the team was not always able to obtain detailed feedback from testers due to constraints on visitors' time.

Figure 3 shows a view of the obstacle maze used in Japan and Switzerland showing all obstacle positions occupied. The maze was 5 m long and 2 m wide and constructed of lightweight materials so it could be easily assembled, disassembled, and transported. Our tests employed from one to four obstacles at a time in various arrangements. Parallel "rails" at ground level set 2 m apart provided for tactile feedback with the long cane for lateral borders of the obstacle maze. With this arrangement, the cane could not be used to detect the location of the obstacles in the upper body zone because posts supporting the obstacles were attached behind the rails and were thus protected from tactile detection. Obstacles were designed to mimic natural surroundings such as protruding sign boards, trees, and open windows. Obstacles could be freely moved from one position to another between individual maze walks with a single tester so that each walk presented a different obstacle layout. Some initial tests incorporated a low-level obstacle such as a box or chair that could be easily detected by the cane or guide dog. This arrangement was conceived for evaluation of the separation of lower-body/upper-body feedback but was not deemed helpful at this stage and was abandoned in most later tests.

Figure 3: *Mobile Obstacle Maze Design*



After a short orientation session demonstrating the characteristics of the prototype and explaining the maze layout, testers were asked to walk through the maze as many times as they wished with the device and their cane or guide dog. Testers were instructed to turn away from the feeling of vibration to navigate around obstacles in the maze. If it was perceived that the tester was having difficulty comprehending feedback signals, they were given further instruction and offered the opportunity to perform further maze walks. Proficiency with mobility aids varied among the testers but a cane or dog was required to stay safely within the maze bounds. Alternative ETAs, if already used by a tester for detecting obstacles above the waist, were also encouraged in the maze after prototype tests for comparison with the user's prototype experience.

Results

Initial Workshops and Interviews

An initial workshop identified head-level and upper-body level obstacle collisions as a problem of high interest. The eyewear form was suggested to be well-suited as a wearable device focused on obstacle warnings at these levels. Among the various electronic aids available for people with visual impairments, protecting the upper half of the body was seen as unique, interesting, and helpful. One tester in the USA noted that collisions with obstacles in the upper body zone are more frequent, severe and problematic than those that affect the lower body. Another commented, "On new paths, we must learn to understand surfaces, steps, and edges. However, the upper part of the body, the face, remain[s] more exposed." It was observed that eyeglasses are already used by many people with vision impairment for correction of remaining functional vision, protection from strong light, and protection of the eyes in the event of a collision with an obstacle: "We put on glasses and take the hit;" "When I wear glasses, they already protect me, because the most delicate part is the eyes." We thus took the decision to work on an ETA in the form of eyeglasses that are designed as a secondary mobility aid to protect the upper-body zone.

Tactile-haptic feedback was positively evaluated for obstacle warnings. An O&M specialist from the USA commented that these features could be beneficial and appropriate for people who are deaf-blind or who have a range of cognitive and attentional issues. Considerably less enthusiasm was expressed for audio feedback because of fear of distraction from audio cues. Our prototypes were made with vibration motors for feedback.

A frequent topic was comparison with existing ETA solutions. Multiple issues with existing products and technologies that participants had tried were identified that suggested drawbacks in their experiences with various device forms and areas for improvements in a new ETA design. Primary criticisms of existing ETAs were bulk, weight, lack of weatherproofing, aesthetics, wearability considerations, and usability challenges.

Reliability of ETAs

Issues were raised regarding existing ETAs, such as inability of some devices to perform in wet weather. Weatherproofing got very positive reactions because several current market offerings do not function or are not reliable in rainy conditions. A strong request for weather resistance was noted for selection of sensors, materials, and design of the final product. As a reliability concern, participants overwhelmingly recommended that the final product should aim only to complement, not replace, traditional mobility aids. Reliability of new AI-enabled devices that claim to replace traditional tools and techniques was questioned. “If something goes wrong, the traditional [long] white cane can reliably get you back.”

Hands-Free Usability

Hand-held devices were appreciated for their simplicity and ergonomics but left no hands free when used with a cane. One participant in the USA noted that people who are blind are functionally “one-handed” because a hand must always attend the cane or guide dog. Multiple participants observed the hands-free aspect as an important advantage of the eyewear form over handheld alternatives: “This wearable solution keeps both hands free.” We noted that it would be helpful to allow the user to interact with the device with their free hand, thus, button presses or taps should be accessible for either left- or right-hand use.

Wearability Observations

A further consideration is wearability in combination with clothing and coverings. A wrist-mounted device and a device worn on the chest did not work with winter clothing layers. A wrist-mounted device with an ultrasound sensor positioned on the band was also used by one tester in Switzerland. He has continued to use it mostly around the house. It did not work for him while wearing long sleeves or a jacket outdoors. This is a problem that eyeglasses can potentially avoid, as eyeglasses must accommodate combination with different articles of clothing if sensors are kept clear of clothing layers, like winter hats, sun hats, or other head and face coverings.

Integration With the Long Cane

An American O&M specialist observed that “the electronic smart cane has not taken off. People want something decoupled from the cane.” A reported drawback of some ETAs integrated in the cane handle is difficulty in understanding the meaning of feedback. Two people from Switzerland told us about a group of fifteen that participated in an extensive 2-week training program with a cane employing laser distance rangers and laser LEDs. Two people in this group continued to use this device after the program. One person was reported by an O&M specialist as an extremely proficient cane user who managed to convince a friend to likewise adopt the ETA. Others in the group found it too complicated to use in everyday life. Two ETAs incorporated in the long cane handle were mentioned to be too bulky and encumbering to cane technique. In response to our suggestion that we could integrate wireless, tactile-haptic receptors in the white cane handle for obstacle warnings, some participants observed that it would be best to create a single stand-alone device that users could simply put on without being concerned by complex setup.

Stand-Alone Operation

Connectivity with the smartphone was desirable for some but not all. Several testers asked for the device to connect to a telephone to interact with audio and send messages vocally (Italy, Japan). Others felt strongly that the device should be immediately usable for people who were older or were not interested in technology. A participant from the Japanese Federation for the Visually Impaired (JFVI) stated that only 50% of blind people in Japan use cell phones, so it was important that the device must function alone and untethered. A Swiss trainer suggested it would be a mistake to make it only work with connected apps: “It must absolutely be stand-alone.”

Aesthetic Considerations

Several ETAs on the market were characterized as bulky or unsightly, including some ETA integrations in the handle of the long white cane, devices worn on the body, and a device designed as eyewear that is no longer available on the market (iGlasses). Eyewear aesthetics were viewed as critical to acceptability of the commercial device. A business representative commented that the iGlasses device was never an option for their blind association’s store because they had an aesthetically displeasing design and lacked quality. A person in the USA thought a sports eyewear style would be a good direction to make them appealing, especially for young people. A style collection was suggested in Switzerland and Italy to allow for choice. A Swiss tester encouraged us to stay focused on obstacle detection while making sure good looks remained paramount. An American tester thought the selling point of style was significant. He had abandoned other smart eyeglasses used for other purposes because of feelings about his appearance. We felt it was critical for the device to remain close to regular eyeglasses in look and quality, while finding a way to offer different models and styles. An interchangeable front was proposed.

Design Challenges and Potential Drawbacks of the Eyewear Form

We heard concerns that, as with many other ETAs, it might be necessary to move the device manually to use techniques for scanning the environment for objects. A tester familiar with iGlasses, which incorporated a single ultrasonic sensor and no directional feedback, expressed concern that this would not be appropriate for a device that is worn on the head, as it would result in excessive head movement while in use.

To avoid the need for complex feedback, a single vertical channel for sensing and alerting to upper-body/head-level obstacles was implemented and no distinction in feedback was made for the height of the obstacle. Thus, vertical head movement was not necessary during foreseen mobility scenarios. The need for side-to-side head motion was addressed in the prototype via the three-part horizontal division of feedback zones (left, center, right). Such a system was reported using haptic feedback in a wristband in Pundlik et al. (2018). It was noted, however, that this system may require training for maintenance of proper forward-facing head position while walking. It may pose difficulties, for instance, for people accustomed to adjusting their head and eyes to focus objects in their path on the functional portion of their retina.

Modification of upper-hand and forearm technique for protection is potentially necessary as taught in O&M training (see Penrod et al., 2010, for description of this technique with other ETAs, e.g., handheld devices). Because the signal energy is emitted and absorbed by the eyeglasses, the user’s arm, when raised, would deflect the signal, causing continuous vibration; thus, compatibility with this self-protection technique is poor. During testing, users were instructed to pay attention to vibration intensity as an indicator of proximity of the obstacle to their head and upper body.

Prototype Testing Results

Nearly all testers were able to understand when they were in danger of colliding with an obstacle. Some collisions were attributed to errors maneuvering around the obstacle. Maze walks ranged from 10 to 80 m in length and averaged 24 m. Total number of collisions were counted for the entire walking length for each tester. By the third run through the maze, all testers except one were able to pass through without major error resulting in frontal collision with an obstacle. Out of 39 participants who walked through the maze, one person committed a single error resulting in collision, two people had two collisions each, and two people had three collisions.

Minor errors were more frequent, including leaving minimal space for passage around the obstacle, thus brushing it with a body part. In these cases (3 testers), further explanation on use of left-right feedback helped ameliorate the issue. A tester that committed three errors involving collisions reported that she had trouble feeling vibrational feedback and eventually concluded that the prototype was unsuitable for her. The tester was significantly shorter than others and had a small face size, resulting in poor fit of the prototype eyewear arms. Figure 4 shows the obstacle maze positioned under a tent canopy at a demonstration event in Japan.

Figure 4: *Mobile Obstacle Maze in Japan*

Obstacle avoidance performance was positively evaluated by most participants while self-reported or observed level of confidence during walks were generally evaluated somewhat lower. Tabel 2 shows counts for obstacle avoidance performance evaluations and Table 3 shows counts for level of confidence during walks. Both figures compare between testers who were blind and those that had low vision.

Table 2: *Evaluation of Obstacle Avoidance Following Maze Walks*

Evaluation	Count Blind	Count Low Vision
1 - Poor	0	0
2 - Fair	2	0
3 - Average	2	1
4 - Good	14	4
5 - Excellent	18	12

Table 3 *Evaluation of Confidence Level Following Maze Walks*

Evaluation	Count Blind	Count Low Vision
1 - Not at all confident	0	0
2 - Slightly confident	6	1
3 - Neither confident nor unconfident	2	3
4 - Moderately confident	11	9
5 - Very confident	15	3

Tests demonstrated no consistent difference in levels of confidence and obstacle avoidance performance evaluations between testers who identified themselves as being blind and low vision. Interest in the device across a range of vision impairments came from interview statements. Some testers mentioned specific vision impairments they thought would benefit from the device, but these results require more careful study because participants' history of vision impairment were not recorded. For instance, a Japanese tester felt "It … could be used daily, especially for people with amblyopia who lack peripheral vision."

Some testers reported lower confidence in the maze while obstacle avoidance performance was highly evaluated. Observation of testers' behavior helped to understand this result: Fluidity of movement during walks was highly variable among testers. Some testers stopped abruptly when the device signalled presence of an obstacle at any threshold distance, demonstrating difficulty comprehending the device or a cautious approach. Reported feeling of confidence was also connected to density of obstacles the tester needed to negotiate. One guide dog user, for instance, asked for us to set up several walks involving a single obstacle moved to various positions after each pass through the course. She felt this best reflected daily mobility situations, given the infrequency of encounters with such obstacles. Once the number of obstacles was reduced, she was able to move fluidly with the help of her guide dog by instructing the dog to move away from the upper-body obstacle.

Tester Feedback on the Prototype

Thirty-three testers' evaluations and comments expressed interest in the device for daily use. All O&M specialists involved in testing expressed interest for inclusion of the final device in training of O&M skills.

Coverage of Path of Travel by Sensors and Feedback System

The sensor coverage of the walking path (approximately 80 degrees horizontal field-of-view) coupled with left-center-right obstacle signalling received positive feedback. In comparison with handheld or cane-handle mounted ETAs, an O&M specialist felt that scanning motions typically required by these devices were difficult for congenitally blind people to understand. He observed that, consequently, they were harder to train, whereas he believed right and left feedback from Lighthouse Tech's device was potentially more intuitive and could require less training effort. A trainer from Switzerland had personally experienced or heard about user experiences with other electronic mobility aids. She felt that the prototype device's left-center-right feedback generally constituted an intuitive system that was easy to understand. She stated that simplicity and low training time was critical to device adoption.

Testers widely felt that qualities of vibration feedback needed improvement to be felt without causing fatigue, as vibration intensity was too strong, and caused the eyewear front of the prototype to vibrate in addition to the arms. Both outdoor and indoor use were considered by many testers and some suggested adjustable distance thresholds and vibration intensity to accommodate indoor use cases. Several testers suggested giving the device owner the option to fine-tune the haptic feedback levels and patterns to adjust for use in different environments.

Redundancy and Extension of Existing Mobility Aids

After testing the prototype, some participants appreciated the potential of the device to add extra security for use with the long cane and extended preview of the path beyond the cane. A participant commented that "sometimes the cane doesn't work, like if you miss something with your sweep. You have redundancy or an extra warning system." Common obstacles included thin signposts, or bicycles on sidewalks that could be missed by the cane: "The device should be helpful to warn about thin metal objects."

Concerns About Use in Crowded Areas

Testers from large cities, such as Tokyo and New York, commented that crowded roads presented challenges for long cane users. One participant that owned an ETA for daily use commented that he liked the way he could use it to detect people. He thought the prototype eyewear device could perform similarly. A Japanese tester with low vision was happy that "the device will always notify you with a vibration if there is someone next to you, so even people who lack peripheral vision can walk safely even in crowded places. It felt as safe as walking with a guide dog."

The amount of information conveyed via feedback was an important topic. Some testers appreciated having the option to receive vibration feedback for location of any object in their path, including people and lateral walls or fences that they would not consider dangerous obstacles: "The more you know, the better off you are" (USA). There were cases, however, where less information was desired: "For example, when you're at the park with your kids and this is a less threatening environment, it would be good to tone it down, and scale back to just important information" (USA). The dual threshold system that allows division between obstacles at close proximity and those at a greater distance from the tester was appreciated for helping users understand the level of danger of their situation. The system was compared positively by some testers to a parking sensor in a car that emits beeps at different frequencies depending on obstacle distance.

Head Posture Considerations

The eyeglasses form factor and system were given positive evaluation, and additional benefits were perceived by specialists. An American O&M specialist thought the device could help people learn to face the direction of travel with their head. He suggested it would be interesting to test further to see if haptic cueing or an audible beep could help people change their head posture, which may be tied to positive O&M outcomes. Trainers told us that they sometimes faced challenges with people pointing their heads down while training with the long cane. This may, however, present additional challenges for design of the eyewear ETA, but could also be understood as an opportunity to encourage improvement in head posture.

Feedback on Aesthetics and Wearability

Positive evaluations of device aesthetics and wearability helped people recommend the device for everyday use: "The [long] white cane already identifies you as a blind person. These glasses also help on the inclusive aspect, which is very important in the working world" (USA). A Japanese tester observed that "devices used by vision impaired people tend to be bulky and heavy, but these smart glasses are shaped like sunglasses and are lightweight, so it's nice to be able to wear them daily without feeling uncomfortable."

Outcomes and Benefits

Lighthouse Tech's design and testing experience could be described as an iterative process involving locating the voices of people that were most appropriate for evaluating acceptability of the device, approving design decisions, and suggesting features or functionality.

We aim to benefit the audience of this paper by providing details about user needs in a wearable ETA. The unique eyewear form and system of obstacle communication were positive benefits that emerged from workshops, interviews, and testing during the design process. Interviews confirmed that people were less willing to embrace solutions that make disability more visible and were excited by the potential of a design approach that put high priority on aesthetics and looks.

Lighthouse Tech's approach involving an artificial maze, if not unique, proved important for obtaining rapid evaluations of performance and soliciting feedback. The maze allowed for quick explanation and comprehension of device operation in a safe setting, while allowing testers to experience obstacle types that could not always be readily located in the settings where tests were conducted. Reported and observed feeling of confidence was influenced by the testers' feelings about the dense artificial maze environment. Several testers asked to walk in the maze with only one or two obstacles to simplify evaluation. Nonetheless, the maze environment benefited the Lighthouse Tech team in terms of efficiency of testing and usefulness of feedback.

Benefits were experienced by people living with blindness and low vision and for O&M specialists, who imagined applications of the device for teaching or correcting behaviors related to head orientation and awareness of surroundings. Because testers were nearly all members of a blind association and many had received support through O&M training, we could not make observations regarding suitability of the device for people with little or no training. Furthermore, no youth or children were included in these testing activities.

Conclusions

ETAs need to process and codify information from the environment (Smith & Penrod, 2010). Our challenge was to devise and validate a system that accommodated incorporation in eyeglasses and communicated information effectively for users. We conducted workshops, customer interviews, and prototype testing to gauge interest in the eyewear form factor as an ETA with the purpose of developing a commercially available device. Results provided evidence for enthusiasm for the proposition of a stylish or fashionable assistive technology device, while we acknowledge that future exploration with an independent reviewer could potentially provide more objective testing.

We received positive feedback on the prototype device's detection and feedback system. Many testers, including O&M specialists, expressed interest in the device for daily use in outdoor and indoor environments for a range of vision impairments. Testers using the obstacle maze demonstrated that obstacle collisions could be effectively avoided within several minutes of presentation of device operation, and fluidity of movement around obstacles in the maze was possible for experienced long cane and guide dog users after several maze walks.

Testers suggested a range of scenarios for use, including for avoiding collisions with obstacles that could be missed by the long cane and guide dog, and to help avoid contact with people. A prominent concern, however, was potential disturbance or annoyance caused by excessive tactile-haptic feedback. Results indicate that testers were interested in increasing their awareness of surroundings and were thus willing to receive feedback for objects or people that did not constitute an immediate threat of injury. Cues for objects in left, right, and central zones and different feedback for near and far zones were appreciated for helping the user better understand the location of objects.

Walking speed during our tests was not measured and thus could not be compared to preferred walking speed of the testers with their preferred mobility aid. Future testing will focus on establishing appropriate defaults for distance range thresholds and sensor coverage or path preview to adapt to the walking speeds and preferences of people with highly developed independent mobility skills. These tests will integrate measures related to preferred walking speed and obstacle density to facilitate these design decisions and aid interpretation of tests for rehabilitation and O&M specialists. Long-term feedback from use in familiar everyday settings is also required.

Declarations

This content is solely the responsibility of the author(s) and does not necessarily represent the official views of ATIA. The author is a full-time employee of Lighthouse Tech SA, which developed the prototype device discussed in this paper. Lighthouse Tech SA fully funded the research and testing reported in this paper. The author was involved in device development and designed the test protocols reported in this paper.

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References

Bamdad, M., Scaramuzza, D., & Darvishy, A. (2024). SLAM for Visually Impaired People: A Survey. *IEEE Access*, *12*, 130165–130211. https://doi.org/10.1109/ACCESS.2024.3454571

Brunes, A., Hansen, M. B., & Heir, T. (2019). Loneliness among adults with visual impairment: Prevalence, associated factors, and relationship to life satisfaction. *Health and Quality of Life Outcomes*, *17*(1), 24. https://doi.org/10.1186/s12955-019-1096-y

Brunes, A., & Heir, T. (2021). Serious life events in people with visual impairment versus the general population. *International Journal of Environmental Research and Public Health*, *18*(21), 11536. https://doi.org/10.3390/ijerph182111536

Chanana, P., Paul, R., Balakrishnan, M., & Rao, P. (2017). Assistive technology solutions for aiding travel of pedestrians with visual impairment. *Journal of Rehabilitation and Assistive Technologies Engineering*, *4*, 2055668317725993. https://doi.org/10.1177/2055668317725993

Chang, K. J., Dillon, L. L., Deverell, L., Boon, M. Y., & Keay, L. (2020). Orientation and mobility outcome measures. *Clinical and Experimental Optometry*, *103*(4), 434–448. https://doi.org/10.1111/cxo.13004

de Boer, M. R., Pluijm, S. M., Lips, P., Moll, A. C., Völker-Dieben, H. J., Deeg, D. J., & van Rens, G. H. (2004). Different aspects of visual impairment as risk factors for falls and fractures in older men and women. *Journal of Bone and Mineral Research*, *19*(9), 1539–1547. https://doi.org/10.1359/JBMR.040504

Dernayka, A., Amorim, M. -A., Leroux, R., Bogaert, L., & Farcy, R. (2021). Tom Pouce III, an electronic white cane for blind people: Ability to detect obstacles and mobility performances. *Sensors*, *21*(20), 6854. https://doi.org/10.3390/s21206854

dos Santos, A. D. P., Ferrari, A. L. M., Medola, F. O., & Sandnes, F. E. (2022). Aesthetics and the perceived stigma of assistive technology for visual impairment. *Disability and Rehabilitation: Assistive Technology*, *17*(2), 152–158. https://doi.org/10.1080/17483107.2020.1768308

Faucett, H. A., Ringland, K. E., Cullen, A. L. L., & Hayes, G. R. (2017). (In)visibility in disability and assistive technology. *ACM Transactions on Accessible Computing*. *10*(4):1–17. https://doi.org/10.1145/3132040

Jacobson, W. H. (2013). *The art and science of teaching orientation and mobility to persons with visual impairments* (Second edition). AFB Press.

Lundälv, J., & Thodelius, C. (2021). Risk of injury events in patients with visual impairments: A Swedish survey study among hospital social workers. *Journal of Visual Impairment & Blindness*, *115*(5), 426–435. https://doi.org/10.1177/0145482X211046666

Manduchi, R., & Kurniawan, S. (2011). Mobility-related accidents experienced by people with visual impairment. *AER Journal: Research and Practice in Visual Impairment and Blindness*, *4*(2), 44–54. https://users.soe.ucsc.edu/~manduchi/papers/MobilityAccidents.pdf

Miller, A., Macnaughton, J., Crossland, M. D., & Latham, K. (2023). “I’m like something out of star wars”: A qualitative investigation of the views of people with age-related macular degeneration regarding wearable electronic vision enhancement systems. *Disability and Rehabilitation*, *0*(0), 1–10. https://doi.org/10.1080/09638288.2023.2278179

Penrod, W. M., Smith, D. L., Haneline, R. & Corbett, M. P. (2010). Teaching the use of electronic travel aids and electronic orientation aids. In W. R. Wiener, R. L. Welsh, & B. B. Blasch (Eds.), *Foundations of orientation and mobility* (3rd ed, pp. 462–485). AFB Press.

Pogrund, R. L., & Griffin-Shirley, N. (Eds.). (2018). *Partners in o&m: Supporting orientation and mobility for students who are visually impaired*. American Printing House for the Blind.

Pundlik, S., Baliutaviciute, V., Moharrer, M., Bowers, A. R., & Luo, G. (2021). Home-use evaluation of a wearable collision warning device for individuals with severe vision impairments: A randomized clinical trial. *JAMA Ophthalmology*, *139*(9), 998–1005. https://doi.org/10.1001/jamaophthalmol.2021.2624

Pundlik, S., Tomasi, M., Moharrer, M., Bowers, A. R., & Luo, G. (2018). Preliminary evaluation of a wearable camera-based collision warning device for blind individuals. *Optometry and Vision Science*, *95*(9), 747. https://doi.org/10.1097/OPX.0000000000001264

Riazi, A., Riazi, F., Yoosfi, R., & Bahmeei, F. (2016). Outdoor difficulties experienced by a group of visually impaired Iranian people. *Journal of Current Ophthalmology*, *28*(2), 85–90. https://doi.org/10.1016/j.joco.2016.04.002

Roentgen, U. R., Gelderblom, G. J., & de Witte, L. P. (2012). The development of an indoor mobility course for the evaluation of electronic mobility aids for persons who are visually impaired. *Assistive Technology: The Official Journal of RESNA*, *24*(3), 143–154. https://doi.org/10.1080/10400435.2012.659954

Smith, D. L., & Penrod, W. M. (2010). Adaptive technology for orientation and mobility. In W. R. Wiener, R. L. Welsh, & B. B. Blasch (Eds.), *Foundations of orientation and mobility, third edition: Volume 1, history and theory.* (3rd ed, pp. 241–276). AFB Press.

van Nispen, R. M., Virgili, G., Hoeben, M., Langelaan, M., Klevering, J., Keunen, J. E., & van Rens, G. H. (2020). Low vision rehabilitation for better quality of life in visually impaired adults. *The Cochrane Database of Systematic Reviews*, *2020*(1), CD006543. https://doi.org/10.1002/14651858.CD006543.pub2

Zijlstra, G., van Rens, G., Scherder, E., Brouwer, D., van der Velde, J., Verstraten, P., & Kempen, G. (2009). Effects and feasibility of a standardised orientation and mobility training in using an identification cane for older adults with low vision: Design of a randomised controlled trial. *BMC Health Services Research*, *9*(1), 153. https://doi.org/10.1186/1472-6963-9-153

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Voices from the Industry

Enhancing Independence: Outcomes of AngelSense Assistive Technology with Behavioral Strategies

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Abstract

This manuscript explores the development and outcomes of the AngelSense Learning Program, a 3-month intervention designed to enhance independence skills and reduce maladaptive behaviors in individuals with special needs. The program is founded on AngelSense Assistive Technology combined with behaviorally-based strategies, providing parents with the tools and support necessary to foster their child's autonomy in natural environments. Through a series of pilot studies, we tested and refined the program, demonstrating significant improvements in participant independence, reductions in caregiver stress, and the emergence of unanticipated skills. The results suggest that this approach offers a scalable, flexible solution that can be applied across diverse age groups and skill levels. The implications for broader implementation and the potential for long-term benefits are discussed, along with recommendations for future research.

Keywords: assistive technology, skill building, independence, behavioral interventions

Enhancing Independence: Outcomes of AngelSense Assistive Technology with Behavioral Strategies

Assistive technology (AT) encompasses a wide range of tools and services designed to enhance the functional capabilities of individuals with disabilities, facilitating greater independence and participation across various life domains. These technologies play a vital role in promoting inclusion and accessibility in education, employment, and daily living activities. Current utilization of assistive technology includes the following:

- Educational Settings: AT is extensively utilized to support students with disabilities by providing access to the general curriculum and fostering inclusive educational environments. Devices and software applications assist in areas such as communication, mobility, and learning, thereby enhancing educational outcomes (Doe, 2022).
- Daily Living and Independence: AT solutions, such as mobility aids, communication devices, and environmental control systems, empower individuals with disabilities to perform daily tasks more independently, significantly improving their quality of life (Smith & Jones, 2023).
- Employment: In the workplace, AT facilitates job performance by offering necessary accommodations, enabling individuals with disabilities to engage in meaningful employment and contribute effectively (Brown, 2021).

The integration of assistive technology is pivotal in breaking down barriers and promoting autonomy for individuals with special needs, aligning with the goals of inclusive practices and equal opportunities.

This manuscript explores the potential of assistive technology, specifically AngelSense, to enhance independence in individuals with special needs, thereby reducing reliance on caregivers. By leveraging technology designed to ensure safety while promoting independence, we aim to demonstrate how individuals with developmental disabilities can experience greater autonomy without compromising their well-being. Through the AngelSense Learning Program, we investigate how this innovative approach can transform the lives of individuals with special needs, reduce reliance on restrictive measures, and foster a more empowered, independent existence.

Personal Statement

In this article, we present a detailed account of our approach, which equips parents with basic behavioral principles specifically to make use of the AngelSense Assistive Technology in a way that addresses their main challenges. We assert that the use of AngelSense technology enhances our ability to deliver a comprehensive approach to skill development and safety consideration to reduce the risk involved in targeting independence. Furthermore, by positioning parents at the center of the intervention process, we facilitate a more effective delivery of care and a smoother transfer of skills across environments. This integrated approach has the potential to reduce the reliance on additional services for individuals with special needs, break the vicious cycle of safety concerns, and ultimately foster greater independence. This level of impact extends into higher levels of independence in each realm of the individual's life, including the school environment, employment or vocational opportunities, and life and adaptive skills.

Target Audience and Relevance

This article is pertinent to multiple professional groups and offers valuable insights as outlined.

Behavior Analysts and Behavioral Service Professionals

The integration of AngelSense Assistive Technology has significantly enhanced our ability to deliver effective skill-building in natural environments by enabling parents to provide remote support to their children. This addresses a critical limitation of center-based and home-based programs, where fading 1:1 support can be challenging. Our skill-building program, tested in three pilot studies, specifically targets these issues and has demonstrated a positive impact on participating families by facilitating the application of acquired skills in daily life. This approach has also resulted in a significant reduction of parent stress and anxiety.

Parents of Individuals with Special Needs

The AngelSense Learning Skill-Building Program has empowered parents of individuals with special needs ranging from ages 3 to 30 by providing training in skill development and behavior reduction using AngelSense technology. The program addresses the need for parents to restrict the environment or avoid community engagement. Participants have achieved significant gains and higher levels of independence as a result of this program.

Educators and School Professionals

The highly individualized AngelSense Learning Program addresses the unique needs of students with special needs, particularly in building independence skills. Educators and school professionals, who often face challenges in fading 1:1 support, can benefit from the program's focus on gradually reducing direct support in a safe and effective manner through the use of AngelSense technology.

Employment Coaches and Mentors

Employment providers frequently encounter difficulties in supporting employees with disabilities. The AngelSense Learning Program offers caregivers—including parents, educators, and mentors—the tools to provide remote support, allowing individuals with special needs to request assistance as needed. This approach promotes greater independence in the vocational setting, ensuring that support is both adequate and flexible.

AngelSense Assistive Technology

To provide a comprehensive understanding of the AngelSense Learning Skill-Building Program, it is essential to first introduce the AngelSense Assistive Technology, which forms the foundation of our approach. The AngelSense includes a wearable device, a caregiver-controlled mobile app, and integrated features that enable real-time location tracking, communication, and remote support. With tools such as an assistive speakerphone, a configurable SOS button, and smart alert capabilities, AngelSense is often used to address safety concerns, promote skill development, and provide caregivers with tools to offer consistent, remote support in real-world settings.

Central to our skill-building program are the device’s speakerphone, SOS button, and Smart Voice. The speakerphone, which can be activated remotely by caregivers via the app, allows for real-time communication with the individual, creating opportunities to target and reinforce skills related to independence. Similarly, the SOS button empowers the individual to immediately contact their caregiver when needed. Smart Voice enables the caregiver or the child to record messages that can be delivered at specified times, upon arrival or departure of a location, or on demand. These features have been instrumental in developing a program that emphasizes the cultivation of independence through guided support and communication.

AngelSense Assistive Technology and Skill Building

Over the past decade, AngelSense has been widely utilized as a safety tool, and during this time we encouraged and witnessed many parents leverage the safety relief to allow more outings and new types of activities as well as use it to support the development of independence skills. Many parents reported that AngelSense enabled their children to safely engage in everyday activities, such as walking the dog around the block, checking the mail, taking public transportation to school or work, and even living independently. These observations led us to hypothesize that integrating AngelSense Assistive Technology with behavior analytic skill-building would encourage more families to expand the use of the technology, yielding significant benefits. Specifically, we anticipated outcomes such as increased independence skills in individuals with special needs, a decrease in maladaptive behaviors (e.g., elopement, meltdowns, aggression, and self-injurious behaviors), and a reduction in caregiver stress.

Method

To evaluate our hypothesis based on caregiver feedback, we conducted a series of pilot studies, each designed to progressively test different aspects of our approach. The first phase focused on reducing maladaptive behaviors, specifically attention-maintained elopement, using the AngelSense Assistive Technology. Building on these initial findings, the second phase targeted the enhancement of independence skills in a select group of individuals with special needs. In the third phase, we expanded our focus to assess the program's effectiveness across a broader range of individuals with varying learning levels. Currently, we are in the fourth phase of our pilot studies, where we are examining the necessary level of support resources and the duration of training required for parents to effectively implement skill-building strategies using AngelSense. The anticipated outcome of this phase is to develop a comprehensive program that equips parents, service providers, educators, and employment coaches with the tools and training needed to provide remote support and foster higher levels of independence in individuals with special needs.

Pilot Phase 1: Decreasing Attention-Maintained Elopement

In Phase 1, a series of function-based skill-building programs were created. The use of AngelSense assistive technology was integrated within the participants' Applied Behavior Analysis (ABA) Therapy. The assistive technology was utilized in a way to teach new adaptive skills to promote more independence in daily life and to help with transitioning to a less restrictive environment. As we know, a common maintaining variable for elopement can often be attention. However, it may not be possible to remove attention in a safe manner. While functional communication training (FCT) procedures can be effective, it may be difficult to transfer outside of tightly controlled environments. Our initial hypothesis was to test and see if attention delivered through the device would compete with the proximal attention maintaining elopement by teaching a high probability response. Participants (parents) were recruited by the AngelSense Learning clinical team and were selected from current AngelSense users that met participation criteria. Parents were given a detailed description of the program and submitted written consent to participate.

Participants. In Phase 1, participants were recruited based on the following criteria.

- Number of Participants*: 2*
- Age Range: *9 to 15 years old*
- Current Therapy Status: Receiving ABA therapy

Within Phase 1, AngelSense collaborated with Board Certified Behavior Analysts (BCBAs) working with an ABA provider. Four individuals met inclusion criteria which included maladaptive behaviors identified for reduction which were controlled largely by attention. An AB design was implemented and replicated across participants to evaluate results.

Procedures. A skill building program was implemented utilizing differential reinforcement and teaching a high-probability response. Participants were taught to respond to a 1-step instruction with the staff just 1–3 feet away and gradually increased in distance as mastery criteria was met.

Phases. The phases were as following:

1. Learner Readiness: Child tolerates wearing device
2. Responds to 1-step instructions with instructor (1–3 feet from staff)
3. Responds to 1-step instructions with instructor (3–6 feet from staff)
4. Responds to 1-step instructions with instructor (staff across room and out of sight)
5. Responds to 1-step instructions with parents (generalize to parents)

Results. With the implementation of a DRA and High Probability Response procedure, we were able to successfully fade out the proximal attention of the staff, while still delivering attention through the 2-way speakerphone on the AngelSense device. In the presence of the Motivating Operation (MO) for attention, if the individual responded to the 1-step instruction that was delivered through the device, we would reinforce with praise through the device. Therefore, we could then utilize this technology to implement a Non-Contingent Reinforcement (NCR) contingency and deliver attention through the device on a specific schedule, or we could utilize a DRA and High Probability response that could change the value of elopement because the individual is still receiving attention. The goal ultimately would be that attention delivered through the device would compete with proximal attention. As a result of this procedure, elopement and challenging behaviors maintained by attention were able to decrease to near-zero levels. This shows that providing attention through the speakerphone was successful in teaching new adaptive skills and simultaneously decreasing the target behavior (see Figures 1a, 1b, and 1c).

Figure 1a: *Participant 1 Results*

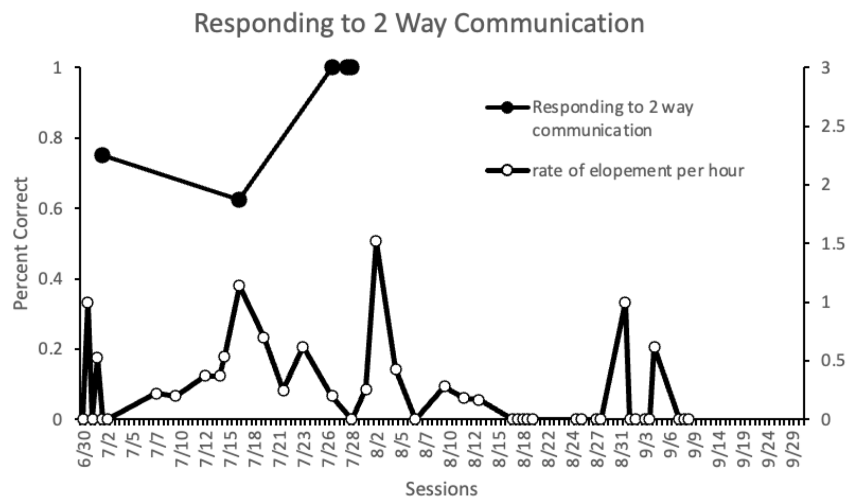


Figure 2a: *Participant 2 Results*

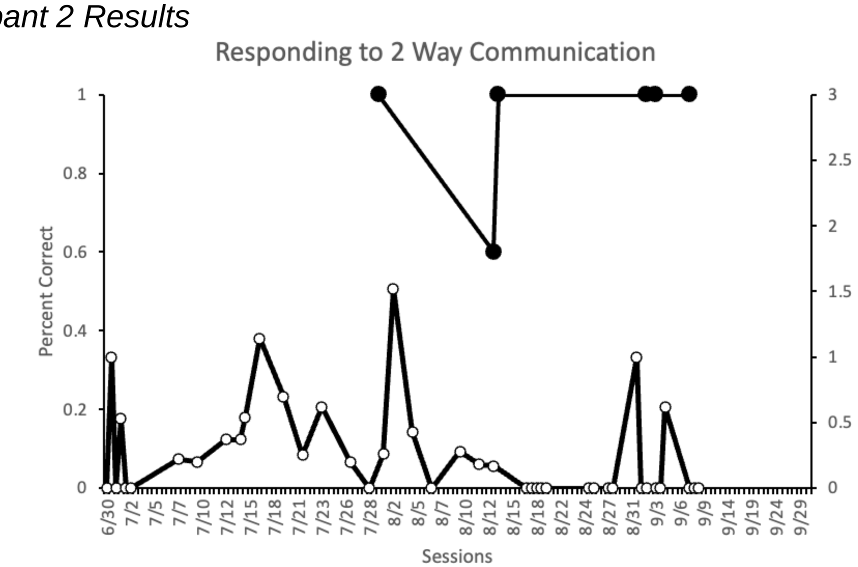
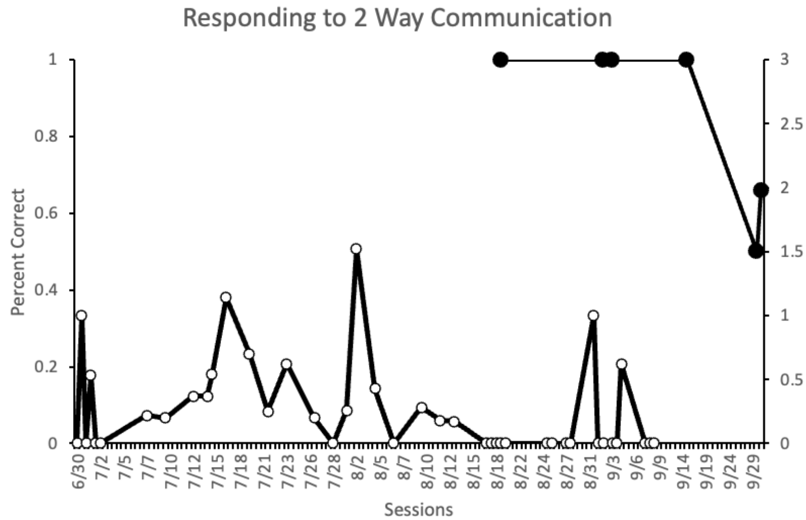


Figure 3a: *Participant 3 Results*



Phase 2: Skill Building for Independence in a Selected Group of Individuals

In Phase 2, we expanded our study to focus on skill building for independence among a targeted group of individuals. Participants (parents) were recruited by the AngelSense Learning clinical team and were selected from current AngelSense users that met participation criteria. Parents were given a detailed description of the program and submitted written consent to participate. The participants met the following criteria:

Participants. In Phase 2, participants were recruited based on the following criteria.

- Number of Participants*:* 3 parents with children diagnosed with Autism Spectrum Disorder (ASD)
- Age Range: *9 to 15 years old*
- Current Therapy Status: Participants were not enrolled in ABA therapy at the time of the study

Inclusion Criteria. Participants were selected based on the following criteria:

- Adequate Listener Responding Skills: The ability to follow instructions and engage in tasks
- Ambulatory: The ability to move independently
- Lower Frequency of Maladaptive Behavior: Reduced instances of behaviors that could interfere with the study
- Trial Capability: The ability to complete 10 trials per week

Procedures. This phase utilized a single-subject design to evaluate the effectiveness of the intervention. The process began with an onboarding meeting and orientation session where parents received initial training. After this, parents met weekly with their clinician, a Board Certified Behavior Analyst (BCBA), to discuss progress, review the implementation of strategies, and interpret the data collected.

Participants were equipped with AngelSense Assistive Technology and were guided by their clinician on the implementation of behaviorally-based strategies aimed at systematically increasing their child's level of independence. During the weekly sessions, parents received specific guidance and recommendations, which they then applied throughout the week. Data was collected using Discrete Trial Training (DTT) whenever a recommendation was implemented. This data was reviewed in subsequent guidance sessions, and clinicians provided additional training to parents on how to modify strategies as needed to ensure continuous progress.

Results. Throughout this pilot phase, two key outcomes were continuously measured: increases in independence skills and reductions in caregiver stress. The data on independence skills was collected weekly during the implementation process, while caregiver stress levels were assessed using the Generalized Anxiety Disorder-7 (GAD-7) scale and the Caregiver Stress and Strain Questionnaire.

The combination of AngelSense Assistive Technology and behavior analytic parent training led to significant progress in the participants' independence skills. Additionally, parents reported a notable reduction in stress levels, indicating that the intervention was effective not only in promoting the independence of individuals with special needs but also in alleviating caregiver stress (see Tables 1 and 2).

Table 1: *Self-reported Measurement of Anxiety*

Over the last 2 weeks, how often have you been bothered by the following problems?	Baseline	Month 1	Month 2	Month 3
Feeling nervous, anxious or on edge	1.67	1.6	1.5	1
Not being able to stop or control worrying	1.67	1.4	1.33	1
Worrying too much about different things	1.67	1.6	1.5	1
Trouble relaxing	2	1.8	1.67	1
Being so restless that it is hard to sit still	1.67	1.2	1	1
Becoming easily annoyed or irritable	1	1.6	1.5	1.33
Feeling afraid as if something awful might happen	0.67	0.6	0.5	0.33
Average	1.48	1.40	1.29	0.95

Table 2: *Caregiver Stress and Strain Questionnaire*

Question	Baseline	Post Implementation
Interruption of personal time resulting from your child's emotional or behavioral problem?	4.50	3.33
You missing work or neglecting other duties because of your child's emotional or behavioral problem?	3.50	3.00
Disruption of family routines due to your child's emotional or behavioral problem?	4.50	3.33
Any family member having to do without things because of your child's emotional or behavioral problem?	3.50	3.00
Any family member suffering negative mental or physical health effects as a result of your child's emotional or behavioral problem?	3.50	3.00
Your child getting into trouble with the neighbors, the school, the community, or law enforcement?	3.00	2.33
Financial strain for your family as a result of your child's emotional or behavioral problem?	3.00	2.67
Less attention paid to other family members because of your child's emotional or behavioral problem?	3.50	2.33
Disruption or upset of relationships within the family due to your child's emotional or behavioral problem?	3.50	2.33
Disruption of your family's social activities resulting from your child's emotional or behavioral problem?	4.50	4.00
How isolated did you feel as a result of your child's emotional or behavioral problem?	3.50	3.00
How sad or unhappy did you feel as a result of your child's emotional or behavioral problem?	4.00	3.33
How embarrassed did you feel about your child's emotional or behavioral problem?	2.00	2.67
How well did you relate to your child?	3.00	3.00
How angry did you feel toward your child?	3.50	2.67
How worried did you feel about your child's future?	4.50	4.33
How worried did you feel about your family's future?	4.50	3.67
How guilty did you feel about your child's emotional or behavioral problem?	4.50	3.33
How resentful did you feel toward your child?	3.50	2.00
How tired or strained did you feel as a result of your child's emotional or behavioral problem?	4.50	4.00
In general, how much of a toll has your child's emotional or behavioral problem taken on your family?	4.00	3.67
Average	3.74	3.10

Phase 3: Skill Building Across Multiple Ages and Learning Levels

In Phase 3, we extended our participant base to examine the scope of individuals with special needs that could gain critical independence skills with our approach. Participants (parents) were recruited by the AngelSense Learning clinical team and were selected following referrals from support coordinators and clinicians working directly with the families. Parents were given a detailed description of the program and submitted written consent to participate.

Participants. In Phase 3, participants met the following criteria.

- Number of Participants*:* 12 parents with children and adults diagnosed with ASD
- Participants were recruited by the AngelSense Learning clinical lead and were referred by support coordinators assisting the
- Age Range: *3 to 30 years old*
- Current Therapy Status: Participants varied in services, including speech therapy, occupational therapy, Applied Behavioral Analysis, or were enrolled in no additional services

Inclusion Criteria. Participants were selected based on the following criteria:

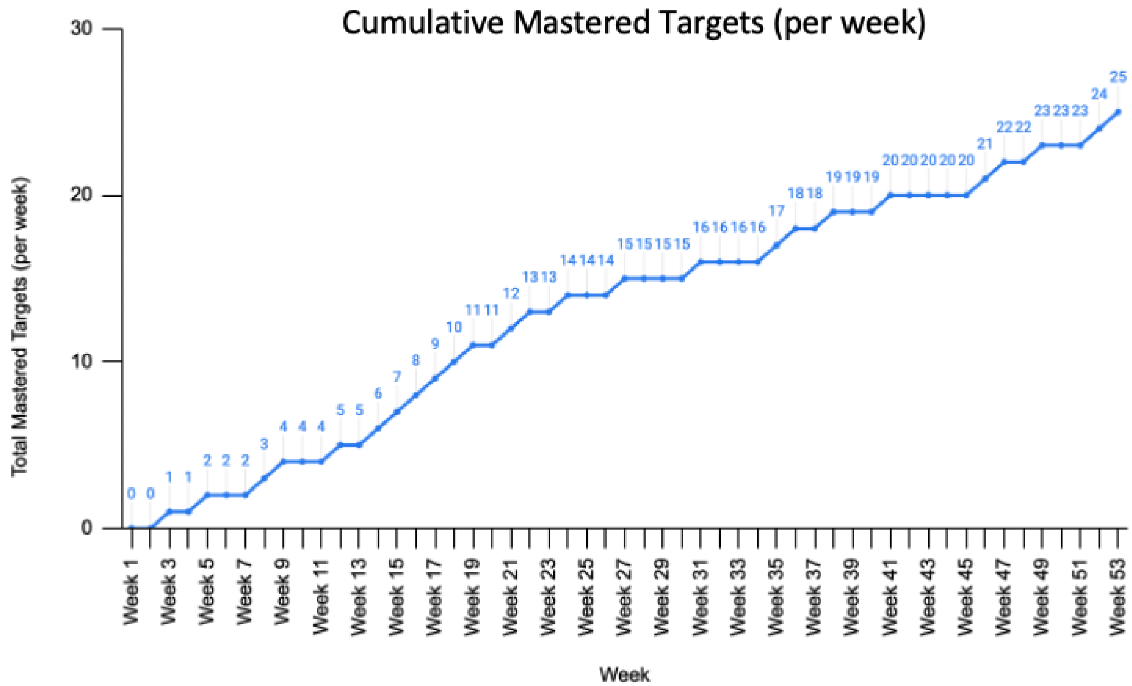
- Availability for Guidance: The ability to meet once a week to discuss progress
- Trial Capability: The ability to complete 10 trials per week

Procedures. This phase also employed a single-subject design to evaluate the program's effectiveness, closely mirroring the approach used in Phase 2. The primary variable altered in this phase was the expanded range of participant ages and skill levels. Parents were provided with AngelSense Assistive Technology, participated in an initial onboarding and orientation session, collected Discrete Trial Training (DTT) data while implementing clinician recommendations, and engaged in weekly guidance sessions with their clinician.

The broader range of ages and skill levels allowed us to target independence skills relevant to various contexts, including school, employment, and community engagement. Participants presented a diverse array of goals, from learning to respond to a caregiver's voice through the speakerphone to attending overnight camps independently after previously relying on constant 1:1 support.

Results. In Phase 3, the primary focus was on measuring the acquisition of independence skills by individuals with special needs. Data collected from parents were used to assess the effectiveness of the program, with the expectation that participants would show a significant increase in independence skills. The single-subject design facilitated the establishment of goals tailored to each participant's use of AngelSense Assistive Technology, resulting in substantial gains in the skills targeted. An additional noteworthy observation was that some participants began acquiring new skills that were not explicitly targeted or measured. This prompted us to collect cumulative data on these emergent skills, as illustrated in Figure 2.

Figure 2: *Cumulative Acquired Skills per Week*



Unexpectedly, several other positive outcomes were reported by parents, including increased confidence in their own abilities and in their child's capabilities. Parents also noted heightened motivation in their child to learn new skills, a significant reduction in maladaptive behaviors not directly targeted by the program, and an enhanced sense of comfort in taking their child on vacations, engaging in community activities, and supporting their participation in school or vocational opportunities.

Building on the previous phases, we have developed and formalized the AngelSense Learning Program. In this final phase, we aim to test our hypothesis that this comprehensive approach can effectively prepare parents for the transfer of treatment and care while reducing the overall need for external services. The current phase involves evaluating the program as a time-limited intervention with extensive support to ensure adequate parent training and implementation.

Phase 4: The AngelSense Learning Program

Building on the previous phases, we have developed and formalized the AngelSense Learning Program. In this final phase, we aim to test our hypothesis that this comprehensive approach can effectively prepare parents for the transfer of treatment and care while reducing the overall need for external services. The current phase involves evaluating the program as a time-limited intervention with extensive support to ensure adequate parent training and implementation. Participants will be recruited by the AngelSense Learning team following referrals from their support coordinators. Parents will be given detailed information regarding the program and submit written consent to participate.

Participants. In Phase 4, we will extend the criteria from Phase 3 to include a broader participant base:

- Number of Participants: 20–25 parents with children diagnosed with ASD
- Age Range: No specific age requirements
- Current Therapy Status: Participants may be engaged in various services, including speech therapy, occupational therapy, Applied Behavior Analysis (ABA), or may not be receiving additional services.

Inclusion Criteria. Participants will be selected based on referrals from support coordinators and must meet the following criteria:

- Availability for Guidance: Ability to attend weekly meetings to discuss progress
- Trial Capability: Ability to complete 10 trials per week

Procedures. Phase 4 will utilize a single-subject design to formalize the AngelSense Learning Program. The program will involve the following components:

- Onboarding Meeting and Orientation: Parents will meet with their clinician to set goals and establish implementation strategies.
- Weekly Guidance Sessions: Parents will have weekly meetings with their clinician to review progress, discuss implementation, and analyze data.
- Asynchronous Support: Parents will have on-demand access to their clinician for voice, text, or video messages, allowing for flexible, real-time guidance.
- AngelSense Learning Online Course: Parents will receive access to an online course that provides behavior-analytic tools to complement the use of AngelSense Assistive Technology.

We anticipate that this phase will validate the effectiveness of combining AngelSense Assistive Technology with behaviorally-based interventions in enhancing independence skills and reducing maladaptive behaviors across various ages, skill levels, and learning styles.

Outcomes and Benefits

The AngelSense Learning Program has demonstrated significant and multifaceted outcomes across the different phases of our research. These outcomes not only highlight the effectiveness of the intervention but also underscore the broader benefits for individuals with special needs, their families, and the professionals who support them.

Enhanced Independence Skills

Across all phases, participants exhibited substantial gains in independence skills. The use of AngelSense Assistive Technology, combined with behavior-analytic strategies, enabled individuals to achieve greater autonomy in daily activities. These skills ranged from responding to caregivers through the device to engaging independently in school, vocational, and community activities.

Reduction in Maladaptive Behaviors

Participants also showed a marked decrease in maladaptive behaviors, such as elopement, meltdowns, and aggression. This reduction was particularly notable in behaviors that had previously hindered their ability to participate fully in daily life. The structured approach of the AngelSense Learning Program provided the consistency and support necessary to address these challenges effectively. Additionally, the ability for caregivers to support their loved ones with special needs through the speakerphone assisted greatly in preventing maladaptive behaviors from becoming maintained by attention.

Increased Parental Confidence and Competence

A significant outcome of the program was the increased confidence and competence reported by parents. Through targeted training and ongoing support, parents felt more empowered to manage their child's needs and to promote their independence. This shift not only reduced caregiver stress but also fostered a more positive dynamic within the family. Parents also reported that the AngelSense Assistive Technology gave them confidence in their child's safety, which allowed them to access experience in higher levels of autonomy.

Emergence of New Skills

In Phase 3, we observed the emergence of new, unanticipated skills in participants, suggesting that the program may have broader developmental benefits. These emergent skills, which were not directly targeted, indicate the potential for AngelSense Assistive Technology and behavior-analytic interventions to stimulate general skill acquisition.

Flexibility and Accessibility of Support

The program's structure, which includes weekly guidance sessions, asynchronous support, and an online training course, ensures that parents can access the necessary tools and guidance at their convenience. This flexibility has proven to be crucial in accommodating the diverse needs and schedules of families, thereby enhancing the program's accessibility and effectiveness.

Broader Applicability Across Ages and Skill Levels

The success of the program across a wide range of ages and skill levels confirms its adaptability and relevance to a diverse population. Whether the goal was to support a young child in becoming more independent in school or to help a teenager transition to vocational opportunities, the AngelSense Learning Program proved effective in meeting these varied needs.

Long-Term Benefits for Families and Service Providers

The positive outcomes in each pilot phase extended beyond the immediate intervention period. Parents reported feeling more comfortable allowing their children to participate in community activities, attend school, or engage in vocational settings independently. This shift suggests potential long-term benefits, including reduced reliance on intensive services and a greater overall quality of life for both the individual and their family.

Discussion

The results of this study highlight the profound impact that the AngelSense Assistive Technology, combined with the AngelSense Learning Program, can have on promoting independence and reducing maladaptive behaviors in individuals with special needs. Findings were consistent across all phases, demonstrating the efficacy and versatility of this approach, aligning with broader research on the integration of assistive technology and behavioral interventions.

Integration of Technology and Behavioral Science

One of the most significant contributions of this program is the integration of assistive technology with evidence-based behavioral science. Previous research has demonstrated that combining assistive technology with cognitive-behavioral programs effectively promotes adaptive skills and reduces challenging behaviors in individuals with disabilities (Stasolla & Boccasini, 2018). Similarly, the AngelSense Learning Program demonstrates broader applicability by integrating parent training and behavioral strategies with the technology's features to address critical challenges, such as generalizing and maintaining skills beyond controlled environments. This integration provides a practical solution for overcoming limitations traditionally faced in therapeutic settings.

The Role of Parents as Central Agents of Change

This study underscores the critical role of parents in the therapeutic process. By positioning parents as central agents of change, the AngelSense Learning Program aligns with findings from Wicker (2022), which highlight the efficacy of parent-mediated technology-based interventions in teaching daily living skills to individuals with autism spectrum disorder. This empowerment not only facilitates skill development in the child but also fosters a collaborative and sustainable approach to care. Parents who are equipped with the right tools and knowledge reported significant improvements in their child's outcomes and their own confidence, validating the potential of this approach.

Preparing Parents for Transfer of Treatment and Care

Traditional behavioral interventions often face limitations in their ability to fade 1:1 support and ensure skill generalization to real-world settings. The AngelSense Learning Program addresses these limitations by enabling parents to reinforce skills in natural environments while maintaining the safety and structure afforded by the technology. This dual approach aligns with broader findings on the role of assistive technology in enhancing autonomy and reducing caregiver dependency (Smith & Jones, 2023).

Emergent Skills and Unanticipated Outcomes

An intriguing finding was the emergence of unanticipated skills during Phase 3 of the study. This outcome resonates with the broader literature suggesting that environments enriched with assistive technology can stimulate generalized skill acquisition beyond the targeted behaviors (Wicker, 2022). Further research is warranted to investigate the mechanisms driving these emergent outcomes and their potential for wider developmental benefits.

Implications for Broader Implementation

The success of the AngelSense Learning Program across diverse participants—including variations in age, skill level, and current therapeutic involvement—suggests broad applicability. This finding aligns with global perspectives on assistive technology’s scalability and adaptability to diverse populations and settings (Brown, 2021). Moreover, the program’s synchronous and asynchronous support design enhances its accessibility for families across geographic and resource limitations, making it a promising model for widespread implementation.

Limitations and Future Directions

While promising, the study with multiple phases has limitations. The reliance on single-subject design, while allowing for detailed analysis, limits the generalizability of findings. Additionally, self-reported data from parents may introduce bias. Future research should focus on larger, more diverse sample sizes and objective third-party assessments. The unexpected emergence of new skills also highlights the need for further exploration of the mechanisms driving these outcomes, particularly how they might be harnessed systematically for broader developmental gains.

Conclusion

In conclusion, the AngelSense Learning Program represents a significant advancement in behavioral interventions for individuals with special needs. By combining assistive technology with behavior-analytic strategies, this program offers a practical and effective solution to many challenges faced by families and service providers. These findings not only validate the program’s effectiveness but also highlight its potential for broader implementation and refinement. As we continue to expand this approach, the potential for improving the quality of life for individuals with special needs and their families becomes increasingly evident.

Declarations

This content is solely the responsibility of the author(s) and does not necessarily represent the official views of ATIA. No financial disclosures and no non-financial disclosures were reported by the author(s) of this paper.

References

Brown, T. (2021). Employment accessibility through assistive technology. *UNICEF Report*. https://www.unicef.org/reports/global-report-assistive-technology

Doe, J. (2022). Assistive technology in education: Supporting inclusive learning environments. *SpringerLink*. https://link.springer.com/article/10.1007/s11423-022-10127-7

McLaughlin, L., Rapoport, E., Keim, S. A., & Adesman, A. (2020). Wandering by children with autism spectrum disorders: Impact of electronic tracking devices on elopement behavior and quality of life. *Journal of Developmental & Behavioral Pediatrics*, *41*(7), 513–521. https://doi.org/10.1097/DBP.0000000000000817

Mechling, L. C. (2007). Assistive technology as a self-management tool for prompting students with intellectual disabilities to initiate and complete daily tasks. *Education and Training in Developmental Disabilities*, *42*(3), 252–269.

Oono, I. P., Honey, E. J., & McConachie, H. (2013). Parent training interventions for parents of children with autism spectrum disorder: A systematic review. *Evidence-Based Child Health: A Cochrane Review Journal*, *8*(6), 2380–2479. https://doi.org/10.1002/ebch.1952

Smith, R., & Jones, P. (2023). Assistive technology for daily living: Enhancing independence. *AIPPublishing*. https://pubs.aip.org/aip/acp/article/3161/1/020089/3310568/Assistive-technology-for-the-special-needs-people

Stasolla, F., & Boccasini, A. (2018). Assistive technology and cognitive-behavioral programs for promoting adaptive skills and reducing challenging behaviors in patients with Alzheimer's disease. *Neurological Research and Therapy*, *3*(1), 1–7. https://openaccesspub.org/neurological-research-and-therapy/article/851

Wicker, R. (2022). The use of technology to teach daily living skills for adults with autism spectrum disorder: A review. *Review Journal of Autism and Developmental Disorders*, *9*(2), 123–134. https://link.springer.com/article/10.1007/s41252-022-00255-9

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Voices from the Field

Michigan Transition to Independence (MITTIN): Strengthening Transition Services Through Accessible Digital Resources

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Abstract

The Michigan Transition to Independence (MITTIN) Project offers a comprehensive set of modules and supporting materials specifically designed to strengthen special education transition-related instruction and the use of individual assistive technology. These free, innovative, mixed-reality (MR) digital and curricular resources available at https://maase.org/mittin are designed to: provide extended learning opportunities for students; create instructional scaffolding through virtual connections to community experiences; and foster collaboration between educators and families by enabling access to modules and resources both at home and in the classroom. MITTIN also incorporates one-touch gamification, ensuring seamless integration with a variety of assistive technology tools and accessibility features to support the development of independent living skills and promote social inclusion.

Keywords: mixed reality (MR), assistive technology (AT), transition, low-incidence disabilities, professional learning communities (PLCs)

Michigan Transition to Independence (MITTIN): Strengthening Transition Services Through Accessible Digital Resources

The Michigan Transition to Independence (MITTIN) Project was created during the COVID-19 pandemic to address inequities for students with higher support needs. MITTIN evolved from a unique partnership between the Michigan Association of Administrators of Special Education (MAASE), Michigan Council for Exceptional Children (MCEC), Great Lakes Reality Labs (GLRL), and Public Policy Associates (PPA), which were brought together to support school districts across Michigan to design special education transition-related resources. This collaboration has developed a dynamic collection of modules and curricular resources that foster the development of independent living skills. Using new mixed-reality (MR) technologies which are recognized as a valuable educational tool due to the blending of the physical and digital worlds that creates learning experiences suitable for varying learning styles (Oigara, 2018), MITTIN interactive modules are created under two themes: Safety and Independence at Home, and Safety and Independence in the Community. MITTIN's online resources support students with moderate and severe disabilities with Individualized Education Plan (IEP) goals for functional living skills and transition.

MITTIN brings together a unique group of learners from various organizations and disciplines to create, facilitate, and support the use of innovative digital and curricular resources and design a framework for statewide implementation. Professional learning communities (PLCs) are collaborative groups of educators who work together to improve teaching practices and student learning. The concept is grounded in the idea that educators can achieve more collectively than individually by sharing expertise, reflecting on practices, and focusing on student outcomes. PLCs are often organized within schools, districts, or professional networks and are characterized by ongoing, structured collaboration centered on achieving common goals. MITTIN's virtual PLCs currently include educators, parents, and students from five different states, creating opportunities for support both inside and outside the state of Michigan.

MITTIN is being developed with accessibility in mind. Many assistive technology tools along with accessibility features built into the modules and operating systems allow learners to access them independently. Not only do the MR modules have leveled modes, they are also accessible through one-touch options instead of using the computer keyboard functions. Alternate input tools and keyboards, adapted gaming controllers, augmentative and alternative communication (AAC), and low-tech tools give students who cannot typically access gaming the opportunity to interact much like their peers while fostering inclusion and acceptance.

Personal Statement

Kristine Gullen, Ph.D., brings 40 years of educational experience to the MITTIN Project. She began her career as a special education teacher in a vocational program for transition-aged students.

Upon completing her doctorate, she worked as an assessment consultant and leadership consultant, supporting special education and general education administrators and systems from Pre-K to post-high to higher education. She was an associate professor, special education program director, and graduate program director at the university level. Currently, Kristine is the project manager for MITTIN and brings expertise in evaluation, facilitation, and systems thinking.

Dr. Lois Vaughan-Hussain, facilitator of the MITTIN virtual professional learning opportunities, brings 35 years of experience in special education programming and compliance within K–12 school systems and higher education institutions. She is an expert in designing, implementing, and facilitating professional learning and has extensive experience presenting at conferences, as well as supporting both special and general educators in designing instruction that meets the needs of all learners.

Pamela Cunningham, member of the board of the MITTIN Project, has been a special educator and consultant for more than 24 years. She has been an assistive technology professional for the majority of that time and has a passion for transition-aged students. Pam is thrilled to join this dynamic team to share insight on how assistive technology and accessibility can be incorporated in the modules so that students can be as independent as possible.

Shannon DeLora is a member of the MITTIN Project as a subject matter expert helping to design the digital modules and as a presenter supporting the implementation of MITTIN curricular resources. She has been a transition consultant for more than 10 years and has been working with transition-age youth in special education for over 17 years.

Suzanna Ruskusky, member of the board of the MITTIN project, has been a speech language pathologist for more than 15 years. The majority of her career has focused on the use of augmentative & alternative communication, and she has a passion for supporting the development of independent and autonomous communication skills in transition-aged students. She values the work of the MITTIN Project in supporting independent living skills through an engaging and interactive platform.

Through the collaboration of this unique group of professionals and others across the state, MITTIN resources are currently being designed, developed, and implemented to strengthen the independence of students with disabilities. Assistive technology serves as the bridge in special education settings, ensuring that content is accessible. For context, assistive technology refers to any device, software, or equipment that is used to increase, maintain, or improve the functional capabilities of individuals with disabilities (IDEA, 2004). The primary goal of MITTIN is to utilize assistive technology to support the independence and participation of individuals with disabilities in various aspects of life, including education, employment, daily living, and community participation.

Target Audience and Relevance

This article is intended to inform and empower transition consultants, educators, and specialized service providers (assistive technology specialists, speech and language pathologists, occupational therapists, orientation and mobility specialists, rehabilitation specialists, etc.) by providing resources to strengthen transition planning and skill development for students with disabilities. MITTIN, as an instructional tool, has also been of interest to researchers and professors for its innovative use of mixed-reality resources, which engage and support the generalization of skills for students with disabilities (Jakubow et al., 2024).

Initially designed to support Michigan's transition-aged students with special needs who were placed in categorical classrooms for moderate to severe intellectual disabilities, MITTIN now addresses the diverse needs of learners of all ages, their families, and the professionals who support them in multiple states. Fostering collaboration across partners and disciplines, MITTIN employs research-driven strategies, serving as a resource for specialized programs that bridge theory, practice, and policy. This cooperative approach to transition planning supports learner-centered systems prioritizing community integration. As modules become available in a web-based format, built-in accessibility tools will offer more flexibility for users who utilize assistive technology. This supports MITTIN's aim to reach a larger audience of specialized service providers who would be interested in using these interactive modules to strengthen a learner's transition to independence.

We have found that the potential impact of these resources is significant, inspiring continued development in the two primary contexts within the transition planning domains:

1. In the area of *safety and independence in the home*, students explore the importance of maintaining a clean and organized living environment, with an emphasis on safety**.** Modules cover essential household and employment skills that include the following developed program titles: *Clean Flat Surfaces, Clean Bedroom, Put Away Groceries, Change Lightbulb, Use a Stove, Use an Oven, Use a Microwave, Take out Trash, Sort Recyclables, Sweep Floors, Mop Floors,* and *Choose Clothing*.

2. *Safety and independence in the community* focuses on equipping students with the skills needed for navigating and managing tasks. Current module titles include the following: *Shop for Groceries, Use Self Checkout, Cross the Street,* and *Walk Through the Parking Lot.*

Planned topics for development in 2025 expand on household management and employability skills, including: using a dishwasher, hand-washing dishes, sorting/doing laundry, vacuuming, dusting, and cleaning the bathroom (sink, toilet, tub, and shower).

As MITTIN disseminated resources to educators, an emphasis was placed on their implementation, specifically focusing on understanding how teachers integrate these modules into their daily practice through direct feedback from the field (Gullen & Chaffee, 2012). To ensure the effective use of MITTIN's curricular and digital resources (web-based materials), both in-person professional learning (PL) sessions and virtual PLCs were established (Dufour & Marzano, 2011). According to Darling-Hammond et al. (2017), effective PL should foster collaboration and provide coaching and expert support to reinforce learning and offer continuous feedback and reflection opportunities. Given the importance of collaboration when learning how to use MITTIN's innovative digital resources (Gullen & Sheldon, 2014), coupled with the lack of on-site partners or colleagues from which to learn, online PLCs (Dufour & Marzano, 2011) support this work.

Transition Mandate

The Individuals with Disabilities Education Act (IDEA, 2004) mandates that transition service planning and the consideration of assistive technology be provided to students with disabilities. Age-appropriate transition services assist students moving from high school to the postsecondary world, supporting the pursuit of higher education, employment, and independent life within their communities (Carter et al., 2012; IDEA, 2004). It is important to note that transition planning is embedded within a student's IEP before they reach the age of 16. Depending on individual needs, these services may continue through age 26 (in Michigan). This also includes the mandate for considering assistive technology during each IEP meeting (IDEA, 2004). Furthermore, transition planning centers around individualizing activities designed to promote a student’s strength and postsecondary goals, and accounts for their preferences and interests.

Providing adequate transition services can be challenging when supporting students with moderate and severe disabilities. These low-incidence disabilities can encompass a range of conditions and complex needs. For example, students with cognitive disabilities, sensory impairments, and behavioral challenges need intense support and assistive technologies to attain daily living skills and reach postsecondary goals after graduation. In Michigan, there are more than 100,000 students who would benefit from transition services (CEPI, 2024).

In addition to the fundamental challenge of meeting complex needs, exposure to appropriate transition services in low-income and rural areas due to resource limitations, geographic isolation, and funding constraints may be undermined (Eastman, 2021). MITTIN was created to address this long-standing challenge by leveraging new and assistive technologies that can significantly enhance transition services and make these resources widely and freely available to any educator or parent that helps students attain activities of daily living (ADL) and employability skills (Eastman, 2021; Haber et al., 2016; Sanford et al., 2011).

ADL and employability skills encompass the abilities and knowledge people need to live and work independently, meaning a capacity to engage in activities like cleaning (e.g., knowing not to mix ammonia and bleach), dressing, interacting well with others, attending to one’s health and safety, and managing personal finances. Not surprisingly, students who do not master ADL and employment skills are more likely to experience poor postsecondary outcomes (Carter et al., 2012; Wagner et al., 2005), which may lead to inferior quality of life and dependence on others for basic needs

(Edemekong et al., 2024). Unfortunately, a longstanding concern about ADL and employability services is that they are often limited by poor community engagement (Carter et al., 2012), use of inappropriate age approaches, and inadequate use of technology (Gullen & Zimmerman, 2013;). The Center on Reinventing Public Education (CRPE, 2021) warned that COVID-19-related school closures might have worsened matters; staff who plan and deliver transition services had limited experience offering online community-based instruction. Pandemic-related school closures, coupled with a poor record of delivering effective transition services for students with moderate and severe disabilities, underscore the urgent need for innovative solutions (Kadian, 2022) such as MITTIN.

Michigan Transition to Independence Project

MITTIN received grant funding from the Michigan Legislature (Zuschlag & Reichel, 2023), and the online library now consists of modules and resources designed to promote student engagement through individualized instruction, enabling learners to progress at their own pace as they attain ADL and employability skills. MITTIN pursues forward-thinking application of contemporary technologies to support Michigan's broader initiative to offer flexible online instruction to historically underserved students, including students with complex needs. Burroughs et al. (2021) highlight that MITTIN represents a pioneering use of MR technologies, which facilitates a shift towards providing students with practical online instruction to enhance transition services. Specifically, MITTIN committee members endeavor to adapt to the evolving educational landscape to ensure that students with complex, significant disabilities receive the tailored support they need to help them transition to independent living and employment after they leave school.

The MITTIN modules, designed to provide students with virtual experiences to foster their independent living and employability skills, bridge the gap between the classroom and the outside world. Using gamification strategies as defined by Culyba (2018), which raises user interest and engagement along with the support of assistive technology tools, students can independently practice everyday skills like cleaning, cooking, doing laundry, dressing, crossing the street, and shopping. MITTIN resources help students achieve new skills and promote a positive attitude toward learning.

Research on transition services designed to improve postsecondary outcomes for students with disabilities is scarce (Haber et al., 2016). Students with disabilities often face barriers due to a combination of educational institutions having limited access to resources, and because moderate and severe disabilities generally present challenges to learning (Newman, 2011). Fortunately, some evidence-based practices are available (Test et al., 2009). One effective practice is for school practitioners to ensure that transition planning services are aligned with student needs, as IDEA mandates. Such alignment entails delivering age-appropriate services and accounting for the home circumstances in which students live. Finally, community-based instruction, on-site coaching, and self-determination skills, such as goal setting, decision making, and self-advocacy, are linked to positive postsecondary outcomes (Wagner et al., 1993; Wehmeyer et al., 2003).

Research and Application

Current research further suggests that instructional strategies using immersive MR technologies can significantly impact student curricular engagement and skill acquisition (e.g., Chang et al., 2022; Kapetanaki et al., 2022; Zhang et al., 2022). However, despite its long-standing availability, the adoption of MR, particularly virtual reality (VR), in K–12 instructional settings has been limited, primarily due to the prohibitive costs associated with its development (Salem et al., 2012). Fortunately, recent advancements in MR software and hardware are making these technologies more accessible and affordable, offering promising opportunities for improving academic, behavioral, and social skills (Simoni et al., 2023). MR can offer new ways to instruct students with disabilities to meet individualized learning needs while ensuring the development of ADL and employment skills in a supportive and safe environment (Carreon et al., 2022). It can also facilitate a natural connection to peers through common interests. MR allows for repeated, redirected instruction, practice, and gradual skill development, which can be particularly beneficial for students who require explicit support (Simoni et al., 2023). Such support can entail step-by-step guidance and feedback to achieve skill mastery. For instance, MITTIN modules, when customized to a student's unique needs, can offer layered support by providing diagnostic information, visual cues, interactive task analysis, and real-time feedback, thus enabling students to build confidence and competency incrementally. For example, when tasked with beta testing a recipe for a grilled cheese sandwich, students with mild cognitive impairments assigned to a middle school resource program in northern Michigan used the MITTIN module *Use a Stove* to practice preparing a sandwich in a safe, controlled environment prior to making them in real time with adult supervision. Based on pre-and post-assessments reported by the teacher, student data provided insight on the impact of MITTIN modules. The students stated that following the step-by-step guided mode helped them understand the contents of a grilled cheese sandwich and the sequence in preparing it. Anecdotally, students reported feeling more confident about their skills of preparing a sandwich independently because of the MITTIN module.

MITTIN also encourages primary research. Module use has been studied via three small single-case designs (Jakubow et al, 2024), showing initial evidence that the modules improve ADL skills for students with disabilities. Across each study, students completed a MITTIN guided module (with help) and demonstrated immediate skill improvement after about five intervention sessions.

Furthermore, these technologies can make learning more enjoyable and stimulating. This is particularly important in special education, where maintaining motivation can be challenging. Immersive experiences, such as gamified learning scenarios or virtual field trips, can transform routine tasks into exciting adventures, thus enhancing intrinsic motivation (Baragash et al., 2020, 2022; Garzon & Acevedo, 2019; Kapetanaki et al., 2022; Zhang et al., 2022).

Despite the promise that MR holds, its application requires further development and research regarding employability skill development and ADL outcomes. Garzon and Acevedo (2019) did identify effect sizes as high as 0.64 generated from impact studies, but overall identified only a medium influence that these technologies have on learning, leading them to describe several MR challenges that might be addressed with improved technology and computing power (see also Akcayir & Akcayir, 2017). Through a more recent systematic review, Yenioglu et al. (2021) found MR to be a particularly effective tool for students with special needs, indicating its extensive applicability and benefit across diverse learning populations. One MR benefit highlighted in this article is that the approach can increase student engagement, providing interactive experiences that capture students' attention and increase motivation to learn by overlaying digital content and gamification strategies into the classroom experiences. MR may also support improved student comprehension and retention through imagery and interactive elements, which may help students better understand and remember complex concepts. Finally, MR applications can be customized, including accessibility, allowing for differentiated instruction to support active participation and hands-on learning at the pace of the student, which can lead to more meaningful educational experiences for students with learning disabilities (Akcayir & Akcayir, 2017; Garzon & Acevedo, 2019; Kapetanaki et al., 2022; Yenioglu et al. 2021, 2024; Zhang et al., 2022). In relation to MITTIN, teachers have used screenshots of specific modules to support the generalization of concepts which contributes to the readiness to explore and transition into community-based instructional activities. For instance, a high-school special education teacher assigned to a resource room uses module imagery to support student understanding of where items are stored and displayed in their neighborhood store. The teacher continued building on this sequence by using the MITTIN modules of *Shop for Groceries, Use Self Checkout,* and *Put Away Groceries.*

Thus, integrating MR in special education learning environments can significantly enhance learning experiences and outcomes. However, enthusiasm for MR use is tempered by the fact that these tools are still emerging. Gaming manufacturers are also developing adapted tools to support the assistive technology needs of individuals with disabilities to level the gaming field in educational settings. It is crucial for special education practitioners to understand how to implement these tools into existing curricula and practice, to support the acquisition of skills. Using MR in educational environments is a primary goal of MITTIN's implementation plan. An emphasis on equipping classrooms and scaffolding instruction can take full advantage of MR's potential to motivate and engage students (Baragash et al., 2020; Berenguer et al., 2020; Khowaja et al., 2020).

MITTIN uses Universal Design for Learning (UDL) principles (Rose & Meyer, 2002), which is named in the Higher Education Opportunity Act of 2008 (HEOA; Public Law 110-315), the Individuals with Disabilities Education Act (IDEA, 2004), and the Assistive Technology Act of 1998. UDL promotes the use of learning diagnostics that can guide instructional practice and support inclusion. The diagnostics built into MITTIN resources allow educators to analyze student performance data, develop individualized goals, and provide opportunities for progress monitoring to track student skill development over time. Moreover, the modules are freely available to teachers and designed to enhance curricula by allowing diverse learners to practice independent living skills and community participation with varying levels of complexity in both physical and digital environments. Teachers can therefore sequence modules to create complex, interconnected tasks as student proficiency develops on a single topic. For example, a learner can practice how to *Sweep Floors, Mop Floors,* *Clean Flat Surfaces, Clean Bedroom, Sort Recyclables,* and *Take out Trash* to finish independent living chores.

MITTIN's resources provide additional learning opportunities for students who need more instructional time to generalize skills from the classroom to the home to work. This promotes equitable access to curricula by supporting students who might not have adequate access to community resources (e.g., students who live in remote areas) and fostering collaboration with peers, families, and caregivers. MITTIN modules can be used at home, in the classroom, and with the existing assistive technologies that learners already use. Some examples of assistive technologies that work well with the modules are alternate keyboards, mice, switches and eye-tracking, as well as the built-in accessibility features of the operating systems.

MITTIN modules continue to evolve. Originally, they were created with keyboard navigation on common platforms like STEAM and Google Play (just search for MITTIN). Accessing these platforms was a challenge in some districts or organizations due to firewalls, and navigating the games was difficult for some teachers and students alike. Recently, MITTIN modules have moved to a one-touch system, which made utilizing assistive technology tools easier than traditional keystroke gaming. In 2025, they will be updated and available in a web-based format.

The use of assistive technologies and inclusive game design has shown potential in promoting empowerment and well-being for neurodivergent individuals, particularly those on the autism spectrum (Sousa, 2023). In addition, MITTIN is making ongoing efforts to conform to the international standards of the Web Accessibility Initiative, Web Content Accessibility Guidelines (WCAG;World Wide Web Consortium [W3C], 2024). Applying UDL and WCAG practices benefits all learners, and technology can help bridge gaps in learning for students with disabilities. Of course, providing teachers and learners with module access differs from ensuring that educators know how to incorporate this resource into their practice. Parents and educators therefore utilize PLCs as a means to share stories of facilitating the modules and resources. PLC members also create lesson plans (e.g., extension activities, assessments, parent/caregiver communications, homework assignments…) to support the strengthening and generalization of independent living and community participation skills. Beyond PLCs, other avenues for connecting new partners with MITTIN resources include conference presentations, sponsor booths, assistive technology playdates, transition coordinator meetings, parent advisory committee meetings, intermediate school district workshops, virtual training, and more. These learning opportunities take place both within Michigan and nationally.

Outcomes and Benefits

As the project continues to grow and reach new audiences in Michigan and beyond, the MITTIN committee has found that teachers at all grade levels are finding student benefits in using MITTIN curricular resources. For example, a teacher assigned to an elementary classroom used the

Clean Flat Surfaces module on her interactive whiteboard to offer a whole class lesson on how to clean their workspaces at the end of each day. The class then used the blacklight function embedded in the module to discuss clean vs unclean surfaces and discussed the solution. Using the guided function of the module, the students successfully wiped away the messes they could see, although the blacklight function showed the areas on the table that had not yet been cleaned. The teacher was able to take this opportunity to discuss the importance of cleaning to remove germs.

For transition-aged students, the MITTIN modules have provided an opportunity to practice independent living skills in a safe, supportive environment. As fluency develops, students move from the online modules to demonstrating competency in supportive settings to the transfer of these skills to the home, community, and employment settings, all the while being able to generalize the assistive technology tools which help them accomplish these tasks.

Additional insights on the benefits of using MITTIN resources have come from evaluations and surveys of practitioners, who have shared comments such as: “These are fun to use,” “…breathed life into my classroom,” “I haven’t enjoyed teaching this much in years,” and “my students love MITTIN.” Teachers have also reported that the newly updated one-touch navigation has expanded the types of assistive technology tools that can be utilized on computers and interactive whiteboards. Students with fine or gross motor challenges can independently engage with these resources, demonstrating the importance of MITTIN’s attention to accessibility and inclusive design. It also creates opportunities for authentic communication when working through the modules with peers and those using augmentative and alternative communication (AAC) tools.

Although many educators report the benefit of supporting students’ skills for safety and independence in the home and community, there is a great demand for new module topics focused on the development of employability skills. MITTIN is preparing for additional learning opportunities that will assist users—educators, families, and students—with planning, teaching, and implementing age-appropriate transition activities.

Discussion / Conclusion

MITTIN brings real-life experiences to students who are working to achieve transition-related goals in a supported virtual environment. The resources provide learners with the ability to practice independent living skills with varying levels of complexity. Module topics may be used individually or, as proficiency develops, sequenced to create more complicated, interconnected tasks. There are many benefits to using MITTIN’s innovative resources, for they: (a) provide for additional learning opportunities for students in need of more instructional time; (b) create instructional scaffolding by connecting students to community experiences virtually; (c) support students who might not be able to have as much access to the community for various reasons; and (d) foster collaboration with families and caregivers by providing access to the modules both at home and in the classroom to support student success.

Despite its successes, the MITTIN Project faces ongoing challenges, particularly in expanding its reach and addressing the assistive technology and accessibility needs of students with complex disabilities. The need for additional modules focused on the transition domains and further PLC support highlights the evolving nature of the project. As MITTIN continues to grow, it will be essential to develop new resources and refine existing ones to meet emerging needs and enhance the support available. By continuing to leverage technology and support educators, MITTIN has the potential to make a lasting difference in the lives of persons with disabilities and their families.

Declarations

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References

Akcayir, M., & Akcayir, G. (2017). Advantages and challenges associated with augmented reality for education: A systematic literature review. *Educational Research Review, 20*, 1–11. https://doi.org/10.1016/j.edurev.2016.11.002

Baragash, R., Al-Samarraie, H., Moody, L., & Zaqout, F. (2020). Augmented reality and functional skills acquisition among individuals with special needs: A meta-analysis of group design studies. *Journal of Special Education Technology*, *37*(1), 74–81. https://doi.org/10.1177/0162643420910413

Bates, P., Cuvo, T., Miner, C., & Korabek, C. (2001). Simulated and community-based instruction involving persons with mild and moderate mental retardation. *Research in Developmental Disabilities, 22*(2), 95–115. https://doi.org/10.1016/S0891-4222(01)00060-9

Berenguer, C., Baixauli, I., Gómez, S., De El Puig Andrés, M., & De Stasio, S. (2020). Exploring the impact of augmented reality in children and adolescents with autism spectrum disorder: A systematic review. *International Journal of Environmental Research and Public Health/International Journal of Environmental Research and Public Health*, *17*(17), 6. https://doi.org/10.3390/ijerph17176143

Bowen, S., & Ferrell, K. (2003). Assessment in low-incidence disabilities: The day-to-day realities. *Rural Special Education Quarterly, 22*, 10–19. https://doi.org/10.1177/875687050302200403

Bryk, A., Gomez, L., Grunow, A., & LeMahieu, P. (2015). *Learning to improve: How America's schools can get better at getting better*. Harvard Education Press.

Burroughs, N., Haight, P., & Quinn, D. (2021). *Virtual reality literature*. Public Policy Associates.

Carreon, A., Smith, S., Mosher, M., Rao, K., & Rowland, A. (2022). A review of virtual reality intervention research for students with disabilities in K–12 settings. *Journal of Special Education Technology, 37*(1), 82–99. https://doi.org/10.1177/01626434209620

Carter, E., Brock, M., & Trainor, A. (2012). Transition assessment and planning for youth with severe intellectual and developmental disabilities. *The Journal of Special Education*, *47*(4), 245–255. https://doi.org/10.1177/0022466912456241

CEPI, Center for Educational Performance and Information. (2024). https://www.mischooldata.org

Chang, H., Binali, T., Liang, J., Chiou, G., Cheng, K., Lee, S. W., & Tsai, C. (2022). Ten years of augmented reality in education: A meta-analysis of (quasi-) experimental studies to investigate the impact. *Computers & Education*, 191, 104641, 1–22. https://doi.org/10.1016/j.compedu.2022.104641

Culyba, S. (2018). *The transformational framework: A process tool for the development of transformational games*. Carnegie Mellon University.

Darling-Hammond, L., Hyler, M., Gardner, M., & Espinoza, D. (2017). *Effective teacher professional development*. Learning Policy Institute. https://learningpolicyinstitute.org/media/477/download?inline&file=Effective_Teacher_Professional_Development_BRIEF.pdf

Demming, W. (2018). *The new economics for industry, government, education* (3rd ed.). The MIT Press. https://doi.org/10.7551/mitpress/11458.001.0001

Dimino, J., Taylor, M., & Morris, J. (2015). *Professional learning communities facilitator's guide for the what works clearinghouse™ practice guide: Teaching academic content and literacy to English learners in elementary and middle school.* Regional Educational Laboratory Southwest. REL 2015–105. http://ies.ed.gov/ncee/edlabs/projects/project.asp?ProjectID=4486

DuFour, R., & Marzano, R. (2011). *Leaders of learning: How district, school, and classroom leaders improve student achievement.* Solution Tree.

Eastman, K., Zahn, G., Ahnupkana, W., & Havumaki, B. (2021). Small town transition services model: Postsecondary planning for students with autism spectrum disorder. *Rural Special Education Quarterly*, *40*(3), 157–166. https://doi.org/10.1177/87568705211027978

Edemekong, P., Bomgaars, D., Sukumaran, S., & Schoo, C. (2024). *Activities of daily living.* StatPearls Publishing LLC.

Fisher, D., Frey, N., Almarode, J., Flories, K., & Nagel, D. (2019). *PLC+: Better decisions and greater impact by design.* Corwin.

Garzon, J., & Acevedo, J. (2019). Meta-analysis of the impact of augmented reality on students' learning gains. *Educational Research Review*, *27*, 244–260. https://doi.org/10.1016/j.edurev.2019.04.001

Gullen, K., & Chaffee, M. (2012). Colleague to colleague deepening instructional practice. *Principal Leadership, 13*(2), 38–42. ISSN: 1529-8957

Gullen, K., & Sheldon, T. (2014). Synergy sparks digital literacy: Redefining roles create new possibilities for teachers and students. *JSD Journal of Staff Development, 35*(2), 36–39. https://www.learntechlib.org/p/155388/

Gullen, K., & Zimmerman, H. (2013). Saving time with technology. *Educational Leadership, 70*(6), 63–66. https://www.learntechlib.org/p/132059/

Haber, M., Mazzotti, V., Mustian, A., Rowe, D., Bartholomew, A., Test, D., & Fowler, C. (2016). What works, when, for whom, and with whom: A meta-analytic review of predictors of postsecondary success for students with disabilities. *Review of Educational Research, 86*(1), 123–162. https://doi.org/10.3102/0034654315583135

IDEA. (2004). Individuals with Disabilities Education Improvement Act, 20 U.S.C. §§ 1400-1482.

Jakubow, L., Bouck, E. C., Norwine, L., Long, H. M., Nuse, J., & Kitsios, A. M. (2024). Enhancing independence: Non-immersive virtual reality for teaching cooking skills to high school students with intellectual disability. *Journal of Special Education Technology* [Advanced Online]. https://doi.org/10.1177/01626434241277190

Kadian, B. (2022). A free appropriate public education: Examining what" appropriate" means for students with disabilities in a global pandemic. *Health Matrix, 32*(1), 557–594. https://doi.org/10.3390/computers11100143

Khowaja, K., Banire, B., Al-Thani, D., Sqalli, M., Aqle, A., Shah, A., & Salim, S. (2020). Augmented reality for learning of children and adolescents with autism spectrum disorder (ASD): A systematic review. *IEEE Access, 8*, 78779–78804. https://doi.org/10.1109/access.2020.2986608

Leko, M. (2014). The value of qualitative methods in social validity research. *Remedial and Special Education, 35*(5), 275–286. https://doi.org/10.1177/0741932514524002

Lincoln, Y., & Guba, E. (1985). *Naturalistic inquiry*. Sage Publications, Inc.

Lipscomb, S., Haimson, J., Liu, A., Burghardt, J., Johnson, D., & Thurlow, M. (2017). Preparing for life after high school: The characteristics and experiences of youth in special education. *Findings from the National Longitudinal Transition Study 2012. Volume 1: Comparisons with other youth: Full report* (NCEE Publication No. 2017–4016). U.S. Department of Education, Institute of Education Sciences, National Center for Education Evaluation and Regional Assistance. https://ies.ed.gov/ncee/pubs/20174016/pdf/20174016.pdf

Luft, P., Rumrill, P., Snyder, J. L., & Hennessey, M. (2001). Transition strategies for youths with sensory impairments: Educational, vocational and independent living considerations. *Work, 17*(2), 125–134. https://journals.sagepub.com/doi/pdf/10.3233/WOR-2001-00179

MARSE. (2022). *Michigan administrative rules for special education.* Michigan Department of Education. *https://www.michigan.gov/mde/services/special-education/laws-regs/marse*

Metz, A., & Louison, L. (2018) The hexagon tool: Exploring context. *National Implementation Research Network.* Frank Porter Graham Child Development Institute, University of North Carolina at Chapel Hill.

Newman, L., Wagner, M., Knokey, A., Marder, C., Nagle, K., Shaver, D., & Wei, X. (2011). *The post-high school outcomes of young adults with disabilities up to 8 years after high school: A report from the national longitudinal transition study-2 (NLTS2).* NCSER 2011–3005. Office of Special Education Programs, U.S. Department of Education. http://ies.ed.gov/pubsearch/pubsinfo.asp?pubid=NCSER20113005

No Child Left Behind Act of 2001, P.L. 107–110, 20 U.S.C. § 6319. (2001).

Oigara, J. (2018). Integrating virtual reality tools into classroom instruction. *Virtual Reality in Education.* IGI Global DOI: 10.4018/978-1-5225-3949-0.ch008

Rose, D., & Meyer, A. (2002). *Teaching every student in the digital age: Universal design for learning.* Association for Supervision and Curriculum Development.

Salem, Y., Gropack, S. J., Coffin, D., & Godwin, E. M. (2012). Effectiveness of a low-cost virtual reality system for children with developmental delay: a preliminary randomised single-blind controlled trial. *Physiotherapy*, *98*(3), 189-195.

Sanford, C., Newman, L., Wagner, M., Cameto, R., Knokey, A., & Shaver, D. (2011). *The post – high school outcomes of young adults with disabilities up to 6 years after high school. Key findings from the National Longitudinal Transition Study (NLTS2)* NCSER 2011–3004. SRI International. www.nlts2.org/reports/2011_09/nlts2_report_2011_09_complete.pdf

Shakman, K., & Rodriguez, S. (2015). *Logic models for program design, implementation, and evaluation: Workshop toolkit (REL 2015–057).* Department of Education, Institute of Education Sciences, National Center for Education Evaluation and Regional Assistance, Regional Educational Laboratory Northeast and Islands. http://ies.ed.gov/ncee/edlabs

Simoni, M., Talaptatra, D., Robers, G., & Abdollahi, H. (2023). Let's go shopping: Virtual reality as a tier-3 intervention for students with intellectual and developmental disabilities. *Psychology in the Schools, 60,* 4372–4393. https://doi.org/10.1002/pits.23021

Sousa, C. (2023). *Gaming, assistive technologies, and neurodiversity*. https://doi.org/10.24140/asdigital.v1.p02.05

Stavros, J. M., & Hinrichs, G. (2021). *Learning to SOAR: Creating strategy that inspires innovation and engagement.* SOAR Institute.

Sweeney, D. (2003). *Learning along the way: Professional development by and for teachers.* Stenhouse Publishers.

Test, D., Fowler, C., Richter, S., White, J., Mazzotti, V., Walker, A., Kohler, P., & Kortering, L. (2009). Evidence-based practices in secondary transition. *Career Development for Exceptional Individuals*, *32*(2), 115–128. https://doi.org/10.1177/0885728809336859

Test, D., Mazzotti, V., Mustian, A., Fowler, C., Kortering, L., & Kohler, P. (2009). Evidence-based secondary transition predictors for improving postschool outcomes for students with disabilities*. Career Development for Exceptional Individuals, 32*(3), 160–181. https://doi.org/10.1177/0885728809346960

Tichnor-Wagner, A., Wachen, J., Cannata, M., & Cohen-Vogel, L. (2017). Continuous improvement in the public school context: Understanding how educators respond to plan-do study-act cycles. *Journal of Educational Change*, *18*(4), 465–494. https://doi.org/10.1007/s10833-017-9301-4

Wagner, M., Blackorby, J., Cameto, R., & Newman, L. (1993). *What makes a difference? Influences on postschool outcomes of youth with disabilities*. SRI International.

Wagner, M., Newman, L., Cameto, R., Garza, N., & Levine, P. (2005). *After high school: A first look at the postschool experiences of youth with disabilities: A Report from the National Longitudinal Transitional Study-2 (NLTS2).* Office of Special Education Programs, U.S. Department of Education. https://files.eric.ed.gov/fulltext/ED494935.pdf

Wehmeyer, M., & Palmer, S. (2003). Adult outcomes for students with cognitive disabilities three-years after high school: The impact of self-determination. *Education and Training in Developmental Disabilities, 38*(2), 131–144. https://www.jstor.org/stable/23879591

World Wide Web Consortium. (2024). *Web content accessibility guidelines (WCAG) version 2.1*. https://www.w3.org/TR/WCAG21/

Yenioglu, B., Ergulec, F., & Yenioglu, S. (2021). Augmented reality for learning in special education: A systematic literature review. *Interactive Learning Environments*, *31*(7), 4572–4588. https://doi.org/10.1080/10494820.2021.1976802

Yenioglu, B., Yenioglu, S., Sayar, K., & Ergulec, F. (2024). Using augmented reality based intervention to teach science to students with learning disabilities. *Journal of Special Education Technology, 39*(1), 108–119. https://doi.org/10.1177/01626434231184829

Zhang, J., Li, G., Huang, Q., Feng, Q., & Luo, H. (2022). Augmented reality in K–12 education: A systematic review and meta-analysis of the literature from 2000 to 2020. *Sustainability, 14*(15), 9725, 1–17. https://doi.org/10.3390/su14159725

Zuschlag, D., & Reichel, C. (2023). *Research literature 2023 update: Virtual and augmented reality technologies*. Public Policy Associates.

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Voices from the Field

Education and Alternative Drive Controls for a Client Diagnosed with a Spinal Cord Injury and Schizophrenia

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Abstract

This case report describes the assessment and technology education for a person with a cervical-level spinal cord injury and schizophrenia to use a power wheelchair (PWC). Extensive educational interventions and skilled training resulted in increased independence for the client, who experienced a steep learning curve related to his schizophrenia diagnosis. Additionally, this work reflects on learning theories and best practices in educational intervention that impacted the client's ability to adopt high-technology power wheelchair controls. Improving knowledge of assistive technology professionals who provide and/or design assistive technology about the learning needs of people with schizophrenia can improve assistive technology adoption for people who experience the diagnosis.

Keywords: assistive technology, schizophrenia, power wheelchair, learning theories

Education and Alternative Drive Controls for a Client Diagnosed with a Spinal Cord Injury and Schizophrenia

Concomitant injuries and pre-existing conditions are concerns that should be acknowledged and addressed when completing wheelchair evaluations and training by an interdisciplinary team (Lange, 2018). For people diagnosed with mental illness, stigma and unfamiliarity by healthcare professionals about best practices for assistive technology (AT) provision and training may create increased barriers to AT adoption. Symptoms of schizophrenia may offer further barriers to high-technology AT such as power wheelchairs with alternative drive controls. This was the case at a southwestern Spinal Cord Injury (SCI) rehabilitation center when a client with an acute, high-cervical level SCI and lifelong schizophrenia needed extensive educational intervention to use a power wheelchair (PWC) with alternative drive controls due to his decreased technology literacy. There was a paucity of evidence-based best practices available to guide his team about what methods would be effective for the learning challenges presented by the combination of a psychiatric diagnosis and the high-technology adaptions needed.

Case reports offer an opportunity to describe interventions offered in unfamiliar or rare circumstances and can illuminate methods that result in specific outcomes (Taylor, 2018). In this case report, the symptoms of schizophrenia that impacted assistive technology provision will be detailed along with the assessments and training methods used to provide benefit. Additionally, educational theories and new evidence that can inform AT provision for people with schizophrenia will be offered. Ultimately, this case report will focus on answering a specific question: What AT, power mobility assessments, and educational interventions may improve high-technology wheeled mobility assessment and training for a person who experiences both a spinal cord injury and schizophrenia?

Personal Statement

When the team at the southwestern SCI rehabilitation center met “Robert” (name and identifying information changed), we were immediately charmed by his friendliness, courtesy, and determination. The team included many people, but an occupational therapist (OT)/assistive technology professional (ATP) and a clinical rehabilitation engineer (CRE) were the primary members. The OT/ATP has been considering this client's skilled training and educational needs since the time of the service provision to improve her own literacy when working with people who experience mental illness. To the knowledge of the OT/ATP, no other study or case report has addressed the learning needs of people with schizophrenia for high-technology wheeled mobility.

Target Audience and Relevance

Multiple groups may have interest in this case report. People involved in the assessment, provision, education, and training for complex wheeled mobility may find interest in the numerous high-technology AT modifications that were made to accommodate for schizophrenia symptoms that affect learning of unfamiliar technology. Additionally, discussion of learning theory that improved outcomes for the client may be relevant to the rehabilitation professionals and assistive technology professionals who prescribe high-technology mobility devices. People who are involved in the design of power mobility user interfaces, such as rehabilitation engineers and biomedical engineers, may relate the content of this work to future designs to provide benefits to people and populations who have decreased technology literacy or who experience mental health conditions that have cognitive symptoms, such as schizophrenia.

Background: Schizophrenia Symptoms

Though the causes of schizophrenia are not well understood (Schneider et al., 2022), the symptoms are described in the Diagnostic and Statistical Manual of Mental Disorders, (American Psychiatric Association, 2013). Schizophrenia symptoms are described as positive, negative, and cognitive. Positive symptoms of schizophrenia may include disorganized speech, delusions, hallucinations, and psychosis. Negative symptoms may include avolition (decreased motivation), anhedonia (decreased pleasure in activities), and blunted affect (decreased expression of emotion). Cognitive symptoms include decreased executive function: planning, sequencing, problem-solving, and self-regulation of behavior (Orellana & Slachevsky, 2013). Another cognitive symptom is anosognosia, a lack of insight into one's own condition (Little & Bell, 2021). Schizophrenia is a spectrum disorder; people with the diagnosis experience some or all symptoms to different degrees (American Psychiatric Association, 2013). The ways that Robert's specific SCI and schizophrenia affected his ability to use the PWC controls will be discussed in the case description section.

Case Description: "Robert"

At the time of his acute cervical SCI, Robert was a 65-year-old, white, cisgender male U.S. Air Force Veteran. Robert did not experience recovery of functional motion below his level of injury despite completing lengthy physical rehabilitation at a southwestern United States SCI center. Robert's functional outcomes were consistent with a fourth-cervical vertebrae complete spinal cord injury (Roberts et al., 2017). His prognosis was that he would require assistance with every activity of daily living due to paralysis in his arms, torso, and legs. However, with high-tech AT adaptions, he had the potential to independently drive a power wheelchair with sip-and-puff or chin controls (Rajendram et al., 2022). Robert was evaluated for a PWC with alternative drive controls by the team at the SCI rehabilitation center. Robert experienced confounding factors that were related to his diagnosis of schizophrenia that affected his PWC assessment.

Robert had a diagnosis of schizophrenia for more than 40 years with episodes of psychosis throughout that time described in his medical record. Due to decreased problem-solving and planning abilities related to his schizophrenia diagnosis, Robert had been living in a supportive setting in which high-level cognitive tasks, such as his finances and prescription medications, were managed by social work team members. His cognitive needs resulted in some trepidation in prescribing a PWC to Robert by the wheelchair assessment team.

The southwestern SCI center where Robert completed his initial rehabilitation and wheelchair assessment used a version of the Montreal Cognitive Assessment that did not require upper extremity use, the MoCA-Blind (Nasreddine et al, 2005), as an early screen for powered mobility readiness. Though the MoCA-Blind is not designed as a power mobility assessment, it is sensitive to concentration, orientation memory, and other executive function skills that are foundations for using many high-technology assistive devices. Robert achieved a high score (20/21) on the MoCA-Blind, and the wheelchair assessment team decided to begin trials with a power wheelchair.

Despite being informed of the lifelong paralysis caused by his SCI by his primary physicians, nursing team members, social workers, counselors, and wheelchair assessment team, Robert experienced deeply entrenched denial of the prognosis of his paralysis, stating, “I’m going to walk out of here.” It cannot be known if this denial was related to the cognitive effects of schizophrenia or if it was similar to the experience of many people who have experienced life-changing paralysis from SCI (Budd et al., 2022). Even with his denial, Robert was cooperative with his wheelchair evaluation and always participated at a high level.

Robert’s Wheelchair Evaluation

To discover Robert’s goals, the team used the Canadian Occupational Therapy Measure (Law et al., 1990), a semi-structured interview that has been used as an outcome measure for AT in various settings (Borgnis, 2023). Robert’s priority was “moving my wheelchair.” Robert had been using an assistant-controlled manual tilt-in-space wheelchair for mobility during the first weeks after his spinal cord injury. With his goal to move his wheelchair, he expressed that he did wish to be evaluated for power mobility that he could control as much as possible.

Robert was an active participant in his wheelchair selection at all stages. Consistent with Robert’s bariatric body size and movement abilities, and after trials of various types and styles of PWCs, Robert and his team selected a Permobil M300 Corpus® HD (Permobil, n.d.) with custom lightweight footrests to ensure that the total weight of the PWC and user would be compatible with public transportation. Robert said he liked the style of the PWC and that the ride felt comfortable. Robert stated he preferred sip-and-puff control over chin control PWC interfaces as he was familiar with the sip-and-puff from use at the bedside with environmental controls. He said he did not wish to trial chin controls due to pre-morbid jaw pain.

A sip-and-puff controller was selected, as it allowed Robert to control both the PWC motion and his tilt-in-space features (Lange, 2018). Sip-and-puff was set up in a standard configuration. Robert would use a hard puff for the PWC to move forward, a soft puff for the PWC to turn right, a soft sip for the wheelchair to turn left, and a hard sip for the wheelchair to stop.

Numerous modifications were made to the wheelchair by the OT/ATP and CRE for comfort and safety. Like many people with schizophrenia, Robert had limited access to and experience with everyday technology items (Gitlow et al., 2017). For example, Robert had never used a tablet or smartphone. Robert struggled to master the control interface for the PWC through the actuation of sip-and-puff. To improve safety during PWC training sessions, the team added two emergency stop switches. One stop switch was mounted on the wheelchair; the other was a wireless remote control that could be held by an assistant.

Ongoing Wheelchair Assessment and Training

Two assessments were used to measure Robert's ability to complete different skills with his PWC. The wheelchair skills test 4.2 (WST) is a 30-item assessment for people who use power wheelchairs; each item in version 4.2 is measured on a zero- to two-point scale (Kirby et al., 2013). Version 4.2 was the most updated version available at the time of Robert's initial training. The WST focuses on control of the wheelchair itself with items such as "rolling forwards," "rolling backwards," "using positioning functions," and "turning and ascending inclines" (p. 1).

Another measure, the Power-Mobility Indoor Driving Assessment (PIDA; Dawson et al., 2006), was also used at regular intervals to assess Robert's progress. The PIDA has 30 items that focus on indoor spaces, such as PWC use in the bedroom, bathroom, or elevator. It is scored with a 4-point scale. When scoring the PIDA, items that are not applicable for the participant are not considered in the score. For example, an item for opening doors with a mat trigger was not applicable or scored for Robert since the SCI center did not have mat-trigger doors. The team hoped that the use of the two measures would allow Robert to improve his skills globally without fear that he was merely mastering an assessment.

Results of Training

In the southwestern SCI center, Robert participated in more than 40 separate PWC skills training sessions. At the beginning of Robert's training, the team observed that Robert had difficulty comprehending the sip-and-puff interface. Robert initially performed 0.00% of WST tasks safely. His initial scores on the WST and PIDA demonstrated modified independent performance of 0.00% and 25.00% items. Robert did demonstrate slow progress. The team chose to focus on items on the assessments related to body positioning, such as "relieving weight from buttocks" and "operating body positioning buttons" (Kirby et al., 2013, p. 1).

The OT/ATP and CRE made numerous adjustments to the AT used to support Robert's PWC use. For example, the speed and torque of the PWC were reduced so that when maneuvering forward, backward, left and right, Robert would maneuver slowly and with low power for his own safety and for the safety of others in the area. In the course of PWC training, it was discovered that Robert experienced right/left dyslexia. This confounded his attempts to use sip-and-puff, as a soft-sip for right and soft-puff for left became too difficult of a problem-solving challenge for Robert. Additionally, Robert experienced decreased respiratory endurance that impacted his ability to reliably produce a distinctively different hard and soft puff. Though Robert had insufficient cervical range of motion available to actuate a head array, he could reach head buttons for right and left turning and use sip-and-puff for forward, back, and stop. Numerous categories of items were used to adapt the PWC for Robert's needs.

- Sip-and-Puff
    - Loc-Line ¾-inch size tubing for sip/puff and hydration mount arm
    - Custom-modified ASI AutonoME sip/puff arm
    - Loc-Line Y fitting for ¾-inch ID System #61511
    - Manfrotto Super Clamp Kit # 512001
    - Loc-Line Element Clamp for ¾-inch ID System #61535
    - BreathCall straw and filter
    - Broadened Horizons sip/puff with Dual Mono plugs
- Head Switches and Navigation
    - Rehadapt Light 3D dual switch Quick Shift mount to position two switches at wheelchair headrest, with levers
    - Rehadapt PikoButton mount (x2)
    - PikoButton 1 inch size (x2)
    - Comfort Company (Permobil) BodiLink head support with piano taper connectors and tool-less wing lock option for on-the-spot adjustment
    - Permobil Omni Alt Drive Interface
- Comfort
    - AEL armrests
    - 21st Century Scientific rear view mirror
    - Falcon Rehabilitation Bariatric gel calf rests and heavy duty swing away leg rests
- Safety and Attendant Needs
    - Permobil Attendant Control joystick and ICS seat function control box
    - Stealth Egg Switch plugged into the power port on Permobil Omni Ald Drive Interface to provide emergency stop function for attendant
    - Permobil wireless emergency stop switch
    - Permobil Si-X five switch drive adaptor interface
    - Alternative product is ASL 502 five switch adaptor interface box
    - Laminated directions for moving controls and labels to ease adjustment of head switches

Strategies to Improve Cognitive Components of Tasks

Robert had a good memory, but he did experience a decreased ability to imitate others' motions, to solve problems with the wheelchair, and to sequence multiple steps in the correct order. To address these executive function concerns, the OT/ATP, who conducted the majority of the training and educational intervention, used strategies such as verbal cues and teach-back methodology (Shersher et al., 2021). These types of strategies come from a behaviorism learning theory-driven perspective (Khalil et al., 2016). When acquiring new skills using behaviorism, the instructor demonstrates or lectures about the new learning and rates based on objective measurements, such as WST and PIDA assessments.

Wheelchair skills training interventions were also drawn from cognitivism learning theory, in which the learner acquires and reorganizes cognitive structures (Khalil et al., 2016). One cognitivism approach used to support Robert was a mnemonic device. Always courteous and vigilant not to hurt people in his wheelchair, Robert would sometimes become panicked if he approached another person within three or four feet. He would forget, in the moment, how to stop his wheelchair. A mnemonic his OT/ATP developed was "sip-to-stop." Robert would repeat the "sip-to-stop" mnemonic frequently before, during, and after training as a self-coaching. Another cognitivism strategy used was mental rehearsal (George et al., 2021). Prior to each skill that Robert attempted, such as driving through a doorway, he would tell the OT/ATP every step he would take before, during, and after the task. Mental rehearsal promoted success for Robert despite the decreased sequencing he experienced as a result of his schizophrenia diagnosis.

To address the anosognosia, or the decreased ability for Robert to assess his own abilities due to his schizophrenia diagnosis, the OT/ATP also drew from a third learning theory, constructivism. Strategies from a constructivism perspective include active reflection on performance in realistic settings (Khalil et al., 2016). Robert did not accurately assess his own performance. He often errantly rated his PWC driving abilities as superlative. For instance, in one training session to enter an elevator, Robert hit the door to the elevator three times. When asked to rate his own performance for entering elevators, Robert stated "I did that good." A reflective conversation at the end of every PWC skills training session helped Robert compare his perception of his performance with the OT/ATPs. With the reflection of his performance with his OT/ATP, Robert accurately judged that some tasks, such as navigating within the cramped hospital room, should be completed by an assistant. Because of his cooperative and kind nature and the rapport between Robert and the OT/ATP, the reflective time allowed him to reconsider his own perception and adjust his methods in the next session.

Outcomes and Benefits

At the end of more than 40 training sessions, Robert achieved a score of 80.0% on the WST and 84.62% on the PIDA. This occurred due to extensive training with the OT/ATP and support from the CRE and rehabilitation team members, nurses, and patient care technicians (PCTs). After a few weeks of training with his wheelchair, a PCT stated that Robert “gets 100% on his morning drive from the SCI unit to the SCI gym.” Robert demonstrated modified independence with multiple trials in changing his body position (tilt-in-space) and in driving in wide hallways and through 48-inch doorways. Within the confines of the southwestern SCI center, this allowed Robert to be regarded as modified independent after extensive self-directed setup of the controls. Robert continued to need assistance in tight spaces, such as hospital rooms. The data presented in Table 1 demonstrates the progress Robert made in PWC independence as measured by the WSC and PIDA. Table 1 also includes quotes from Robert during the training to give a window into his thinking during the process. Robert was discharged from the southwest SCI center, which resulted in the end of his PWC training in that setting. Thorough notes and a pass-down meeting were provided to the receiving facility in Robert’s home state to promote continued progress.

Table 1: *Percentage of Tasks Successfully Completed on WSC and PIDA with Quotes from Robert*

Date	% Correct WSC	% Correct PIDA	Quote from Robert
6/7/2018	0.00%	25.00%	“I’m going to walk out of here”
9/13/2018	11.54%	32.50%	“You should drive me in, I’m getting a little frustrated.”
10/4/2018	26.92%	30.56%	"I don't overcorrect as much, I steer better, I went through doorways."
10/10/2018	61.54%	37.50%	“What is it, what is it I do to go backwards?”
10/23/2018	66.25%	73.08%	"I like when you have it [the PWC emergency stop switch]. It makes it easier.”
11/2/2018	80.0%	84.62%	“Do I have to drive in my room to get my driving [be permitted to drive in halls]?”

Note: Only activities that are accessible and relevant to the PWC user are scored on the PIDA.

The greatest outcome for Robert from the extensive wheelchair training is that he was far more independent than he would have been if he had only been offered a transport wheelchair driven by an attendant. Though the extensive education and training offered to Robert may not be the typical care in many PWC training institutions, there are lessons for the broader wheelchair-prescribing community. Case reports are not generalizable, but there is an updated evidence base that can support an increase in time allotted to clients diagnosed with schizophrenia who require high-technology AT for daily living skills.

Discussion/Conclusion

This case report demonstrates that extensive training/educational sessions can promote independence in high-technology AT use for a person with complex learning needs. Robert demonstrated the ability to use his PWC controls to change his body position and to move through wide hallways and wide doorways in an institutional setting independently after setup of the controls. Though objective measures for Robert demonstrated that he had not yet achieved modified or full independence with his alternative drive controls in all settings, being able to change his body position and drive in open spaces improved his skin integrity/safety and quality of life. The implications of this case report are that it may be possible to improve the ability of a person who experiences schizophrenia to use high-technology assistive devices. More time will be reasonable and necessary to provide measurable impact. Use of multiple objective outcome measures was beneficial to Robert, his OT/ATP, and the interdisciplinary team at the SCI center, as all could see that improvement was occurring. Autonomous PWC driving (Ezeh et al, 2017) and updated intuitive controls to promote PWC use for people who cannot use their hands and arms (Ashok, 2017) will benefit people experiencing schizophrenia who use PWCs in the future.

Connection to Growing Evidence Base on Learning and Schizophrenia

People diagnosed with schizophrenia have decreased access to everyday technology compared to the rest of the population (Gitlow et al., 2017). This decreased access results from a lower socioeconomic status that many people with the diagnosis experience (World Health Organization, 2022). Robert's lack of experience with everyday technology was a barrier for his wheelchair skills training. For example, Robert used a low-technology flip phone that was programmed by his mental health case manager. Robert did not have experience with computers, tablets, or smartphones from which he could learn other forms of AT. Lacking experience with everyday technology meant that teaching the PWC control interface was more challenging than it would have been if the inequity had not been present. Those involved in wheelchair assessment and training should request more sessions and more time for training sessions for people who have less experience with technology.

The extensive training provided to Robert is consistent with the growing literature base about the learning needs of people diagnosed with schizophrenia. Kaizerman-Dinerman et al. (2023) found that participants diagnosed with schizophrenia demonstrated higher scores on executive function assessments after extensive cognitive training. Orlov et al. (2021) found that spacing training sessions over more days and weeks improved memory formation of a novel task for people diagnosed with schizophrenia. Researchers hypothesized that the benefits of sleep on memory consolidation may provide the benefit. Tanaka et al. (2022) found that research participants diagnosed with schizophrenia are less adept at imitating motion compared to people without a schizophrenia diagnosis. As motion imitation is a commonly relied-upon skill for assistive technology training, it is important for assistive technology prescribers to know that the strategy may not be as effective for people with a schizophrenia diagnosis. However, there is hope for learning new activities, such as high-tech assistive technology. Hasan et al. (2022) found that people with schizophrenia can learn novel tasks despite decreased intrinsic and extrinsic brain activation and differences in dopamine sensitivity. Consistent with this case description, researchers implore that more time should be incorporated into a treatment plan for a person with schizophrenia who is learning a new task (Hasan et al., 2022; Kaizerman-Dinerman et al., 2023; Tanaka et al., 2022). As of the date of this case study, other literature supporting the use of powered mobility for people with complex learning needs is not found. Further research that considers the benefit of training opportunities for people with learning challenges is indicated.

Declarations

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References

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). American Psychiatric Association. https://doi.org/10.1176/appi.books.9780890425596

Ashok, S. (2016). High-level hands-free control of wheelchair – a review. *Journal of Medical Engineering & Technology, 41*(1), 46–64. https://doi.org/10.1080/03091902.2016.1210685

Borgnis, F., Desideri, L., Converti, R., & Salatino, C. (2023). Available assistive technology outcome measures: Systematic review. *JMIR Rehabilitation and Assistive Technologies. 10*(1) 1–19. https://doi.org/10.2196/51124

Budd, M. A., Gater, D. R., & Channell, I. (2022). Psychosocial consequences of spinal cord injury: A narrative review. *Journal of Personalized Medicine. 12*(7) 1–22. https://doi.org/10.3390/jpm12071178

Dawson, D. R., Kaiserman-Goldenstein, E., Chan, R., & Gleason, J. (2006). *Power-mobility indoor driving assessment manual (PIDA)*. Department of Occupational Therapy, Extended Care Division. https://www.carolinatherapy.net/wp-content/uploads/Power-Mobility-Indoor-Driving-Assessment.pdf

Ezeh, C., Trautman, P., Devigne, L., Bureau, V., Babel, M., & Carlson, T. (2017). Probabilistic vs linear blending approaches to shared control for wheelchair driving. *International Conference on Rehabilitation Robotics (ICORR)* (pp. 835-840). https://doi.org/10.1109/SMC.2017.8122584

George, O., Smith, R., Madiraju, P., Yahyasoltani, N., & Ahamed, S. I. (2021, July). Motor imagery: A review of existing techniques, challenges and potentials. In *2021 IEEE 45th Annual Computers, Software, and Applications Conference (COMPSAC),* pp. 1893–1899. IEEE. https://doi.org/10.1109/COMPSAC51774.2021.00286

Gitlow, L., Abdelaal, F., Etienne, A., Hensley, J., Krukowski, E., & Toner, M. (2017). Exploring the current usage and preferences for everyday technology among people with serious mental illnesses. *Occupational Therapy in Mental Health, 33*(1), 1–14, https://doi.org/10.1080/0164212X.2016.1211061

Hasan, S. M., Huq, M. S., Chowdury, A. Z., Baajour, S., Kopchick, J., Robison, A. J., Thakkar, K. N., Haddad, L., Amirsadri, A., Thomas, P., Khatib, D., Rajan, U., Stanley, J. A., & Diwadkar, V. A. (2023). Learning without contingencies: A loss of synergy between memory and reward circuits in schizophrenia. *Schizophrenia research*, *258*, 21–35. https://doi.org/10.1016/j.schres.2023.06.004

Kaizerman-Dinerman, A., Roe, D., Demeter, N.. Josman, N. (2023).Do symptoms moderate the association between participation and executive functions outcomes among people with schizophrenia? *BMC Psychiatry*, *23*, Article 42. https://doi.org/10.1186/s12888-022-04510-0

Khalil, M. K., & Elkhider, I. A. (2016). Applying learning theories and instructional design models for effective instruction. *Advances in Physiology Education*, *40*(2), 147–156. https://doi.org/10.1152/advan.00138.2015

Kirby, R. L., Rushton, P. W., Smith, C., Routhier, F., Best, K. L., Cowan, R., Giesbrecht, E., Koontz, A., MacKenzie, D., Mortenson, B., Parker, K., Smith, E., Sonenblum, S., Tawashy, A., Toro, M., & Worobey, L. (2013). *The wheelchair skills program manual.* Dalhousie University. https://wheelchairskillsprogram.ca/en/skills-manual-forms-version-4-2/

Lange, M. (2018). Powered mobility: Alternative access methods. In M. Lange & J. Minkel (Eds.), *Seating and wheeled mobility: A clinical resource guide* (pp. 179–198). SLACK, Incorporated.

Law, M., Baptiste, S., McColl, M., Opzoomer, A., Polatajko, H., & Pollock, N. (1990). The Canadian occupational performance measure: An outcome measure for occupational therapy. *Canadian Journal of Occupational Therapy*, *57*(2) 82–87. https://doi.org/10.1177/000841749005700207

Little, J. D., & Bell, E. (2021). Anosognosia and schizophrenia—A reminder. *Australasian Psychiatry: Bulletin of Royal Australian and New Zealand College of Psychiatrists*, *29*(3), 344–345. https://doi.org/10.1177/1039856220928866

Nasreddine, Z. S., Phillips, N. A., Bédirian, V., Charbonneau, S., Whitehead, V., Collin, I., Cummings, J. L., & Chertkow, H. (2005). *Montreal cognitive assessment (MoCA)* [Database record]. APA PsycTests. https://doi.org/10.1037/t27279-000

Orellana, G., & Slachevsky, A. (2013). Executive functioning in schizophrenia. *Front Psychiatry*, *24*(4), 1–15. https://doi.org/10.3389/fpsyt.2013.00035

Orlov, N. D., Sanderson, J., Muqtadir, S. A., Kalpakidou, A. K., Michalopoulou, P. G., Lu, J., & Shergill, S. S. (2021). The effect of training intensity on implicit learning rates in schizophrenia. *Scientific reports*, *11*(1), 6511. https://doi.org/10.1038/s41598-021-85686-5

Pollak, J. (2021). Psychological and cognitive insight: How to tell them apart and assess each. *Psychological Times*, *38*(4), 31–35. https://search.ebscohost.com/login.aspx?direct=true&db=cul&AN=149670799&site=ehost-live&scope=site

Rajendram, R., Preedy, V. R., & Martin, C. R. (2022). *Diagnosis and treatment of spinal cord injury: The neuroscience of spinal cord injury.* Academic Press.

Roberts, T. T., Leonard, G. R., & Cepela, D. J. (2017). Classifications in brief: American spinal injury association (ASIA) impairment scale. *Clinical Orthopaedics and Related Research*, *475*(5), 1499–1504. https://doi.org/10.1007/s11999-016-5133-4

Schneider, M., Müller, C. P., & Knies, A. K. (2022). Low income and schizophrenia risk: A narrative review. *Behavioural Brain Research*, *435*, Article 114047. https://doi.org/10.1016/j.bbr.2022.114047

Shersher, V., Haines, T. P., Sturgiss, L., Weller, C., & Williams, C. (2021). Definitions and use of the teach-back method in health care consultations with patients: A systematic review and thematic synthesis. *Patient Education and Counseling, 104*(1), 118–129. https://doi.org/10.1016/j.pec.2020.07.026

Smith, E. M., Low, K., & Miller, W. C. (2018). Interrater and intrarater reliability of the wheelchair skills test version 4.2 for power wheelchair users. *Disability & Rehabilitation*, *40*(6), 678–683. https://doi.org/10.1080/09638288.2016.1271464

Tanaka, M., Osanai, T., Kato, T., Ogasawara, H., & Wada, K. (2022). Visual imagery imitation skills and cognitive functions in patients with schizophrenia. *Hong Kong Journal of Occupational Therapy*, *35*(1), 105–112. https://doi.org/10.1177/15691861221102777

Taylor, R. B. (2018). *Medical writing: A guide for clinicians, educators, and researchers* (3rd Ed.). Springer. https://doi.org/10.1007/978-3-319-70126-4

World Health Organization. (2022, January 10). *Schizophrenia*. https://www.who.int/news-room/fact-sheets/detail/schizophrenia