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Preface

The Center on Disabilities at California State University, Northridge is proud to welcome you to the fifth issue of the *Journal on Technology and Persons with Disabilities*. These published proceedings from the Annual CSUN Assistive Technology Conference, represent submissions from the Science/Research Track presented at the event held March 1-3, 2017.

The Center on Disabilities at CSUN has been recognized across the world for sponsoring an event that for more than 30 years highlights the possibilities and realities which facilitate the full inclusion of individuals with disabilities. Over the last three decades, it has truly evolved into the most significant global platform for meeting and exchanging ideas, continually attracting more than 4,000 participants annually.

We were once again pleased that the fourth Call for Papers for the Science/Research Track in 2016 drew a large response of more than 40 leading researchers and academics. A panel of more than 30 highly-qualified peers from around the world formed the program committee and was chaired by Dr. Klaus Miesenberger. The expertise of the program committee ensured that each contribution was expertly and equitably peer-reviewed and only those submissions of the highest caliber were accepted for presentation and publication. Demonstrating a clear focus on scientific excellence, this fourth Journal and the Science/Research Track at the conference, document CSUN's commitment to involve scientific researchers from all over the world to fulfill its mission as a platform of exchange with full cooperation and support of all stakeholders.

We would like to thank the authors, the Science/Research Track review panel, the Center on Disabilities team at CSUN, and the editorial staff for their professional support. As always, we are grateful for and appreciate the many participants and partners who have contributed to the CSUN Assistive Technology Conference throughout the first 31 years. As we begin to move into our 4th decade, we will continue to seek out this support and collaboration and hope you will join us at our 2017 event where the conference will convene for the first year as the "CSUN Assistive Technology Conference".

Welcome once again to our 5th publication of "The Journal on Technology and Persons with Disabilities." We hope you will continue to enjoy our endeavors and with your continued support of the Center on Disabilities at CSUN and the annual conference we can all work together in our mission of "changing the world for people with disabilities."

Sandy Plotin
Managing Director, Center on Disabilities

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Crowdsourcing-Based Mobile Application for Wheelchair Accessibility

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Abstract

Creating an optimal travel plan is not an easy task, particularly for people with mobility disabilities, for whom even simple trips, such as eating out in a restaurant, can be extremely difficult. Many of their travel plans need to be made days or even months in advance, including the route and time of day to travel. These plans must take into account ways in which to navigate the area, as well as the most suitable means of transportation. In response to these challenges, this study was designed to develop a solution that used linked data technologies in the domains of tourism services and e-governance to build a smart city application for wheelchair accessibility. This smart phone application provides useful travel information to enable those with mobility disabilities to travel more easily.

Keywords

Linked data, crowdsourcing, wheelchair accessibility, mobility disabilities, semantic web, mobile application

Introduction

Travelling to have dinner with friends in a restaurant, shop, or visit a museum should not require too much time or advanced planning, and for most people, these outings are simple. However, even simple trips can be extremely difficult for people with mobility disabilities, who may need to plan their travel days or months in advance. In fact, the market for accessible tourism is tremendous (Darcy and Dickson, 2009; Buhalis et al. 2005). According to the World Health Organization (2015), over a billion people, approximately 15% of the world's population, have some form of mobility disability. In Switzerland, the number of people with mobility disabilities reached 780,000 in 2012 (Swiss Federal Statistical Office, 2012). Disabilities (physical, sensory, or cognitive) limit people's long-term ability to participate in daily life activities and interact with their environments (family, profession, schools, means of transport, etc.).

Information systems consist typically of multiple databases with independent data stored on different computer systems and in different data models, many of which commonly contain overlapping and inconsistent data. Although there are many ways to make the data useful, the most fundamental is to enable anyone to access and use it without formatting or licensing restrictions. However, traditional web technologies do not allow people to obtain information easily from different databases, as the data are usually stored in a variety of formats. To link the data and obtain useful information, users must spend considerable time collecting and comparing the adaptive information from different sources and databases to understand to what the data refer, and the way in which the information is interrelated. Semantic-based, linked data technologies make data more meaningful and useful. By providing identifiers (URIs) in datasets, such as places, transportation, and geographic areas, we applied linked data to individual data items and statistical observations. Thus, our algorithms were able to identify crowdsourcing data with semantic-based, linked data technologies, which then can be used to link information that is more useful. For example, once a user collects data about a point of interest, or POI (e.g., longitude, latitude, and the accessibility criteria), our application identifies whether the POI is a restaurant or museum. Further, the linked data technologies also allow us to provide additional information when it is available on the Web, such as its hours of operation, telephone number, or menu and prices. To provide context descriptions and location information, the mobile application links each POI to some external ontologies, including DBPedia (Auer et al., 2007) and Geonames (Wick and Vatant, 2012). By applying standardized ontologies, our semantic-based solutions offer another significant contribution that makes information easy to share, publish, and reuse as structured data and domain knowledge. The use of linked data is ideal in helping people with mobility disabilities make their travel plans; it also provides complementary services for tourism businesses simultaneously.

Therefore, the main objective of this research was to use crowdsourcing data to design and develop a visualized travel accessibility system in the form of a mobile application for people with mobility disabilities. We referred to this as WEMAP, and created a User Story to illustrate our solution (Figure 1). We adopted a design science approach that would answer the following research questions:

- When making travel plans, what are the real needs of people with mobile disabilities?
- How does one design and develop a mobile application by applying new approaches for semantic-based, linked data technologies and information visualization?

- How does one build a solution that can generate door-to-door routes automatically to avoid obstacles to wheelchair accessibility and make the journey easier for people with mobility disabilities?

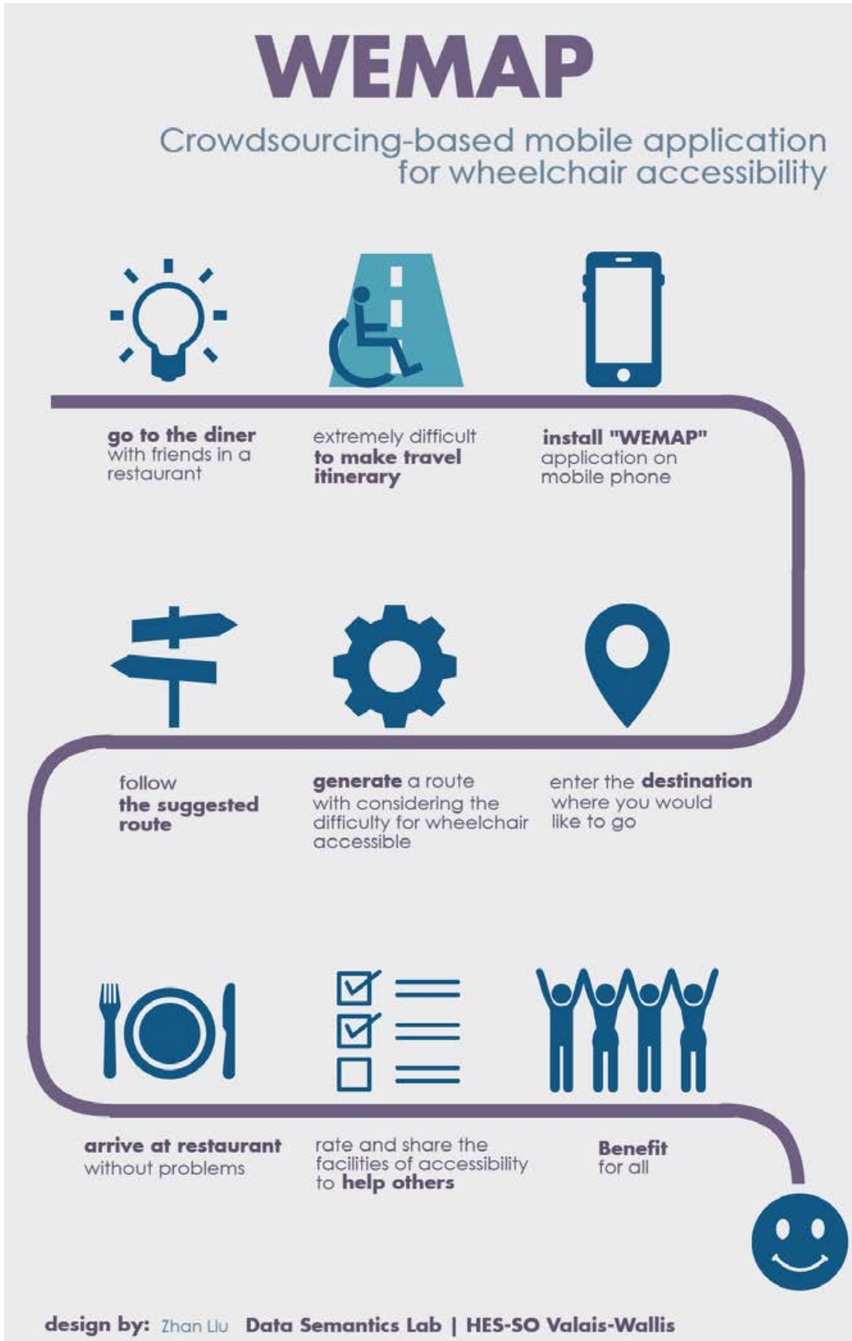

Fig. 1. User Story of WEMAP

Discussion

In this section, we first introduce the methodology we used in the study. Then, we highlight the key findings from online surveys that describe the business needs of travelers with mobility disabilities. Next, we present the process with which we designed and developed the mobile application and relevant functions. Finally, we discuss the results of evaluation obtained in focus group interviews, including the application's usefulness and effectiveness for people with mobility disabilities.

Methods

This project adopted the framework of information systems research presented by Hevner et al. (2004), as illustrated in Figure 2. First, we spoke with people with mobility disabilities and asked them to complete an online survey to identify their business and tourism needs to ensure the applied relevance of the research. Then, travelers with mobility disability requirements were examined to match the linked data-related technology environment for the research and identify the research artifacts through environmental field-testing. To achieve rigor in this project, we drew on existing theories and knowledge-based methods and then added newly generated knowledge to that base. The central design cycle focused on the construction and evaluation of artifacts and processes through qualitative and quantitative evaluation methods. Accordingly, we conducted several focus group interviews to assess the usefulness and functionality of the system. These were conducted iteratively in parallel with software development to ensure that their suggestions were incorporated in the design.

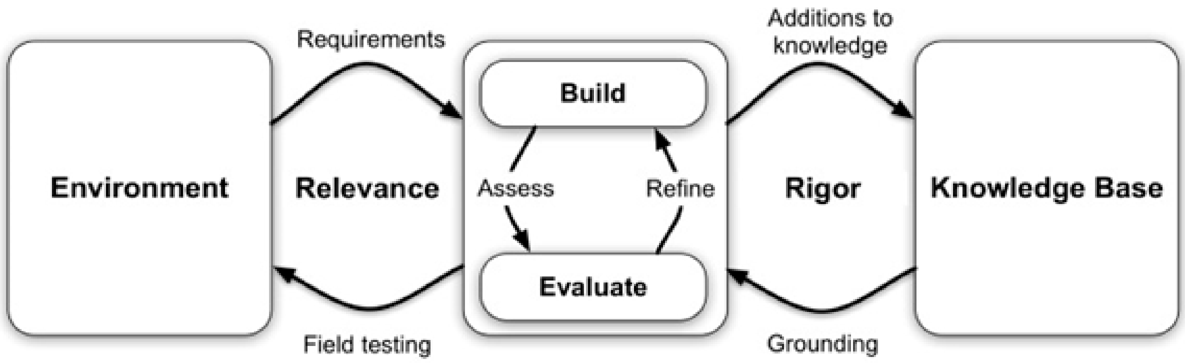

Fig. 2. Information Systems Research Framework (Based on Hevner et al., 2004).

Business Needs and Key Findings from Online Survey

We used a quantitative method in the form of an online survey to determine the users' real needs with respect to accessibility. We recruited 74 participants, 52 women and 22 men with different backgrounds (e.g., professor, social educator, journalist, secretary, psychologist, etc.). They ranged in age from 17 to 77 years, with a mean of 40.5. Sixty percent of the participants were accompanying persons for people with mobility in their professional or private lives, and the remainder were people with mobility disabilities. Most participants (75%) indicated that they used a wheelchair for their normal travel.

In this step, we examined primarily two objectives: the scope of information about mobility disabilities (types of mobility, frequency of trips, means used, facilitators or obstacles identified), and evaluation of mobile application ideas. The results showed that disabled access in the Canton of Valais is unsatisfactory for people with mobility disabilities. The average rating of satisfaction concerning existing information about mobility disabilities was 4.64/10, as shown in Figure 3, where zero signified no satisfaction at all, and 10 signified total satisfaction.

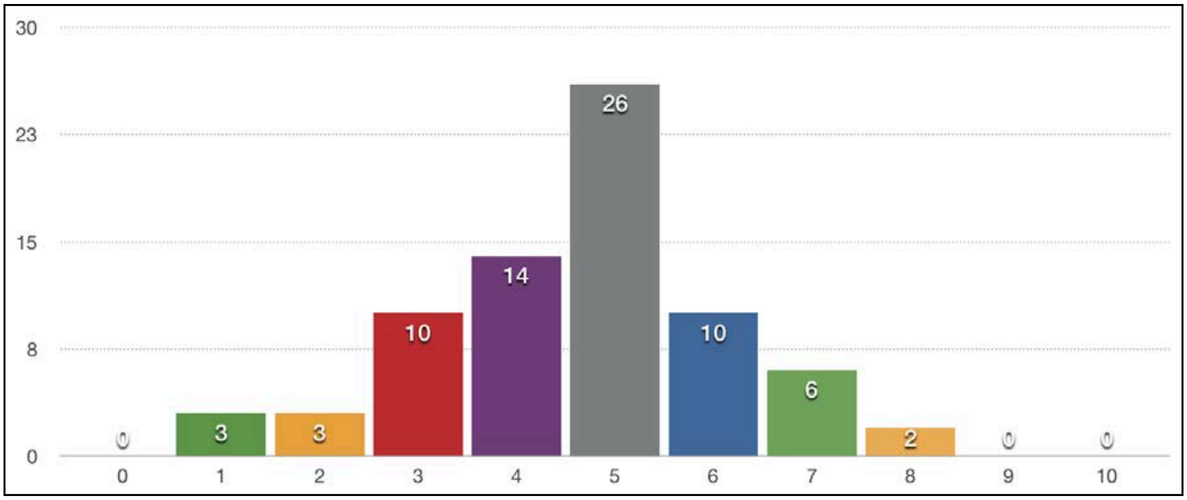

Fig. 3. Satisfaction with Existing Information on Mobility Disabilities (Canton of Valais, Switzerland).

The idea of the application was welcomed widely, with a rating of 9.08/10 (shown in Figure 4). The participants stated that it would very useful for people with mobility disabilities, and for those who worked with disabled people as well. They indicated that they intended to use the application and make contributions to help others as well.

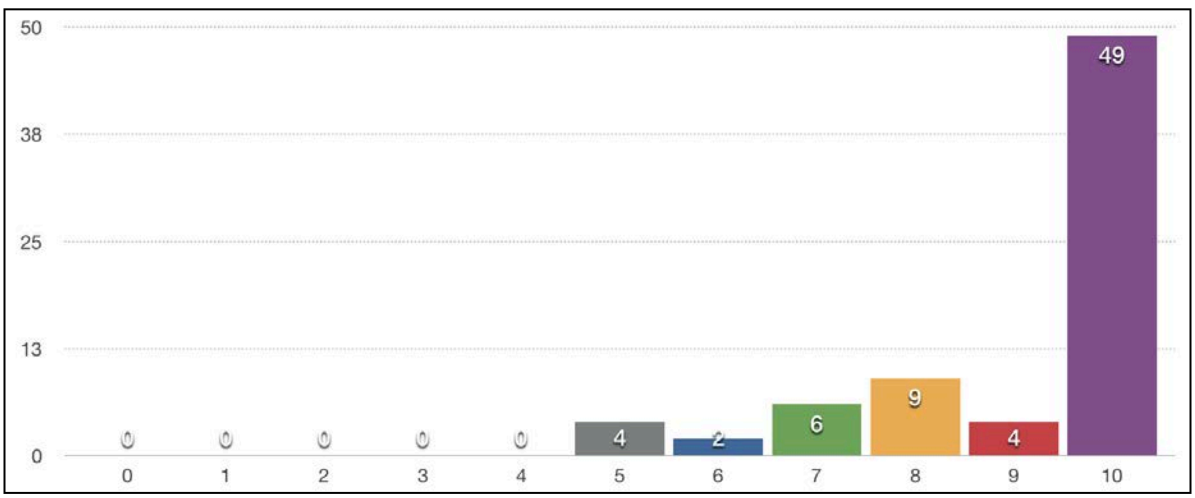

Fig. 4. Satisfaction with WEMAP Application Ideas.

Moreover, our participants rated and defined six accessibility criteria: 1) slope of over 10 degrees; 2) parking for people with disabilities; 3) disabled toilets; 4) entrances without steps; 5) obstacles on the path, and 6) sidewalks. Table 1 shows these criteria and their definitions.

Table 1. Accessibility Criteria and Definitions.

Criteria Name	Definition
Slope > 10 degrees	Slope of more than 10 degrees of angle
Parking for people with disabilities	Identified as accessible and reserved for people with disabilities
Disabled toilets	Adapted toilets for people with disabilities, including room size requirements, large space, toilet support
Entrances without steps	Entrances to buildings have no steps
Obstacles on the path	Some form of substrate is an obstacle to accessibility (e.g. too soft, gravel, grass)
Sidewalk < 1.5 meters	The dimension of the level landing should be at least 1.5m x 1.5m to allow wheelchair users to stop and rest without blocking the flow of pedestrians

Related Works

Several studies have been conducted on the subject of wheelchair accessibility. Most traditional solutions have focused on data collection and visualization using the approach of crowdsourcing in a set of specific places (i.e. AxsMap; Wheelmap; AmiWheelChair; Wegoto; Access and Earth), that help people with mobility disabilities find places suited to their needs. These often allow users to add data in the defined POIs, and provide a rating system on accessibility information. However, most of the data collected from these applications are closed, and are not structured as linked data. Table 2 compares various existing solutions and their functionalities. We argue that it would be difficult to share and re-use these data for other purposes or platforms. In addition, the information these solutions provide about accessibility in Switzerland is rather limited. Finally, and most importantly, none of them provides automatic door-to-door route generation functions so that people with mobility disabilities can enjoy greater freedom in their decisions. In this paper, we created the WEMAP mobile application to fill these research gaps.

Table 2. Comparison of Existing Mobile Applications.

Functionalities	Axs Map	Wheel Map	Ami-WheelChair	Wegoto	Access Earth
Add information	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Add the steps	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Rate a location	**Yes**	**Yes**	No	No	**Yes**
Rate the entryway	**Yes**	**Yes**	No	No	**Yes**
Rate parking facility	**Yes**	**Yes**	No	No	**Yes**
Take a photo	No	**Yes**	**Yes**	No	No
Add review	**Yes**	**Yes**	Yes	No	No
Incentive mechanism	**Yes**	No	No	No	No
Login and profile	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Multi-language	No	**Yes**	No	No	No
Mobile app (Android)	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Mobile app (HTML5)	**Yes**	**Yes**	No	No	No
Wheelchair sensors/monitor	No	No	**Yes**	No	No
Different types of street	No	No	No	**Yes**	**Yes**
Calculate the short route	No	No	No	**Yes**	No
Structured data (schema.org)	No	No	No	No	No
Open data	No	No	No	No	No
Open source	No	**Yes**	No	No	No
Linked data from other resources	No	No	No	No	No
Plan the journey from door to door	No	No	No	No	No

Mobile Application Design and Development

Once we understood the users' real needs, we began to design and develop the mobile application. We built an easy solution that allowed visualization of linked data to help people with disabilities make their travel plans. This solution was constructed based on three different approaches, i.e., integrated-source, business-source, and crowd-source. Using linked data technologies, the integrated-sources function defines and integrates the data from different sources about accessible tourism with different formats. Moreover, we integrated information provided by local businesses and other facilities, such as stations, museums, shops, hotels, and restaurants. Actually, many facilities provide relevant information on their websites, but such information is usually scattered, and in certain circumstances, not easy to access. Exploiting and establishing the structure of linked data can help identify good evidence types for information integration. Thus, our objective was to integrate business-sourced information as a tool with which people with disabilities can determine what buildings are accessible, and to what extent. Nevertheless, self-assessment as a single source of data is somewhat biased, as the meaning of the statement "We are disability friendly" varies. To this end, we included a platform that allowed people to rate the accessibility of the facilities and, more importantly, to share that crowd-sourced information. In this way, the more evaluations users made, the more useful and reliable the information became. We believed that ratings provided by the "disabled community" would be more reliable, because people without disabilities cannot understand fully the challenges and problems that the disabled face. Hence, ratings and comments made by people who identify themselves as members of the "disabled community" should be given more weight, and listed at the top of the comments.

The following figures show the interfaces of the mobile application WEMAP. We developed this application, which included two main functions: data collection and visualizing route services, with the HTML5, PHP, and Javascript languages. The first function allowed users to add information from a list to a new or existing location, as shown on the left side of Figure 5. This list contained a set of POIs based on the user's position, or a specific address within a 300-meter radius. Once the user selected a POI, our system automatically crawled and linked the POI's information to other open ontologies, such as its address, phone number, official website, Wikipedia page from DBPedia, if available, location descriptions from GeoNames, and weather information. Then, users could select the criteria, as well as add photos and comments (shown in the middle of Figure 5). If the POI had been defined already by another user, users also could rate the existing information to control its quality (shown on the right side of Figure 5).

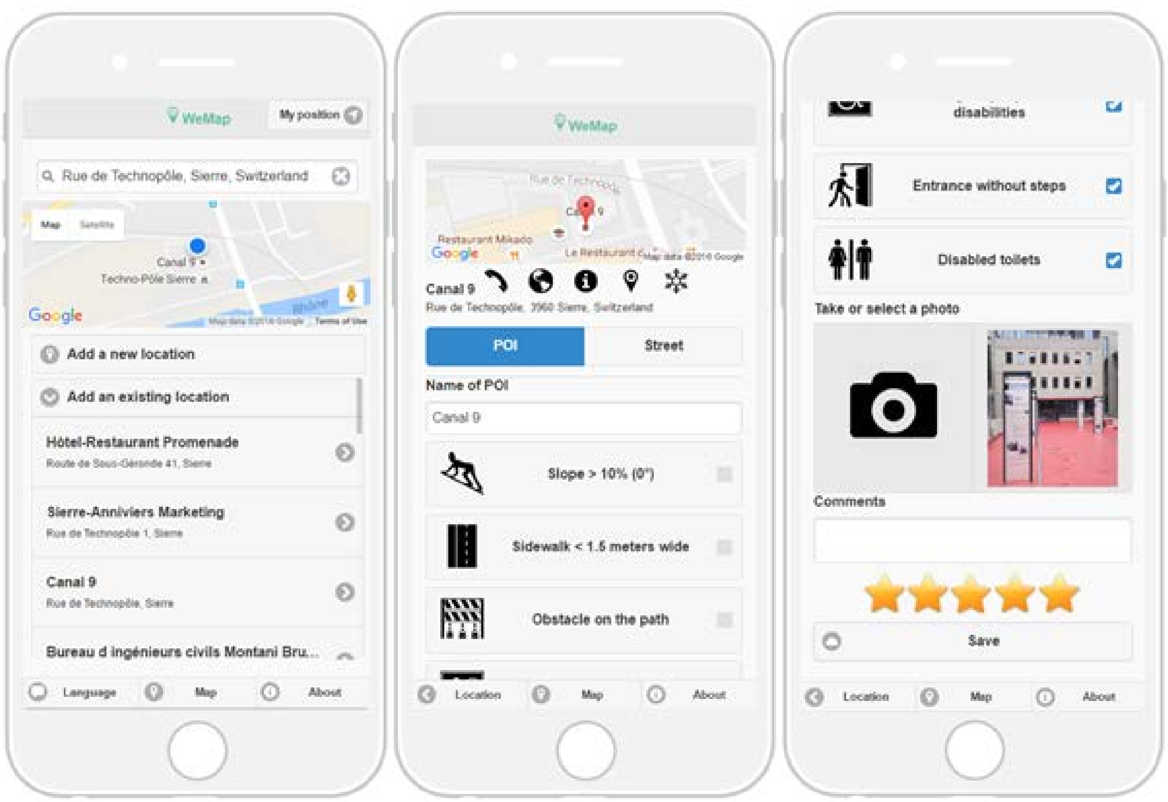

Fig. 5. WEMAP Data Collection Interfaces.

The Route Service function generates door-to-door routes automatically to avoid obstacles to wheelchair accessibility. This function allows users to select the travel mode from among wheelchair, pedestrian, bicycle, and car, as indicated on the left side of Figure 6. By entering the addresses of departure and destination, and selecting avoiding road types, users can generate their travel routes, as WEMAP calculates and finds a suitable route to satisfy the user's needs. For example, if there is an avoiding road between the departure and destination markers, our application suggests an alternative road to reach the destination, as shown in the middle of Figure 8. Moreover, detailed information is available and displayed on the map. Users can find these details by clicking on each marker—the details also can be modified (as shown on the right side of Figure 6). Finally, to motivate users to add information to this application, we award five credits for each new location added, and two credits for rating the existing location. The credits can be used for route services.

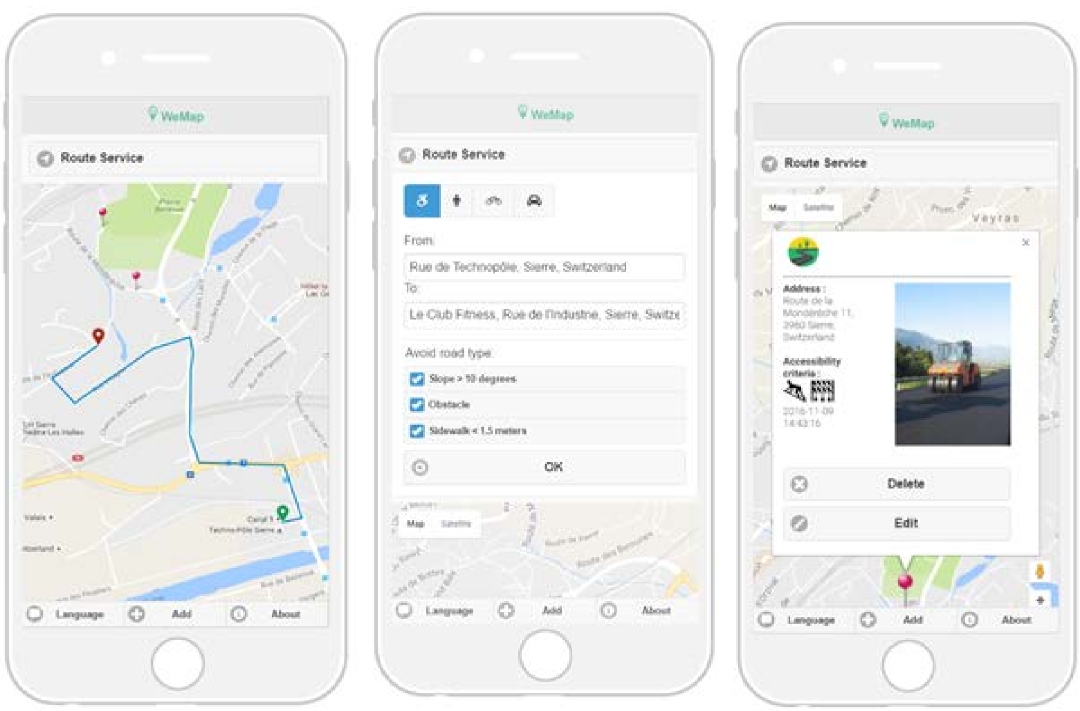

Fig. 6. WEMAP Route Services Interfaces.

Usefulness Evaluation

We tested and evaluated the mobile application with people from the Canton of Valais. To date, more than 800 POIs have been collected from the cities of Sion, Sierre, and Val d'Anniviers with the help of Swiss Post. We invited 12 participants who completed our online survey during an earlier stage to use the WEMAP mobile application. We also conducted three focus group interviews with four people per group. During the interviews, we asked about the users' experiences with respect to how easy it was to use the application and its utility in making their travel plans. At the end of the discussion, 11 out of 12 participants indicated that WEMAP could play a useful role in their lives and expressed their willingness to continue using it.

Conclusions

In this paper, we described a semantic linked data technology-based solution to help people with mobility disabilities plan their travels. To accomplish this, we collected and analyzed both unstructured and structured data from different databases, sources, and analyses available from social experts and organizations. Most importantly, we designed and presented the scientific methodology to build a user-friendly, crowdsourcing-based mobile application by integrating this heterogeneous information. Our solution allows people with mobility disabilities to search for and access useful, real-time information.

This research contributes significantly to both the tourism industry and the scientific community. For the tourism industry, it provides excellent opportunities to develop an accessible strategy that will increase competitiveness, as the market is predicted to grow because of the aging population. Therefore, regions that are experiencing low growth in tourism can benefit from investments in accessible tourism services and maintain and/or develop more activities. Moreover, the intensive analyses performed in this research provided a comprehensive view of disabled travelers' preferences for products and services, and also can help us understand the decisions made by potential tourists. From a scientific perspective, we filled an important gap in the literature on linked, data-based technologies for tourism services, as little is known to date about tourism-related services and products for people with disabilities. By analyzing the special needs of actual disabled persons, our study provided a better understanding of these factors. In addition, our results allowed us to enhance our knowledge of the ways in which disabled travelers perceive and evaluate tourism destinations.

Future research could include integrating photo recognition approaches to control the quality of the data users input automatically. In particular, we intend to double-validate the accuracy of information by both humans (rating system) and machines (photo recognition). Moreover, we intend to add some mini games to our mobile application as an incentive to motivate users to include more information that will help people with mobility disabilities.

Acknowledgments

The University of Applied Sciences and Arts Western Switzerland (HES-SO) supported the work described in this paper under grant number 61932. We thank Fabian Cretton and Professor Anne Le Calvé from HES-SO Valais-Wallis for their suggestions on technologies of Semantic Web and linked data. In addition, we thank Dominique Rion from Swiss Post for helping us collect the data from the Canton of Valais.

Works Cited

Auer S, Bizer C, Kobilarov G, et al (2007) DBpedia: A Nucleus for a Web of Open Data. In: Proceedings of the 6th International The Semantic Web and 2Nd Asian Conference on Asian Semantic Web Conference. Springer-Verlag, Berlin, Heidelberg, pp 722–735

Buhalis, D., Michopoulou, E., Eichhorn, V., and Miller, G. (2005). Accessibility market and stakeholder analysis - One-Stop-Shop for Accessible Tourism in Europe (OSSATE). Surrey, United Kingdom: University of Surrey.

Darcy, S., and Dickson, T. (2009). A Whole-of-Life Approach to Tourism: The Case for Accessible Tourism Experiences. Journal of Hospitality and Tourism Management, 16(1), 32-44.

Hevner, A., March, S., Park, J., and Ram, S. 2004. Design science in information systems research. Management Information Systems Quarterly. 28, 1 (March. 2004), 75-105.

McGuire, F. 1984. A factor analytic study of leisure constraints in advanced adulthood. Leisure Sciences. 6, 3 (Jan. 1984), 313–326. DOI= http://dx.doi.org/10.1080/01490408409513038

Murray, M., and Sproats, J. 1990. The disabled traveler: tourism and disability in Australia. Journal of Tourism Studies. 1, 1 (May. 1990), 9-14.

Smith, R. W. 1987. Leisure of disabled tourists: barriers to participation. Annals of Tourism Research. 14, 3 (Feb. 1987), 376-389. DOI= http://dx.doi.org/10.1016/0160-7383(87)90109-5

Wick, M, Vatant, B (2012) The geonames geographical database. http://geonames.org Accessed 09 March 2016

World Health Organization, 2015. Disability and health, Fact sheet. http://www.who.int/mediacentre/factsheets/fs352/en/

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THE JOURNAL ON TECHNOLOGY AND PERSONS WITH DISABILITIES

Introducing the University Assistive Technology Specialization in Visual Impairments

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Abstract

There is a long-standing demand for highly trained assistive technology (AT) experts in the field of visual impairments. There have been many viable attempts at establishing an AT credential for people with visual impairments. The efforts have all fallen short of that elusive goal until now. The opportunity finally exists to train professionals at the university level in the field of visual impairments to meet this long-standing demand. On May 1, 2016 the Academy for Certification of Vision Rehabilitation and Education Professionals (ACVREP) launched the Certified Assistive Technology Instructional Specialist for People with Visual Impairments (CATIS) credential. At the exact same time, the first university training program in AT for people with visual impairments began offering coursework. This paper details ACVREP's CATIS eligibility criteria and, in doing so, outlines the CATIS qualification requirements. The body of knowledge, structure, content and other important details of the CATIS credential are included to further explore the context of the guidelines and translation into a viable training program.

Keywords

Assistive technology, blind, certification, personnel preparation, visually impaired

Introduction

There is a long-standing demand for highly trained assistive technology (AT) professionals in the field of visual impairments (Edwards and Lewis; Kapperman, et al.; Kelly, 2008, 2009, 2011, 2016). Augusto and Schroeder explained that university preparation programs must add and develop their curricula to offer specialized training in AT for pre-service vision professionals, newly proclaimed vision professionals, and veteran vision professionals. More than a decade later, Kelly's (2008) research outlined the need for a national effort to develop a new specialty in AT in the field of vision, similar to the effort that was undertaken to establish the orientation and mobility specialty: "Further study that takes into account the need for this innovative aspect of education can best be geared toward gradually expanding a specialty in assistive technology training for the blind that reflects existing, emerging, and ever-changing technologies relevant to the field of visual impairment...this new aspect of education that embraces the existing, emerging, and ever-changing aspects of assistive technology is ready for immediate attention. If the necessary research was generated and policies were adopted, the education of visually impaired students could reorient itself immediately with this emphasis" (p. 96).

The opportunity finally exists to train professionals at the university level in the field of visual impairments to meet this long-standing demand. There is now a specialty in AT for professionals who work with people with visual impairments (that is, those who are blind or have low vision) (Kelly, 2016). In May of 2016 the Academy for Certification of Vision Rehabilitation and Education Professionals (ACVREP) launched the Certified Assistive Technology Instructional Specialist for People with Visual Impairments (CATIS) credential (Kelly, 2016). At the exact same time, the first university training program in AT for people with visual impairments began offering coursework within the Visual Disabilities Program at Northern Illinois University (NIU). Although the CATIS program of study is brand new, the NIU Visual Disabilities Program is well-established since its founding more than 50 years ago in 1964. These accomplishments are a direct response to what has been documented in the literature for the past two decades in terms of developing a new specialization in AT in the field of vision (Augusto and Schroeder; Kapperman, et al; Kelly, 2008). There were, however, many stumbling blocks involved in getting to this point. The discussions leading up to the launch of the new ACVREP CATIS credential first started in the 1990's during conferences related to assistive technology (ACVREP). There have been many viable attempts at establishing such a credential but they have all fallen short of that elusive goal until now in large part because of the challenge of answering the overarching question: "How do we figure out who is qualified for the assistive technology credential?" (ACVREP).

This paper overviews the response to this pressing question in terms of the ACVREP's CATIS eligibility guidelines. The body of knowledge, structure, content and other important details of the CATIS requirements are included to further explore the context of the guidelines and translation into a viable training program.

Discussion

CATIS Eligibility Criteria

In order to answer the question of who is qualified for this new AT credential, it is important to look toward the specific methods for acquiring CATIS eligibility outlined and established in the CATIS handbook (ACVREP). Those pursuing CATIS eligibility through Category 1 complete either a university/college degree program in assistive technology for the visually impaired or a university certificate program in assistive technology for the visually impaired and a full-time (350 hour) internship supervised by a CATIS. To qualify for CATIS eligibility through Category 2, it is required that there be a university degree, AT education/technical training in AT for individuals who are visually impaired, general technical training, a high degree of direct work experience providing AT instruction and assessment to people with visual impairments, and a 350-hour internship supervised by a CATIS. Table 1 shows the approved education and work experience requirements for acquiring CATIS eligibility through Category 2.

Table 1. CATIS Category 2 Educational and Work Requirements.

Degree Type	**AT Education/Technical Training for VI Individuals**	**General Technical Training (Post-Secondary)**	**Experience Providing AT Evaluation/ Training to VI Individuals**
Master's degree with an emphasis in vision studies (TVI, COMS, CVRT, CVLT).	Post-secondary credit hours of AT education or technical training equal of no less than 30 contact hours	15 contact hours	1,000 hours in the most recent 3 years
Master's degree in Special Education or Rehabilitation with no emphasis in vision studies	Post-secondary credit hours of AT education or technical training equal to no less than 45 contact hours	15 contact hours	1,500 hours in the most recent 3 years
Bachelor's degree or higher in any other field	Post-secondary credit hours of AT education or technical training equal to no less than 60 contact hours	15 contact hours	2,000 hours in the most recent 3 years

Source: Academy for Certification of Vision Rehabilitation and Education Professionals. *Certified Assistive Technology Instructional Specialist Handbook*. May 2016, www.acvrep.org/certifications/catis. Accessed 26 November 2016.

Note: AT = assistive technology; TVI = Teacher of Students with Visual Impairments; COMS = Certified Orientation and Mobility Specialist; CVRT = Certified Vision Rehabilitation Therapist; CVLT = Certified Low Vision Therapist.

Thus, there is a full-time internship requirement for both CATIS Category 1 and Category 2 and anyone who meets the CATIS requirements through Category 1 or Category 2 is also required to pass the CATIS certification exam.

CATIS Proficiencies

A review of the body of knowledge of the ACVREP CATIS puts into context the competencies in assessment, configuration, instruction and exploration. These domain areas are not perfectly even in weighting, as demonstrated in Figure 1, but operate dynamically and intersect to create a well-versed professional. As the name CATIS specifies with the inclusion of the word ‘instructional’, professionals in this new domain are expected to be teachers/trainers and not simply a prescriber of technology. This is an important distinction consistent with accepted best practices (Cook and Polgar). These best practices are expanded with the inclusion of the Expanded Core Curriculum (ECC) for individuals with visual impairments (Sapp and Hatlen) offering a broader systemic understanding of the impact of a visual impairment beyond individual tasks. The dilemma of training a professional well versed in visual impairments as well as instruction and technology has made the development of this new credential vital to the future of the field.

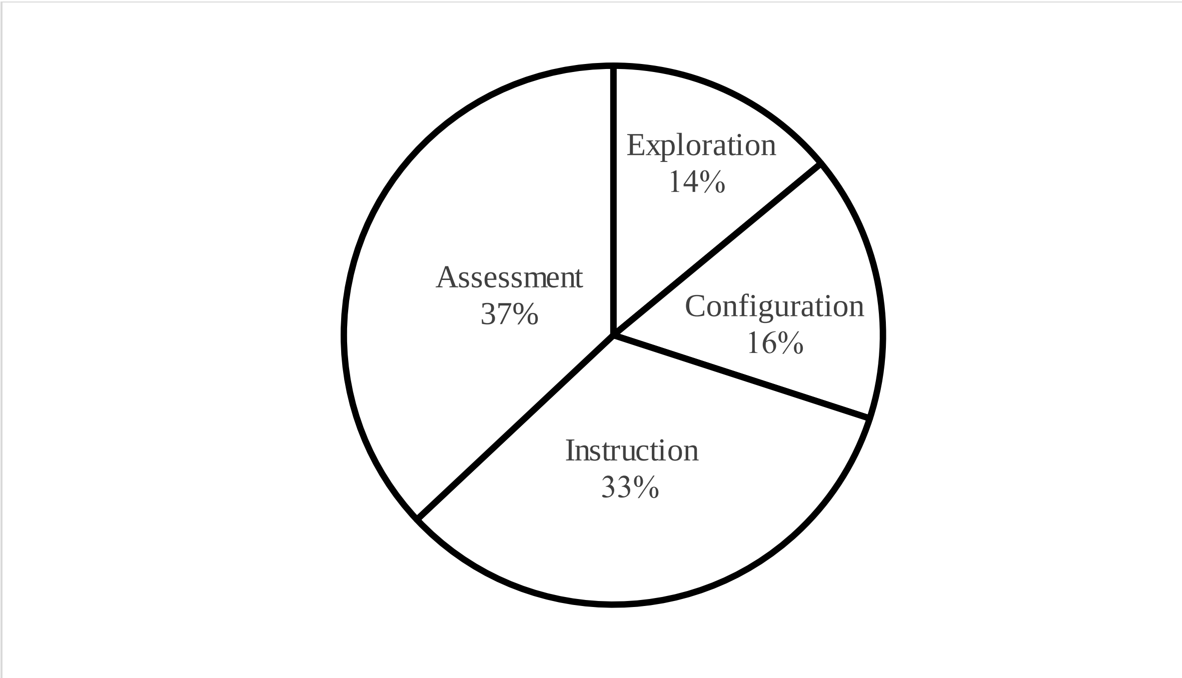

Fig. 1. Percentage of items in the CATIS body of knowledge by CATIS domain area.

The knowledge domain of assessment includes a wide range of evaluation and information. Sensory impairments impact life in a variety of ways and information gathering must include sources such as medical professionals, individuals, family members, and other involved specialists. Information should include both objective data (acuity and ocular health) and functional use of existing vision (reading rate, print size, braille use, environmental conditions, etc.) (Corn and Lusk). The vision specific information must also be taken into consideration along with additional implications, even including cognitive and neurological functioning. The gathered medical and functional information must then be paired with the individual capacities making use of high-low & hard-soft technologies (Cook and Polgar; Zabala et al.).

Instruction lies at the core of the field of visual impairments and includes use of vision (Erin and Topor), literacy skills (Holbrook et al.), use of optical devices (i.e. low tech) (Bell Coy and Andersen), and assistive technology (Presley) in an extensive manner. The context of visual impairments saturates the work of a CATIS, but the body of knowledge demands a rigorous understanding of learning styles, teaching methods and flexibility in instructional design as well. To meet the spirit of maximizing independence and self-determination (Sapp and Hatlen) the CATIS must also attend to the ability of the client to select and adapt the technology on their own, including regular maintenance and troubleshooting. Since many devices for individuals who are blind include braille and/or auditory feedback as the only means of output, some familiarity with the use of non-visual feedback is critical and will frequently require specific lessons for the client in addition to the capacity of the instructor. These examples of the instructional body of knowledge provide a portion of the content which also includes access technology use of mainstream device and applications.

The understanding of client or student needs, existing barriers, and instructional approaches address the direct services of a CATIS, but do not address the technological capacity and professional maintenance of skills. The configuration domain within the body of knowledge includes the hard skills (e.g., computer analytics) of the professional working directly with the technology to ensure the best results from delivery and instruction (ACVREP). These skills must detail hardware familiarity as well as software and operating system (OS) troubleshooting (ACVREP). Where information technology (IT) professionals are sometimes available to assist in these areas, personal and end site services too frequently demand technical expertise to repair, install or consult regarding the highly specialized technology in visual impairments.

The pace of technology is acknowledged through the exploration body of knowledge. With the emergence of rapid patching and updates, as well as annual version releases, a CATIS must be well equipped with conferences, websites, and training sources to stay current with their skills. These sources must include sources within the field of visual impairments and also broader settings so that the CATIS can be a well-informed professional participating on assistive technology teams. The CATIS professional should also be prepared to train others and share knowledge with the ability to develop tutorials, reviews and training manuals as needed (ACVREP).

Structure of the CATIS University Training Program

The CATIS is not intended to supplant any existing roles, but instead to elevate a cadre of professionals that will take their place among similarly trained individuals in other specialty areas. This philosophy of teamwork and collaboration has fueled the design of the Northern Illinois University CATIS certification efforts. The program was originally designed with the intent of preparing AT specialist certified in professional domains of visual impairments who would also be eligible for the Rehabilitation Engineering and Assistive Technology Society of North America (RESNA) Assistive Technology Professional (ATP) certification. During the refinement and proposals of this program of study this new AT certification specific to visual impairments has emerged. In the interest of the highest quality of instruction the NIU CATIS program seeks to prepare professionals who can meet both sets of requirements either upon graduation or after, during professional growth and experience.

More specifically, the NIU CATIS program was designed in a unique manner to offer more than one way of acquiring ACVREP CATIS eligibility. Multiple pathways have been developed to support both new and existing vision professionals at the same time. This high degree of differentiation in AT coursework is not something that has not previously been built-into a single university program infrastructure (Augusto and Schroeder; Kapperman; Kelly, 2008). However, evidence of the variety of approaches can be observed through review of separate programs offering Assistive Technology Professional certification.

The CATIS eligibility options at NIU include the following three pathways: (#1) traditional and comprehensive school year coursework and a full-time internship for new professionals earning a master's degree in AT for people who are visually impaired, (#2) AT graduate coursework (specifically, a graduate certificate program in AT for people with visual impairments) and a full-time internship for existing vision professionals (i.e., Teachers of Students with Visual Impairments [TVIs], Certified Orientation and Mobility Specialists [COMS], and Certified Vision Rehabilitation Therapists [CVRTs]), and (#3) on-line synchronous workshop series over 16-weeks to prepare existing AT professionals with support to their personal body of knowledge in preparation for testing and certification.

The design of the NIU master's degree program in AT for new CATIS professionals in the field is three-fold. Individuals are first educated in the specific academic specialties in visual impairments and assessment, including for example knowledge of the visual system and its functional use, literary braille code, basic orientation and mobility, and collaboration principles and skills for professionals working with people who are visually impaired. Candidates are next trained in a wide range of low-tech and high-tech low vision and blindness specific assistive technology tools for compensation with attention to the user experience. Finally, methods of instruction address advanced assistive technology skills and topics specific to people who are visually impaired with and without additional disabilities. This three-area focus reflects the CATIS core domain proficiencies outlined by the ACVREP. The training specific to technology assessment draws heavily upon the existing SETT (Zabala et al.) and HAAT (Cook and Polgara) models practiced by AT professionals in school settings and rehabilitation. This approach addresses the training of new professionals being introduced to practices, but there exists a large group of existing professionals that work in the area of AT.

addresses the training of new professionals being introduced to practices, but there exists a large group of existing professionals that work in the area of AT.

For professionals already versed in the domain of visual impairments and experienced in instructional methods, the NIU program has created the summers-only AT graduate certificate program to bring AT skills up to speed with the increased demands attention to AT instruction. It is required that any existing vision professionals accepted into the summers-only AT graduate certificate program at NIU have already acquired the non-AT specific core domain vision knowledge and expertise outlined in the CATIS handbook. The intensive summers-only program at NIU provides the AT coursework (a series of 4 graduate-level university courses) and a full-time AT internship that are included in the core domain and required for ACVREP eligibility. As presented at the onset of this paper, the vast majority of currently practicing professionals lack the AT expertise that meets the ACVREP CATIS standards.

Conclusions

This multifaceted approach of creating new professionals and training existing professionals is a direct response to ongoing and emerging demands in the field of practice. The goal of the CATIS program is to prepare extensively experienced vision professionals to collaborate on equal footing with other domain AT specialists. Existing AT specialists that have emerged from other disciplines such as physical therapy, occupational therapy, and communications areas will have new resources and colleagues as a result of the ACVREP CATIS. Vision professionals will now have a certification demonstrating their capacity and body of knowledge as part of an international accrediting body.

The need for the CATIS and supporting university coursework is long overdue. For the first time in history, the requirements for qualification as an AT specialist in the field of visual impairments have been explicitly established. Many of the eligibility requirements can only be fulfilled through formal university training. As outlined in this paper, universities with specializations in the area of visual impairments are uniquely situated to contribute the growth of this new assistive technology credential.

Works Cited

Academy for Certification of Vision Rehabilitation and Education Professionals (ACVREP). *Certified Assistive Technology Instructional Specialist Handbook*. May 2016, www.acvrep.org/certifications/catis. Accessed 26 November 2016.

Augusto, Carl R., and Paul W. Schroeder. "Ensuring Equal Access to Information for People who are Blind or Visually Impaired." *Journal of Visual Impairment & Blindness,* vol. 89, no. 4, 1995, pp. 9-13.

Bell Coy, Jennifer K., and Erika A. Anderson. "Instruction in the Use of Optical Devices for Children and Youths." In Anne Corn Editor & Jane Erin Editor (Eds.), *Foundations of Low Vision (2nd ed).* AFB Press, 2010. pp. 527-588.

Cook, Albert, and Jennifer Polgar. (2015). *Assistive Technologies: Principles and Practice (4th ed.)*. Elsevier Health Sciences, 2015.

Corn, Anne, and Kelly Lusk. "Perspectives on Low Vision." In Anne Corn Editor & Jane Erin Editor (Eds.), *Foundations of Low Vision (2nd ed).* AFB Press, 2010. pp. 3-34.

Edwards, Barbara J., and Sandra Lewis. (1998). "The Use of Technology in Programs for Students with Visual Impairments in Florida." *Journal of Visual Impairment & Blindness,* vol. 92, no. 5, 1998, pp. 302-312.

Erin, Jane, and Irene Topor. "Functional Vision Assessment of Children with Low Vision, Including those with Multiple Disabilities." In Anne Corn Editor & Jane Erin Editor (Eds.), *Foundations of Low Vision (2nd ed).* AFB Press, 2010. pp. 339-397.

Holbrook, M. Cay., et al. "Instruction of Literacy Skills to Children and Youths with Low Vision." In Anne Corn Editor & Jane Erin Editor (Eds.), *Foundations of Low Vision (2nd ed).* AFB Press, 2010. pp. 484-526.

Kapperman, Gaylen, et al. “Survey of the Use of Assistive Technology by Illinois Students Who are Visually Impaired.” *Journal of Visual Impairment & Blindness*, vol. 96, no. 2, 2002, pp. 106-108.

Kelly, Stacy M. *Correlates of Assistive Technology Use by Students Who are Visually Impaired in the U.S.: Multilevel Modeling of the Special Education Elementary Longitudinal Study*. Unpublished Ed.D., Northern Illinois University, 2008.

Kelly, Stacy M. “Use of Assistive Technology by Students with Visual Impairments: Findings From a National Survey.” *Journal of Visual Impairment & Blindness*, vol. 103, no. 8, 2009, pp. 470-480.

Kelly, Stacy M. “Assistive Technology Use by High School Students With Visual Impairments: A Second Look at the Current Problem.” *Journal of Visual Impairment & Blindness*, vol. 105, no. 4, 2011, pp. 235-239.

Kelly, Stacy M. “Introducing the New Assistive Technology Credential and Project VITALL University Training Program.” *Visual Impairment and Deafblind Education Quarterly*, vol. 61, no. 4, 2016, pp. 25-29.

Presley, Ike. “The Impact of Assistive Technology: Assessment and Instruction.” In Anne Corn Editor & Jane Erin Editor (Eds.), *Foundations of Low Vision (2nd ed)*. AFB Press, 2010. pp. 589-654.

Sapp, Wendy, and Phil Hatlen. “The Expanded Core Curriculum: Where we Have Been, Where we are Going, and How we Can Get There. *Journal of Visual Impairment & Blindness*, vol. 104, no. 6, 2010, pp. 338-348.

Zabala, Joy, S. et al. “SETT and ReSETT: Concepts for AT Implementation.” *Closing the Gap*, vol. 23, no. 5, 2004, p. 1.

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Automatic and Semi-automatic 2-tier Check System for EPUB Accessibility

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Abstract

With rapid development of electronic publishing technologies, e-books, especially EPUB, are being published at the same level of paper books publication volume. But still e-books with accessibility features are rare in the Korea market due to the production cost. Generally, EPUB accessibility means that people with disabilities can perceive, understand, navigate, and interact with the books. Similar to Web, e-books offers the possibility of unprecedented access to information and interaction for many people with disabilities. That is, the accessibility barriers to text, audio, and image can be much more easily overcome through EPUB accessibility technologies. Also EPUB accessibility benefits others, including older people with changing abilities due to aging.

We think the rareness of accessible e-books is caused by the complexity of generating EPUB with accessibility. In this paper, we aim to propose 2-tier automatic accessibility check mechanism and implement it to help EPUB production system make easier e-books with accessibility than before. To do this, we extract 158 check items from several accessibility guidelines. The usability of this system has evaluated with EPUB e-books which has several in-accessible elements. This system was installed and managed by the National Library of Korea after the verification for each process.

Keywords

Accessibility, EPUB, Self-diagnosis Checker, Web Checker, Guidelines

Introduction

There are several EPUB accessibility guidelines such as IDPF (International Digital Publication Forum), BISG (Book Industry Study Group) and DAISY consortium. These guidelines are well constructed and described concrete expressions about 'to-do' and 'not-to-do'. The fundamental test sheets from 3 sites provide the essential accessibility check points and instructions to the person conducting the test.

In the viewpoint from publishers and writers who are not familiar to web technology, HTML, CSS and EPUB structure, it needs a lot of manual work to make EPUB which is complying with 3 kinds of guidelines. This difficulty prevents the progression of mass production of accessible EPUB.

Actually in Korea, publishers convert EPUB from PDF or ADOBE InDesign files, insert some multimedia files, add some JavaScript to represent an interaction, and distribute it without accessibility features. It shows they don't have any interest to make accessible EPUB files. When inspecting EPUB file which has been deposited at the National Library of Korea, we found that more than 95% does not have any accessibility features.

At first we defined 156 accessibility check points precisely and designed 2-tier automatic checker based on those items. Therefore e-book publishers can check their EPUB accessibility automatically whenever needed and get some exact information about which line and which column should be changed and what HTML element should be input. They just follow the system and end to get EPUB with accessibility.

We have experienced the automatic accessibility checkers for web contents and known their potential shortfalls; it means that they cannot check for all potential barriers. The same situation happens at the EPUB field. If there is no interaction between the checker and the e-book reader doing an accessibility review, one can be guaranteed that not all potential barriers are being considered. Anywhere that meaning is being reviewed, for instance, a human must make a decision. That is, accessibility checking technology is very poor at determining whether epub:type attribute is meaningful enough, or whether the page number accurately is the same as the number at paper book, to name two examples. In these and other cases, a person must decide. Taking these shortcomings into account, the checker was developed to address the problems. We propose the check process makes 2-tier structure, one level is automatic check system and the other is semi-automatic check system.

Related Research

The automatic accessibility check system must be based on EPUB accessibility guidelines from several organizations. We reviewed IDPF "EPUB3 accessibility guidelines", BISG "The Quick Start Guide to Accessible Publishing" , DIAGRAM CENTER "Top Tips for Creating Accessible EPUB3 Files", W3C "Web Content Accessibility Guidelines (WCAG) 2.0" and "Accessible Rich Internet Applications (WAI-ARIA) 1.0".

"EPUB3 accessibility guidelines" has been designed to help the creation of accessible EPUB 3 content. It includes a quality assurance checklist together with instruction on how to implement the requirements. It covers from semantic representation with logical reading order to scripted interactivity with canvas and contains roughly 63 categories. We extracted what can be implemented in the form of the automatic checker from those guidelines.

"The BISG Quick Start Guide to Accessible Publishing" serves as the model for best practices in creating accessible digital content for those who live with disabilities, in compliance with international standards. It also addresses why and how to create, distribute, and display accessible digital content and provides an overview of the critical importance of accessibility. It is very similar to EPUB3 accessibility guidelines and connects to “Image Guidelines for EPUB 3” from DIAGRAM. We implemented a check routine whether images has alternate text or image descriptions and whether EPUB has the accessibility metadata.

“Web Content Accessibility Guidelines (WCAG) 2.0 covers a wide range of recommendations for making Web content more accessible and provides to make content accessible to a wider range of people with disabilities, including blindness and low vision, deafness and hearing loss, learning disabilities, cognitive limitations, limited movement, speech disabilities, photosensitivity and combinations of these. EPUB has the foundation of web contents such as HTML, CSS, etc. each element and each page of EPUB should follow WCAG specifications. We make the checker utilize the success criteria A level of WCAG and will have to extend the deeper level AA or AAA.

Accessibility of web content requires semantic information about widgets, structures, and behaviors, in order to allow assistive technologies to convey appropriate information to persons with disabilities. “Accessible Rich Internet Applications (WAI-ARIA) 1.0” provides ontology of roles, states, and properties that define accessible user interface elements and can be used to improve the accessibility and interoperability of web content and applications. These requirements can be activated the interaction with e-book readers. We align these features into semi-automatic checking process which has linked to both web viewer and web editor.

As a result of reviews of the previous guidelines, we extracted 156 check items(Kim) such as the definition of the language used, the existence of separate style file, whether or not to use of bold tag, the existence of TOC, etc.

In the part of web accessibility checker (Greg Gay et al) developed open, interactive, customizable, web accessibility checking tool. Their checker allows the reviewer to interact with the system while conducting an accessibility review, making decisions on issues the checker cannot identify with certainty. It is very similar to our semi-automatic check process which can address issue points automatically at web viewer and can make the reader/editor change those points at the web editor if it doesn't satisfy the accessibility rule. Their checker is working only on web contents not on EPUB contents.

IDPF EpubCheck is a tool to validate EPUB files. It can detect many types of errors in EPUB. OCF container structure, OPF and OPS mark-up, and internal reference consistency are checked. It can verify whether EPUB file is compliant to EPUB structure and specifications. It cannot verify the accessibility of EPUB. So we would utilize EpubCheck only to verify whether the file is EPUB or not whenever our system gets one.

Check Process and System Components

Our system handles the EPUB accessibility under 2-tier process which has the 1st tier, PC version and the 2nd tier, Web version. We call the 1st tier as automatic checker and the 2nd tier as semi-auto checker.

Whenever the system gets EPUB, the 1st tier, automatic checker, automatically check the 39 accessibility check points for both EPUB contents and EPUB structure. It lists up errors as the table form and notifies the position, the row and the column number, for each issue at component files of EPUB as shown at Fig.1. Also it represents the correct specification so that editors can change the issue points.

After finishing the 1st tier process, EPUB file is uploaded onto web system to start the 2nd tier process, semi-auto checker which handle the rest 117 check points. Whenever the system gets EPUB, the system automatically select the experts from the accessibility expert pool which has been registered lots of specialists into the system and send the request mail to them.

Once some experts get the request mail, they log in to the system and start the 2nd tier process as shown at Fig.2. Semi-auto checker searches error points that may have accessibility issues and show them at the web viewer. Experts check those points manually and verify whether those points have problems or not. The final defect reports gathered from experts were sent to the original publishers. Finally publishers and editors can change all errors and restart the process. PC version as shown at Fig.1was developed with C# and is working only on windows OS. It has 6 menus such as Open (EPUB), Report (open issue report), Batch (handling several EPUB files at the reserved time), Help, Preferences, Exit. It consists of three modules such as EPUB decomposition module, accessibility check module, EPUB.

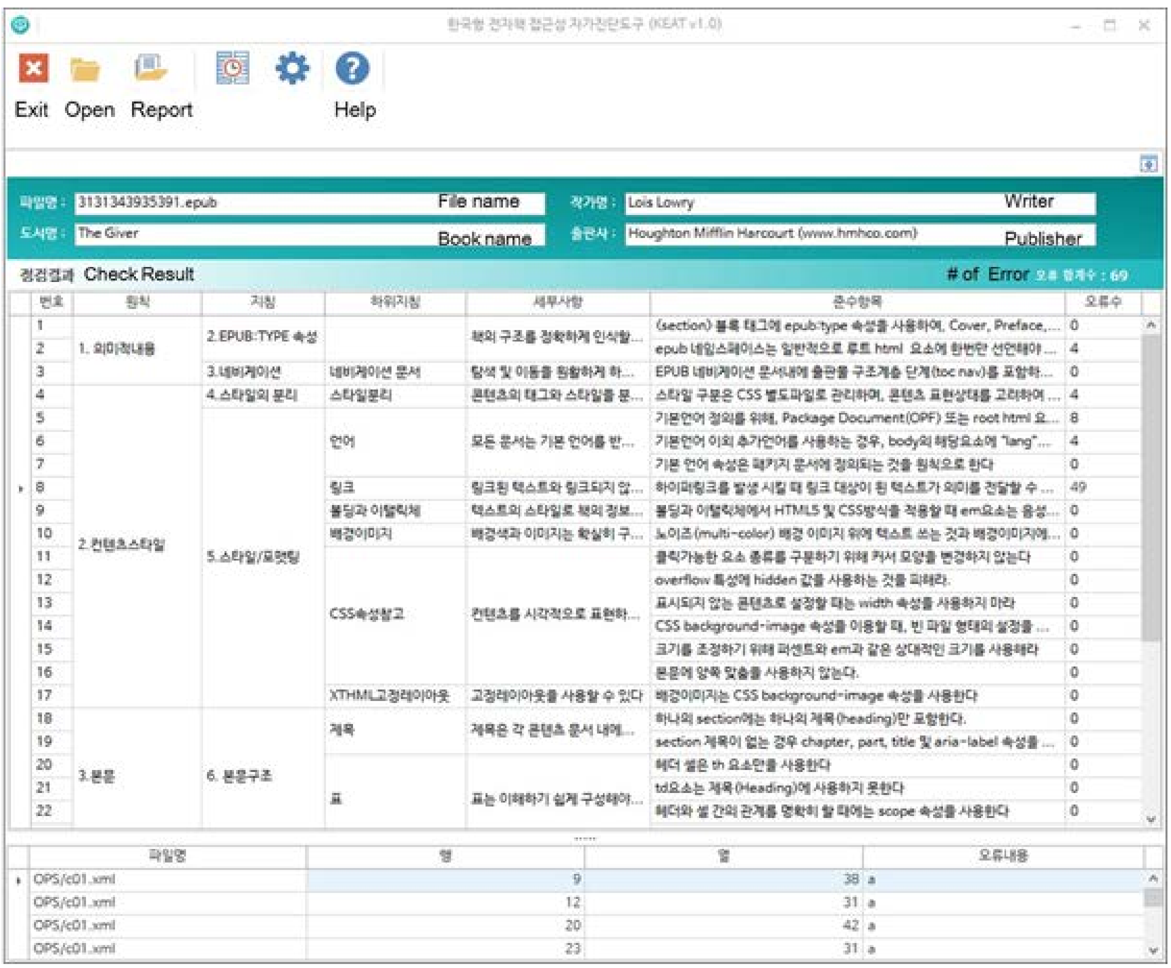

Fig.1. Automatic Checker

Web version as shown at Fig.2 was developed with Java and Maven. It has 3 parts such as Administrator (managing all specialists and procedures, reviewing the statistical data), Publisher (confirming the status of their EPUB files), and Expert (attending the 2nd tier work). It consists of five modules such as EPUB management module, accessibility check module, EPUB viewer, Process management module, and Person management module.

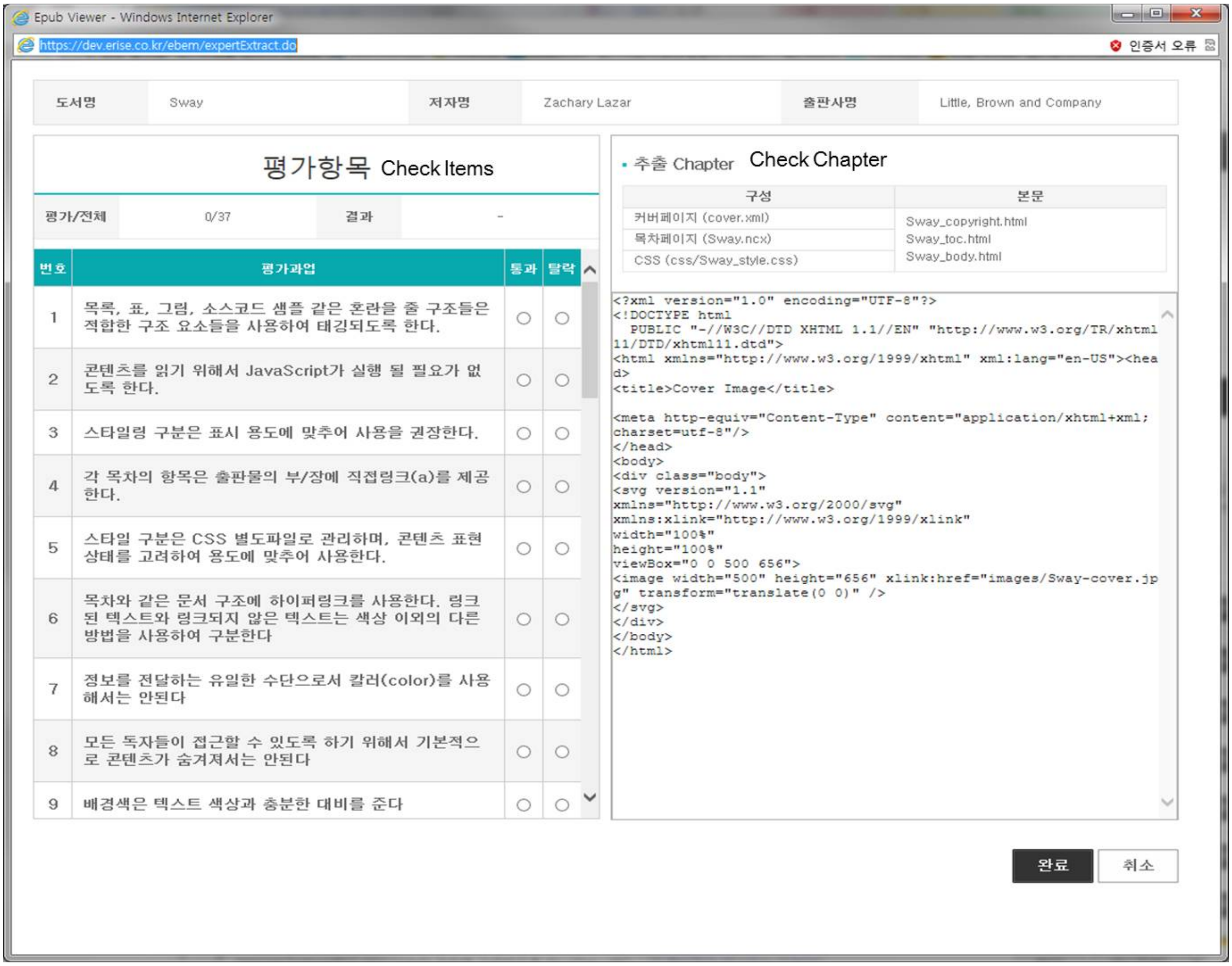

Fig. 2. Semi-auto checker on the web

To estimate the coverage of the automatic system, we selected 50 EPUB files which has deposited into the national library of Korea and investigated how Korea EPUB files are well in compliance with the accessibility specification.

Korea EPUB publishers have generally used "SIGIL (Hendricks)" which is free, open-sourced editing software for e-books in the EPUB format since EPUB format was announced in the market. This software can support some accessibility features at the current version. But 50 sample EPUB files have 148 accessibility defects per each file on average. We think those sample files were generated from old version SIGIL which was not supported the accessibility features.

Also we found publishers are not sympathetic to the need of accessibility features due to the production cost and time even though new authoring tools could support some points. Major issues happen intensively at eight parts:

- To define the default language for an XHTML document, the lang and xml:lang language attributes need to be attached to the root html element. It occupies 41% over all defects.
- In the case of multilingual publications, best practice is to always specify the language in each content document to ensure proper rendering. It occupies 21% over all defects.
- When using the epub: type attribute in a content document, the epub namespace must be declared on the element containing the attribute, or on one of its ancestors. It occupies 13% over all defects.
- Images that are central to the understanding of a publication must always include a text alternative in their alt attribute. It occupies 7% over all defects.
- When creating hyperlinks, the text inside of the link can provide the full context of what is being linked to or the link can have alternate text. It occupies 7% over all defects.

- Separating style from markup is consequently not just about keeping CSS in a separate file from your markup, but recognizing that markup must convey meaning to be useful to all readers. It occupies 7% over all defects.
- When using bolding and italics, EPUB follow the rules of HTML5 and CSS standard. It occupies 2% over all defects.
- Avoid justifying text, as the uneven spacing that occurs between words can reduce the readability for some people. It occupies 1% over all defects.

Fortunately those eight parts can be modified only if they can be detected. It means that our system can change a manual process into the automatic detection process and reduce both the production time and cost.

Discussion and Conclusion

We proposed the Automatic Check System for EPUB Accessibility which was based on EPUB3 accessibility guidelines from IDPF and other organizations. It has some limitation because it is impossible to check all accessibility features automatically but designed 2-tier system to extent the automatic process.

Through real field test, we found the 1st tier automatic system could pick up all problematic items which defined as 39 check points and is responsible for 25% of all 156 check points. Other parts of guidelines are linked to the 2nd tier system. The 2nd tier system can point out the rest part of items so that e-book publishers can confirm them.

But we have lots of accessibility features which can be checked automatically. We have only scratched the surface of what can be done to improve the automatic accessibility check and make the difficult task of EPUB accessibility work easier. We could use a learning mechanism for an automatic checker using a model trained from specialist's decision about whether the part to be problematic is a real issue point.

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Works cited

Book Industry Study Group, "BISG Quick Start Guide to Accessible Publishing." March 2016

DIAGRAM Center, "Top Tips for Creating Accessible EPUB3 Files." http://diagramcenter.org/54-9-tips-for-creating-accessible-epub-3-files.html Accessed August 23, 2016.

DIAGRAM Center, "Image Guidelines for EPUB 3." http://diagramcenter.org/59-image-guidelines-for-epub-3.html accessed August 23, 2016.

Greg Gay, Cindy Qi Li, "AChecker: Open, Interactive, Customizable, Web Accessibility Checking", Proceedings of the 2010 International Cross Disciplinary Conference on Web Accessibility (W4A), Article No. 23, 2010

Hendricks, Kevin B. (June 18, 2016). "Sigil-0.9.6 Released". https://github.com/Sigil-Ebook/Sigil/releases accessed August 23, 2016.

International Digital Publishing Forum, "EPUB3 accessibility guidelines." https://idpf.github.io/a11y-guidelines/ accessed August 23, 2016.

International Digital Publishing Forum

https://github.com/IDPF/epubcheck accessed August 23, 2016.

Kim, Hyun-young, "memoir for E-book accessibility management and certification system." Project completion report of the Korea national library for the disabled, December 20, 2015.

World Wide Web Consortium, "Web Content Accessibility Guidelines (WCAG) 2.0." https://www.w3.org/TR/WCAG20/ accessed August 23, 2016.

World Wide Web Consortium, "Accessible Rich Internet Applications (WAI-ARIA) 1.0." https://www.w3.org/TR/wai-aria/ accessed August 23, 2016.

Textile-Based Assistive Wearables

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Abstract

Advances in computing technology such as conductive textiles and shrinking chip sizes offer new possibilities for assistive technology (AT). Wearable computing platforms provide many advantages (e.g., reachability, continuous support, communication) that may be especially useful for AT. We provide a snapshot of wearable assistive computing literature spanning the past 20 years in an effort to better understand the trends, usage patterns in this space. We focus especially on the emerging capabilities of textile-based wearable computing platforms. Additionally, we reflect on the trajectory of these technologies and suggest potential directions for the development of computer-based wearable assistive technologies.

Keywords

Wearable computing, assistive technology, e-textiles, design considerations

Introduction

Approximately 19% of the US population lives with a disability (Brault 4). Assistive technology (AT) can help overcome many challenges imposed by an inaccessible environment, such as through the use of sensory substitution (e.g., converting visual information into sound), alternative computer input and output (e.g., eye tracking), and communication support (e.g., text-to-speech). AT presents both benefits and drawbacks, with an average of 1/3 of all AT devices abandoned often due to functional and social-cultural reasons (Kintsch and DePaula 2). Some of these problems may be addressed by creating AT that is less heavy, bulky, and obtrusive.

In this paper, we explore the benefits of textile-based wearable computing AT, as these devices may potentially provide support without drawing too much attention. The rise of mobile computing platforms and microelectromechanical systems have solved several power, weight, size, and bandwidth constraints which previously hampered wearable computing development. Similarly, advances in e-textiles (e.g., conductive fabrics) enable worn computers that are lighter, smaller, and more flexible, enabling them to be worn comfortably throughout the day or to be designed to look like “normal” attire, avoiding the unwanted attention that some AT produces.

This paper presents an overview of textile-based wearable assistive technology developed over the past 20 years. We specifically focus on how these wearable technologies (wearables) can improve usability, comfort, and social acceptability for people with disabilities (PwD), and identify general trends, opportunities, and challenges for developing new wearable AT.

Discussion

A Brief History of Wearable Assistive Technology

Many of the earliest types of wearables can be considered assistive in nature, intended to overcome some congenital or acquired limitation. Perhaps the oldest documented assistive device, a prosthetic toe, was discovered on a nearly 3000 year-old Egyptian mummy (www.bbc.com/news/education-19802539). Eye glasses, hearing trumpets, braces, and prosthetics represent other historical forms of worn assistive technology, and illustrate the long history of wearing assistive devices on, or as part of, one's body.

While most wearables have taken a "one size fits all" approach, the developers of modern wearables (e.g., smart watches), are beginning to discover what designers of worn AT have known for years: namely that technology must be designed to match the user's shape, abilities, and style. The following sections detail wearable textile-based AT from research and industry.

Sensory Substitution and Enhancement Devices

While the notion of wearable computers to enhance our capabilities is relatively recent (Starner 44), much AT has been designed to enhance or replace a user's senses. For example, though not a worn e-textile device, a mobility cane enables a visually impaired person to use their senses of touch and hearing in place of vision. Researchers and designers have extensively explored how wearable AT can be applied in this capacity, especially for pedestrian navigation, language translation, and non-verbal cue detection. A primary challenge lies in providing proper feedback during the task, without overwhelming or distracting the user. For this reason, wearable AT capable of haptic feedback has often been explored due to its ability to provide instructions with minimal distraction. Ross's wearable wayfinding system uses a combination of vibratory, tonal, and speech feedback to assist with street crossing (51), and was specifically designed to provide feedback without distracting the user from his or her environment.

Similarly, Zelek et al.'s wayfinding vibro-tactile glove was designed to provide feedback as the user encountered objects to the front, left, or right (627). In other cases, haptic output is used because the other sensory modalities are impaired. Gollner et al. developed a language translation glove for deaf-blind individuals (127). This system was optimized for rich touch feedback, using an intricate network of sensors and vibration motors to recreate this palmar-based touch-alphabet. A primary obstacle to sensory substitution is that different senses have different levels of communication bandwidth; thus, we must often design “shorthand” systems that convey highly encoded information via the substituted sensory channel.

Navigation, Wayfinding, and Mobility Support

Supporting independent navigation is a primary goal of many assistive devices, and wearable AT may directly benefit independent navigation by leveraging wearable sensors and actuators to convey information. Worn AT devices present the added benefit of providing subtle, private feedback. For example, the Nuviun LeChal shoe (http://nuviun.com/content/news/gps-smart-shoes-guide-the-blind-track-fitness) tracks a blind user’s location via GPS and provides guidance via haptic feedback on the user’s foot, eliminating the need to carry a device or constantly check for the next instruction.

Textile-based AT has also been used to enhance motor control and balance by sensing the user’s motion and providing compensatory support. For example, Paradiso et al. developed smart footwear which used a musical beat to help improve gait response in individuals with Parkinson’s disease (1342). Wall and Weinberg created a smart belt for individuals with vestibular injuries that detected loss of balance and provided haptic instructions for a user to correct their posture (86). Liu et al. developed e-textile pants with embedded sensors that provided clinicians with detailed feedback about an elderly wearer’s stability (696).

Supporting Rehabilitation and Restoring Function

In contrast to AT, which is designed for use over long periods of time, rehabilitation devices support physical, sensory, and cognitive therapy which are designed to aid someone in a short-term recovery process, with the goal of returning to a previous functional state. As a result, the root cause, motivation, duration, and context of use of rehabilitative devices may vary significantly from that of AT designed for long-term use.

Physical therapy (PT), a form of rehabilitation, often involves prolonged repetitive exercises, which can be tedious and fatiguing. Attempts to keep users engaged during PT have involved integrating visual feedback into devices to visualize progress and motivate the user. For example, PT Viz presents visual feedback on a wearable knee brace as the user performs PT exercises (Ananthanarayan et al. 1247). Another approach is to train exercises through haptic feedback. The Mobile Music Touch (MMT) glove supports dexterity rehabilitation for individuals with quadriplegia by providing haptic stimulation to the hands throughout the day. MMT's feedback consists of haptic taps on the user's fingers, synched to historically popular American songs, such as Jingle Bells, for a more engaging form of PT (Markow et al. 6).

A common risk of in-home PT entails performing exercises incorrectly, which can lead to reinjury or abandonment of PT altogether. Providing guidance about how to use AT and perform exercises can help reduce added stress or self-doubt on the user's behalf. Mollii is a full-body electrotherapy garment designed for neuromuscular conditions (http://inerventions.se/en/). The garment helps eliminate the reliance on a clinician for proper e-stim patch placement, enabling in-home use. Telemedicine can also provide support by connecting the user to a remote therapist or physician. PT Viz was designed to support collaborative goal making between patient and clinician, enabling nearly real-time feedback from the therapist (Ananthanarayan et al. 1250).

Communication Support

Augmentative and alternative communication (AAC) address challenges related to producing speech and text to communicate (Beukelman and Mirenda). These devices often take the form of tablets or PCs that can be difficult to hold or carry, especially for people with comorbid motor disabilities. Moreover, large AAC devices can obstruct natural communication, such as by blocking eye contact between communication partners. Worn devices can support communication through less intrusive form factors and user interfaces. Profita's e-textile wearable AAC board was designed to support use during equine therapy as the physical demands of riding a horse limit the user's ability to carry a large device (231). The Mobile Lorm Glove is a hardware- instrumented glove that translates Lorm, a hand-touch alphabet developed for individuals who are deaf-blind, into text messages on a mobile phone to improve communication for deaf-blind individuals while minimizing reliance on an interpreter (Gollner et al. 129). The message recipient can respond by typing a text message into their mobile phone, which is then translated into a vibro-tactile message presented on the glove.

Wearable AT also presents opportunities for recognizing and interpreting other sign languages, such as American Sign Language (ASL). Some ASL recognition systems use a stationary camera, which requires the user to stand in a fixed location. Wearable systems would permit the device to move with the user throughout the day. Starner et al. developed an ASL recognition system that used a hat-mounted camera to capture images of the wearer's hands (1371). While ASL translation remains an active problem, wearable systems present an opportunity to create more usable ASL translation systems.

Behavioral and Social Support

We are witnessing a significant rise in the prevalence of developmental disabilities such as autism spectrum disorder (ASD) (Kientz et al. 28), which can affect an individual's ability to interact socially. Wearable AT can assist people with these types of disabilities by providing the user or caregiver with feedback about one's behavior. For example, wearable sensing systems can track a user's affective state facilitating improved behavior mediation or improved caregiver intervention (Kientz et al. 31). Furthermore, wearable AT can potentially draw less attention to the user, which could increase the adoption of these technologies, as social inclusion is cited as one of the most important values for many individuals with a cognitive disability (Lewis 12).

Some people with ASD and related conditions can be calmed in stressful situations through the application of constant pressure to the torso. Squease is an inflatable vest designed for those with ASD, ADHD, and other cognitive disabilities (www.squeasewear.com). Squease uses a manually operated pump for inflation, but could be extended in the future to provide pressure as needed by sensing the user's emotional state. While many types of AT focus on enabling the user to act without assistance from others, some individuals will still require support from caregivers. AT can help support communication between the user and one's care network, lending to better decision-making and informed intervention methods (Kientz et al., 29).

How Assistive Technology Can Help Wearable Technology (and vice versa)

As AT designers have long considered how to make technology that can be comfortably worn, insights from the design of wearable AT can inform the design of mainstream wearables, especially in scenarios when the wearer's ability is *situationally impaired* by context, such as when the user's visual attention is distracted, or when the user's hands are occupied. Likewise, we can look to mainstream apparel and the fashion industries to inform issues concerning comfort and aesthetics of worn devices. Items worn on the body are considered highly personal and are projections of self- and group-identity (Shinohara and Wobbrock 706). Exploring the emotional effects of worn devices could provide insight into the adoption and retention of AT.

There are also a number of higher level usability challenges that affect both AT and mainstream wearables. Designing AT and wearable devices requires creating new input and output techniques based on the user's abilities in the context of use. Feedback from these systems should convey only that information which is most relevant, and this information should be delivered in a useful, meaningful, and appropriately-timed manner. These devices must be available when desired and then easily dismissible when no longer needed (Ross 52). Feedback may need to be converted from visual or audio to another sensory representation, or may need to be presented multi-modally.

Opportunities for Future Research

Advances in textile-based wearables are proceeding on several fronts. Novel nanotechnology and fabrication techniques have resulted in textiles with circuitry embedded directly in the fabric, enabling computing devices that can flex and stretch like conventional clothing. Such systems can also lend to new interface designs and gesture input which can be performed by individuals with a variety of abilities. Do-it-yourself tools for developing soft circuits, such as LilyPad (http://lilypadarduino.org/), enable users with limited technical skills, such as people with disabilities and their caregivers, to create their own wearable devices. And finally, managing battery power and charging through the use of wireless and inductive charging can reduce the physical challenges of manipulating the physical device (Kane et al. 118).

Conclusion

Wearable AT has a long and established history in the lives of people with disabilities. As wearable technology enters the mainstream, there are new opportunities to provide better support for people with disabilities through commercial systems that can extend beyond the limitations of cumbersome prototypes. Beyond that, there exist opportunities for designers of mainstream wearable technologies to learn from the history of wearable assistive technology to create designs that are more usable and acceptable to both disabled and non-disabled audiences.

Works Cited

Ananthanarayan, Swamy, et al. "PT Viz: towards a wearable device for visualizing knee rehabilitation exercises." *Proceedings of CHI.* ACM, 2013.

Beukelman, David, and Pat Mirenda. "Augmentative and alternative communication: Supporting children and adults with complex communication needs." (2005).

Brault, M.W. "Americans with disabilities: 2010. US Department of Commerce, Economics and Statistics Administration." *US Census Bureau* (2012).

Gollner, Ulrike, et al. "Mobile Lorm Glove: introducing a communication device for deaf-blind people." *Proceedings of TEI.* ACM, 2012.

Kane, Shaun K., et al. "Freedom to roam: a study of mobile device adoption and accessibility for people with visual and motor disabilities." *Proceedings of ASSETS.* ACM, 2009.

Kientz, Julie A., et al. "Pervasive computing and autism: Assisting caregivers of children with special needs." *IEEE Pervasive Computing* 6.1 (2007): 38-35.

Kintsch, Anja, and Rogerio DePaula. "A framework for the adoption of assistive technology." *SWAAAC 2002: Supporting Learning Through Assistive Technology* (2002): 1-10.

Lewis, Clayton. "HCI for people with cognitive disabilities." *ACM SIGACCESS Accessibility and Computing* 83 (2005): 12-17.

Liu, Jian, et al. "Local dynamic stability assessment of motion impaired elderly using electronic textile pants." *IEEE Transactions on Automation Science and Engineering* 5.4 (2008): 696-702.

Markow, Tanya, et al. "Mobile Music Touch: Vibration stimulus in hand rehabilitation." *2010 4th International Conference on Pervasive Computing Technologies for Healthcare.* IEEE, 2010.

Paradiso, Joseph A., et al. “Interactive therapy with instrumented footwear.” *CHI'04 Extended Abstracts on Human Factors in Computing Systems*. ACM, 2004.

Profita, Halley.” An electronic-textile wearable communication board for individuals with autism engaged in horse therapy.” *Proceedings of ASSETS*. ACM, 2012.

Ross, David A. “Implementing assistive technology on wearable computers.” *IEEE Int. Sys.*16.3 (2001).

Shinohara, Kristen, and Jacob O. Wobbrock. “In the shadow of misperception: assistive technology use and social interactions.” *Proceedings of CHI*. ACM, 2011.

Starner, Thad. “The challenges of wearable computing: Part 1.” *IEEE Micro,* 21.4 (2001): 44-52.

Starner, Thad, et al. “Real-time american sign language recognition using desk and wearable computer based video.” *Transactions on Pattern Analysis and Machine Int*. 20.12 (1998): 1371-1375.

Wall, Conrad, and Marc S.Weinberg. “Balance prostheses for postural control.” *IEEE Engineering in Medicine and Biology Magazine* 22.2 (2003): 84-90.

Zelek, John S., et al. “A Haptic Glove as a Tactile-Vision Sensory Substitution for Wayfinding.” *Journal of Visual Impairment & Blindness* 97. 10 (2003): 621-632.

THE JOURNAL ON TECHNOLOGY AND PERSONS WITH DISABILITIES

Smartphone Use and Activities by People with Disabilities: User Survey 2016

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Abstract

Access and use of mainstream wireless technology is essential to social and economic participation, which can be especially challenging to people with disabilities. Technology ownership rates are indicative of general access to these critical technologies. However, analysis of the activities of technology users can provide more detailed assessment of the nature and degree of technology access. This article presents findings from the Survey of User Needs (SUN) for Wireless Technologies, a large, multi-year survey on use of consumer wireless technology by people with disabilities, conducted by the Rehabilitation Engineering Research Center for Wireless Technologies. Because of their versatility (connectivity, size, and portability) smartphones have come to occupy the center of many people's digital experience. Data are presented on the ways people with disabilities use their smartphones, including voice calling, text messaging, emailing, using mobile apps, social networking, etc. Analysis of smartphone activities is provided on three areas: 1) adults with physical, cognitive, and sensory disabilities analyzed as a group; 2) the impact of key demographic variables – age, race/ethnicity, household income; 3) activities by disability type (blindness, deafness, difficulty speaking, etc.).

Keywords

Information & Communication Technology (ICT), Research and Development, Accessibility

Introduction

Access and use of mainstream wireless technology has become essential to social and economic participation. Digital exclusion means less independence and greater social exclusion. If you don't have access to mainstream consumer information and communication technology, you're not part of the conversation, both literally and figuratively. Ownership rates are generally indicative of access to these critical technologies. However, analysis of the activities of technology users can provide more detailed assessment of the nature and degree of technology access. This article presents findings from the Survey of User Needs (SUN) for Wireless Technologies, a large, multi-year survey on use and usability of mainstream wireless technology by people with disabilities, conducted by the Rehabilitation Engineering Research Center for Wireless Technologies (Wireless RERC). Data are presented on the ways people with disabilities use their smartphones, including voice calling, text messaging, using mobile apps, social networking, accessing the Internet, etc.

Because of their versatility (connectivity, size, and portability) smartphones have come to occupy the center of many people's personal communications infrastructure and digital life. Data from the CTIA-The Wireless Association show over 378 million wireless service subscriber connections in the United States (CTIA 2015), substantially exceeding the total national population. The Pew Research Center reports steadily rising rates of cellphone ownership (including smartphones), from 73% of American adults in 2006 to 92% in 2015 (Pew 2015). Smartphone ownership has risen from 35% of American adults in 2011, to 56% in 2013, and 68% in 2015; the tablet ownership rate rose from 10% to 34% and 45% (Table 1).

People with disabilities have access to mainstream mobile wireless technology at generally the same rates as the general population. Survey research data collected by the

Rehabilitation Engineering Research Center for Wireless Technologies (Wireless RERC) indicate that 84% of people with disabilities own or use a cellphone or smartphone. Including tablets raises the wireless device ownership rate for people with disabilities to 91%. Table 1 shows that the smartphone ownership rate among people with disabilities has risen from 57% to 72% in the three years from 2012-2013 to 2015-2016. Tablet ownership rose from 35% to 50%.

Table 1. Device Ownership by Adults with Disabilities (SUN) and in the General Population (Pew Research Center), 2012-2015.

Device Type	SUN 2012-2013	SUN 2015-2016	Pew 2013	Pew 2015
Basic Phone (e.g. Motorola Razr, Pantech Breeze, Nokia 6350)	27%	13%	35%	24%
Smartphone (e.g. iPhone, Android phone, Windows phone)	57%	72%	56%	68%
Tablet (e.g. iPad, Kindle Fire, Galaxy Tab, Microsoft Surface)	35%	50%	34%	45%

Overall ownership rates of mobile wireless devices, particularly smartphones, provide a key indicator of access to wireless technology (Morris et al. 2016; 2014). However, understanding what people with disabilities *do* with their devices will shed light on how and whether they are realizing the rapidly expanding potential of their technology. This article provides analysis of the smartphone activities and behaviors on three levels /dimensions:

1. Analysis of adults with disabilities analyzed as a group; includes comparison with the data from the Pew Research Center for the general population of adults.
2. Analysis of the impact of key demographic variables – household income and age – on smartphone activities.

3. Analysis of smartphone activities and behaviors by disability type (blindness, deafness, difficulty speaking, etc.) will provide additional insight into the specific behaviors of each group, and perhaps identify opportunities for serving them better.

Discussion

Originally launched in 2002 and now in its 5th version, the SUN has been updated over the years to keep current with the rapid pace of technological change. This unique, nationwide survey on wireless technology use by people across disabilities has come to be an important reference for the wireless industry, government regulators, people with disabilities, disability advocates, and other researchers. Over 7,500 people with all types of disabilities have completed at least one of the previous versions of the SUN since 2002. Sample size for the current version of the SUN is 1,168 respondents across the disability categories listed in Table 2. Participants were recruited using convenience sampling via email, the web, personal outreach, telephone, and in-person interviews. The mean age of all respondents who reported a disability was 59.29 years and 52.23 for the 2012-2013 and 2015-2016 surveys, respectively. Whites accounted for 81 percent and 84 percent of the earlier and later samples, respectively. Females represented 58% of respondents in both surveys. Regarding income, 61 and 56 percent of the earlier and later samples reported annual household income below $50,000.

Table 2. Wireless RERC Survey of User Needs: Sample by Disability Type (% of respondents).*

Disability Type	**2012-2013 Respondents (%) (n = 1068)**	**2015-2016 Respondents (%) (n = 970)**
Difficulty walking, standing or climbing stairs	39%	42%
Hard of hearing	24%	31%
Deaf	12%	12%
Low vision	16%	13%
Blind	8%	6%
Difficulty using hands or fingers	25%	25%
Difficulty concentrating, remembering, deciding	25%	21%
Frequent worry, nervousness, or anxiety	23%	23%
Difficulty using arms	17%	20%
Difficulty speaking so people can understand me	15%	17%

* Figures add to more than 100% because many respondents reported more than one disability.

Four of the top-level disability categories (difficulty walking/standing, hearing, seeing, and thinking) are used by the U.S. Census Bureau's American Community Survey (Ruggles et al 2015). The other four top-level categories are adapted from the semi-annual National Health Interview Survey (NHIS) conducted by the Centers for Disease Control and Prevention (CDC 2015). The SUN 5 questionnaire permits segmentation by disability sub-types (e.g., low vision/blind as a subtypes of difficulty seeing; and deaf/hard of hearing as subtypes of difficulty hearing). Basing the disability categories on existing national databases permits comparison with the SUN sample in order to identify possible validity threats due to convenience sampling.

Key smartphone activities examined include texting, mobile Internet, emailing, using apps, social media, maps/GPS, voice calling and video calling/chats. Analysis focuses on demographics (household income and age) and disability type. Data from the Pew Research

Center's survey on smartphone activities and the 2012-2013 SUN are used for comparison. Key questions addressed include:

- Do people with disabilities use functions and services such as email, text messaging, mobile Internet and social media at the same rate as the general population (disability divide – Horrigan 2010; Kessler Foundation and NOD 2010)?
- Do younger adults with disabilities use wireless technology more broadly and more intensively (use of more of these functions with greater frequency and duration) than older users (age divide – Wireless RERC 2013)?
- Among people with disabilities, does income affect use of these wireless functions and services (economic access – Morris et al 2014)?
- Do people with certain disabilities use these functions and services more or less than people with other disabilities (Morris et al 2014)?

People with disabilities engaged in core cellphone activities at similar rates as the general population in 2012-2013 (Table 3) and in 2015-2016 (Table 4), although with some variation for specific activities. Table 3 shows activities for owners of *all types of mobile phones* (basic cellphones and smartphones), while Table 4 shows activities for *smartphones only*. This difference in reporting between the two periods was made necessary by the way the Pew Research Center reported data, likely a reflection of the expanded adoption of smartphones since 2013. It might have seemed important to Pew researchers to include all mobile phone users in 2013 when a substantial portion of the population used regular cellphones, but not so much by 2015. The fact that many of the features and functions listed in Tables 3 and 4 are much more easily, or even exclusively, accessible via smartphones may have informed decisions regarding data collection and reporting. Because of these differences the Pew data for the two time periods cannot be compared, nor can the SUN data for these two tables.

Table 3. Wireless Activities for C*ellphone* Users with Disabilities (SUN 2012-2013) and the General Population (Pew Research Center, April-May 2013).

Wireless Activities	**SUN 2012-2013***	**Pew 2013****
Texting	71%	81%
Internet	60%	60%
Email	61%	52%
Mobile apps	48%	50%
Social media	48%	N/A
Maps/GPS	45%	49%
Voice calling	64%	N/A
Video calling	25%	21%

Table 4. Wireless Activities for *Smartphone* Users with Disabilities (SUN 2015-2016) and the General Population (Pew Research Center, 2015).

Wireless Activities	**SUN 2015-2016***	**Pew 2015****
Texting	88%	97%
Internet	81%	89%
Email	85%	88%
Mobile apps	70%	N/A
Social media	66%	75%
Maps/GPS	74%	41%
Voice calling	67%	N/A
Video calling	39%	N/A

These core activities for both groups include: text messaging, accessing the Internet, sending and receiving email, using mobile apps, social networking, getting directions/navigation, and listening to music. Notably, three functions have become almost universally used by smartphone users in the general population – and widely used by the smartphone users with disabilities – in recent years: text messaging, accessing the Internet and emailing. The 2013 Pew data also include video calling/chats, as do the SUN data for both 2012-2013 and 2015-2016. In 2013, both the Pew and SUN samples reported similar rates of video calling/chats (21% and 25%, respectively). SUN respondents in 2015-2016 reported substantially higher rates of video calling/chats than their peers in the earlier survey, a trend that probably holds for the general population. This trend is likely the result of the proliferation of smartphones with bigger and higher-resolution screens, expanded access to high-speed, low-latency 4G networks in the U.S., and the proliferation of video-calling applications and services (Facetime, WhatsApp, etc.). It should be noted that video calling can be a key assistive technology for people with speech, hearing, and cognitive limitations, which might cause its use to be more common in the population of people with disabilities.

Two demographic variables – income and age – often affect adoption of technology, particularly for new technologies which tend to be expensive and relatively unknown to the general population. However, as technologies mature, prices go down and social acceptance expands. More than 8 years have passed since the iPhone was launched and more than 15 years since the first Blackberry devices with two-way messaging appeared. Additionally, the relative costs and benefits of competing technologies (landline phone service and personal computers) can drive adoption of new technologies (smartphones and mobile services) by people with fewer financial resources – the phenomenon known as “wireless substitution” (Blumberg and Luke 2016). These income and age variables for technology adoption are expected to influence the smartphone activities by people with disabilities as well as the general population. However the fact that smartphones can offer highly economical and robust assistive solutions can alter the impact of income and age on smartphone use. Smartphone features and functions like screen navigation by touch (e.g., VoiceOver on iOS and TalkBack on Android), speech generating apps, mobile memory aids for people with cognitive needs, and video-calling for people with speech-hearing needs represent critical assistive technology solutions to some users. Consequently, several expectations about smartphone activities of people with disabilities can be identified:

- Smartphone users with higher incomes are more likely to use smartphone features and functions than their peers with lower incomes.
- Older smartphone users with disabilities are less likely to use smartphone features and functions than their younger peers.
- Age and income divides related to smartphone activities have diminished in recent years.
- People with specific disabilities (e.g., speech-hearing difficulties) use some smartphone features and functions more than people with different disabilities.

SUN data show that annual household income does have an effect on smartphone activities in the expected direction – respondents with higher income are more likely to use a range of smartphone features (Tables 5 and 6). However, income effects are primarily evident in the more recent period (2015-2016) than the earlier period (2012-2013). Only email shows a clear positive relationship with household income, and this relationship is relatively weak. For the more recent survey most of the activities listed in Table 6 show moderate or strong positive relationships with household income, especially use of mobile apps and social media. Email, video calling, and mobile Internet show moderate positive relationships with household income. These results run contrary to expectations, as the diffusion of technology over time should soften income effects. One possible explanation is that early adopters (smartphone users represented a much smaller percentage of the earlier SUN sample) tend to be intensive users regardless of income or other demographic characteristics. By this logic the smartphone activity of later adopters would be more likely to show demographic effects.

Table 5. Which Features and Functions Do You Use on Your Smartphone? (Wireless RERC 2012-2013, by gross Annual Household Income).

Features/Functions	Less than $35,000 (n = 216)	$35,000 - $49,999 (n = 80)	$50,000 - $74,999 (n = 103)	$75,000 or more (n = 169)
Texting	90%	98%	92%	89%
Internet	85%	88%	84%	88%
Email	86%	86%	86%	91%
Mobile apps	70%	65%	67%	73%
Social media	68%	74%	67%	73%
Maps/GPS	71%	58%	64%	67%
Voice calling	62%	63%	71%	63%
Video calling	34%	26%	36%	33%

Table 6. Which Features and Functions Do You Use on Your Smartphone? (Wireless RERC 2015-2016, by Gross Annual Household Income).

Features/Functions	Less than $35,000 (n = 246)	$35,000 - $49,999 (n = 80)	$50,000 - $74,999 (n = 137)	$75,000 or more (n = 195)
Texting	86%	88%	91%	90%
Internet	78%	83%	85%	86%
Email	81%	85%	88%	90%
Mobile apps	63%	68%	72%	79%
Social media	66%	78%	76%	83%
Maps/GPS	66%	71%	66%	69%
Voice calling	70%	70%	59%	70%
Video calling	36%	41%	39%	45%

SUN data show much broader effects of age on smartphone activities (Tables 7 and 8), especially for the earlier time period. The data support expectations that age has an inverse relationship to use of smartphone features and functions – younger smartphone owners are more likely to report higher rates of use than their older peers – and that age effects diminish over time (despite the findings for income reported above). In the earlier period there is at least a moderate inverse linear relationship been age and all eight smartphone activities/functions listed (Table 7). For five of these activities – using Internet, mobile apps, maps, voice calling, and video calling – the gap between the percentage of 18-29 year olds and people 65 years or older who use these functions is over 20 percentage points. For use of maps/GPS the difference is very large: 62 percent. In the more recent period use of Internet, mobile apps, and video calling still showed substantial differences between the youngest and oldest age cohorts of smartphone owners (Table 8). The gap in use of social media between youngest and oldest smartphone users actually increased substantially (from 9 to 35 percent) compared to the earlier period. For other activities, internet, email, and maps, the differences diminished compared to the earlier period.

Table 7. Which Features and Functions Do You Use on Your Smartphone? (Wireless RERC. 2012-2013, by Age).

Features/Functions	**18-29 (n = 58)**	**30-49 (n = 244)**	**50-64 (n = 225)**	**65+ (n = 65)**
Texting	95%	91%	93%	83%
Internet	91%	89%	87%	66%
Email	90%	88%	86%	80%
Mobile apps	81%	73%	69%	46%
Social media	74%	72%	68%	65%
Maps/GPS	88%	77%	60%	26%
Voice calling	71%	66%	65%	48%
Video calling	52%	36%	26%	22%

Table 8. Which Features and Functions Do You Use on Your Smartphone? (Wireless RERC 2015-2016, by Age).

Features/Functions	**18-29 (n = 65)**	**30-49 (n = 216)**	**50-64 (n = 253)**	**65+ (n = 152)**
Texting	88%	91%	89%	84%
Internet	86%	88%	82%	68%
Email	86%	90%	85%	80%
Mobile apps	75%	78%	67%	63%
Social media	83%	79%	63%	48%
Maps/GPS	72%	81%	75%	62%
Voice calling	72%	74%	63%	65%
Video calling	51%	51%	34%	24%

Crosscutting income and age divides, are some notable differences in wireless activities between disability types (Tables 9 and 10). Perhaps least surprising is that people with hearing and speaking difficulties use voice calling the least by a substantial margin in both the earlier and later periods. Perhaps more surprising is that people with seeing and hearing limitations use social media the least among the eight disability groups represented in Tables 9 and 10. One explanation is that these two disability types include low vision and hearing which commonly result from aging related decline in function. These results might be driven as much or more by age than disability. Areas of similarity in smartphone activities across disability type include core functions of text messaging, Internet access, and email. People with all disability types in both periods of time utilized these services at high rates in both the earlier and later time periods. Furthermore, there was relatively little variation in use across disability types.

Table 9. Which Features and Functions Do You Use on Your Smartphone? (Wireless RERC 2012-2013, by Disability or Impairment)

Features/ Functions	**Thinking (n = 143)**	**Anxiety (n = 132)**	**Seeing (n = 158)**	**Hearing (n = 228)**	**Speaking (n = 86)**	**Using arms (n = 87)**	**Using hands, fingers (n = 133)**	**Walking, climbing stairs (n = 199)**
Texting	87%	86%	89%	93%	87%	87%	89%	88%
Internet	83%	83%	84%	86%	83%	85%	86%	83%
Email	85%	81%	81%	89%	90%	84%	87%	86%
Mobile apps	64%	69%	73%	67%	65%	67%	71%	68%
Social media	71%	67%	60%	61%	69%	71%	68%	67%
Maps/GPS	64%	67%	67%	73%	70%	64%	65%	69%
Voice calling	71%	67%	77%	48%	44%	75%	73%	74%
Video calling	28%	27%	30%	35%	44%	31%	29%	26%

Table 10. Which Features and Functions Do You Use on Your Smartphone? (Wireless RERC 2015-2016, by Disability or Impairment)

Features/ Functions	**Thinking (n = 144)**	**Anxiety (n = 15)**	**Seeing (n = 159)**	**Hearing (n = 341)**	**Speaking (n = 99)**	**Using arms (n = 118)**	**Using hands, fingers (n = 150)**	**Walking, climbing stairs (n = 264)**
Texting	87%	91%	88%	90%	88%	84%	87%	86%
Internet	85%	85%	79%	82%	80%	77%	80%	80%
Email	85%	88%	81%	88%	86%	81%	85%	83%
Mobile apps	71%	76%	74%	69%	68%	70%	69%	70%
Social media	71%	73%	55%	64%	71%	71%	71%	66%
Maps/GPS	74%	78%	75%	75%	74%	64%	67%	71%
Voice calling	77%	76%	77%	58%	50%	72%	75%	73%
Video calling	42%	42%	39%	33%	53%	37%	41%	36%

Additionally, there have been some notable changes in wireless activity for specific disability types over the past few years. Use of voice-calling has increased substantially for people with cognitive, emotional, hearing and speaking limitations over time. This likely reflects in part the “wireless substitution” (Blumberg and Luke 2016) trend by which increasing percentages of the population “cut the cord” of landline telephone subscription in favor of mobile wireless telephony. Notably, use of voice-calling has been relatively stable for people with vision, upper extremity and mobility difficulties. It is well known that blind individuals enthusiastically embraced the iPhone after Apple introduced the VoiceOver touchscreen navigation feature for the iPhone in mid-2009. Anecdotal evidence also indicates that people with vision or mobility limitations have regarded mobile voice-calling as a key personal security feature for going outside the home.

Conclusions

The maturing of mobile information and communication technologies (ICT) – including smart mobile devices and the networks over which they operate – over the past several years has made available unprecedented technological capabilities to the mass public. Now, substantial majorities of the general population and the population of people with disabilities own and regularly use these sophisticated technologies. For both populations the smartphone has come to occupy the center of their information and communications infrastructure – critical tool supporting independence, community participation, employment, education, and more. There has been little difference in smartphone (and tablet) ownership rates between the two groups since 2012, most likely a reflect of the critical nature of the tools and generally high levels of accessibility of these devices for people with disabilities. Also, both groups showed substantial increases since 2012 in use of core and extended functionality of their smartphones, including text messaging, email, using the Internet and social media, and using mobile apps. However, the expansion in use of these functions was generally greater for the general population. For smartphone users who reported a disability, income, age and disability type had variable effects on smartphone activities. In most cases, the trends supported expectations of diminishing differences as smart mobile technology matured. These results do not suggest that barriers to accessibility and use of mobile smart technology have been largely overcome. Instead, they suggest that these technologies constitute critical tools for all individuals, perhaps especially for people with disabilities. Also, barriers to access persist. The analysis provided here can help researchers, engineers, regulators, advocates, and people with disabilities understand the topography of mobile wireless access and use.

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Works Cited

Blumberg, Stephen J., and Julian V. Luke. “Wireless Substitution: Early Release of Estimates from the National Health Interview Survey, January–June 2016.” Centers for Disease Control and Prevention, 2016. Web. 30 November 2016.

CDC/National Center on Health Statistics, National Health Interview Survey, 2015. Web. 29 November 2016.

CTIA-The Wireless Association. “Wireless Industry Summary Report, Year-End 2014.” CTIA, 2015. Web. 28 August 2016.

Duggan, Maeve and Aaron Smith. “Cell Internet Use 2013”, Pew Research Center, September 16, 2013. Web. 25 November 2016, http://pewinternet.org/Reports/2013/Cell-Internet.aspx.

Horrigan, John B. “Broadband Adoption and Use in America.” U.S. Federal Communications Commission, 2010. Web. 28 November 2016.

Kessler Foundation and National Organization on Disability. “The ADA, 20 Years Later.” 2010. Web. 22 November 2016.

Morris, John T., Michael L. Jones, and W. Mark Sweatman. “Wireless Technology Use by People with Disabilities: A National Survey.” Journal on Technology and Persons with Disabilities, 2016. Volume 4: 101-113. Web. 29 November 2016.

Morris, John T., James L. Mueller, and Michael L. Jones. Wireless Technology Uses and Activities by People with Disabilities.” Journal on Technology and Persons with Disabilities, 2014. Volume 2: 29-45. Web. 29 November 2016.

Morris, John T. and James L. Mueller. "Blind and Deaf Consumer Preferences for Android and iOS Smartphones." Inclusive Designing: Joining Usability, Accessibility, and Inclusion. Ed. Pat Langdon, et al. London: Springer, 2014. 69-79. Print.

Pew Research Center. "U.S. Smartphone Use in 2015." Web. November 18, 2016. http://www.pewinternet.org/2015/04/01/us-smartphone-use-in-2015/

Pew Research Center. "Device Ownership over Time", 2015. Web. August 28, 2016. http://www.pewinternet.org/data-trend/mobile/device-ownership

Pew Research Center. "Cell Phone Activities 2013" Web. November 22, 2016 www.pewinternet.org/files/old-media/Files/Reports/2013/PIP_Cell%20Phone%20Activities%20May%202013.pdf

Steven Ruggles, Katie Genadek, Ronald Goeken, Josiah Grover, and Matthew Sobek. "Integrated Public Use Microdata Series: Version 6.0 [Machine-readable database]." Minneapolis: University of Minnesota, 2015. Web. 30 November 2016.

Wireless RERC. SUNspot: Adults with Disabilities, Age and Use of Wireless Devices, July 2013. Web. 27 September 2016.

2017 THE JOURNAL ON TECHNOLOGY AND PERSONS WITH DISABILITIES

BreatheWell: Developing a Stress Management App on Wearables for TBI & PTSD

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Abstract

Hundreds of thousands of United States military service men and women have returned home from recent conflicts with post-traumatic stress disorder (PTSD) and/or traumatic brain injury (TBI) resulting in debilitating stress and anxiety. Slow, deep, diaphragmatic breathing is commonly prescribed by healthcare providers as an intervention strategy for emotion regulation and stress management. However, due to the cognitive ramifications of prolonged stress and TBI, people living with PTSD and TBI often find it challenging to learn the technique, remember to practice it and recognize when to use it. This article describes the development and initial user-testing of BreatheWell, an app designed for wearable technology aimed at assisting military service members with PTSD and TBI to manage stress, although the target user population could be expanded to other populations that would benefit from stress management and cognitive aids. BreatheWell was developed for Google Glass and for Android Wear smartwatches to remind users to initiate daily practice of relaxation breathing and provide support for pacing inhalation and exhalation. Development efforts were based on user-centered design principles. Information about service members' attitudes towards these emerging technologies was gained in the process. Future directions include development of a biosensor cueing system.

Keywords

Brain injury, stress, wearable technology, Google Glass, smartwatch, sensor technology

Introduction

BreatheWell is a breathing retraining app developed for Android Wear smartwatches and Google Glass to assist military service members with PTSD and TBI to manage stress. Both Android Wear smartwatches and Google Glass, aka “Glass”, are wearable computers that use a smartphone-like format allowing users to download apps designed for brief interactions. Android Wear smartwatches are worn on the wrist and have varying features, depending on the manufacturer, but all are designed in the shape of a wristwatch. Google Glass is a head mounted wearable with an optical display designed in the shape of a pair of eyeglasses. Separate versions of BreatheWell were developed for Android Wear and Glass. Both versions of BreatheWell have features not found in smartphones versions including the ability to program reminders to practice deep breathing at user-specified intervals, the ability to customize picture (Glass version) and sound options with a user’s own photos and music, and the ability to view the user’s heart rate in real time (Android Wear version).

Posttraumatic Stress Disorder (PTSD) and traumatic brain injury (TBI) frequently co-occur in military service members returning from Iraq and Afghanistan, often impacting independent living and quality of life (Tschiffely et al. 2015). Common clinical features of PTSD include increased anxiety and perceived threat, avoidance of anxiety and the presence of hyper-arousal symptoms: anger, startle response, hyper-vigilance and difficulty concentrating (American Psychiatric Association 2013). Deficits in memory and executive functioning, common cognitive sequelae of TBI, can add to stress and anxiety and can complicate and even hinder recovery from PTSD. Further, the physiological and emotional impacts of intense and prolonged stress also appear to hinder recovery from TBI (Cooper et al. 2000).

When a person is exposed to a stressor, the sympathetic nervous system is activated, resulting in the “fight or flight” response (Jansen et al. 1995). This response produces a physiological reaction causing heart rate and respiration to increase, the pupils to dilate and the digestive and reproductive systems to slow down. The American Institute of Stress (AIS) recommends deep, focused breathing to activate the body's parasympathetic nervous system, which facilitates homeostasis after the fight or flight response (Take a Deep Breath 2012). Deep breathing increases the supply of oxygen to the brain and initiates a "relaxation response" by decreasing metabolism, heart rate, and blood pressure, which together cause muscles to relax and tension to ease (Take a Deep Breath 2012). Slow diaphragmatic, breathing has been documented to improve mood stabilization and anxiety/anger management and is commonly used as a tool for emotion regulation and is (Brown et al. 2013). Breathing retraining, the practice of using slow, deep breathing to promote relaxation, is a widely used technique in stress reduction therapies. It can be used to manage acute stress as well as aid processing during cognitive behavioral therapy interventions (O'Donohue and Fisher 2009; Ursano, et al. 2004, VA/DoD 2012).

Executive dysfunction, a common sequela of TBI, makes patients more vulnerable to intrusive memories and emotional dysregulation, and it interferes with self-awareness, self-monitoring and initiation of emotion regulation strategies. Additionally, executive dysfunction and deficits in memory can reduce the effectiveness of breathing retraining by interfering with a person's ability to pace their breathing, remember and initiate daily practice and/or use deep breathing during periods of increased stress. Daily practice during periods of low stress is particularly important to support effective use during periods of high stress.

Mobile applications, or "apps", can be used to pace breathing during low and high stress periods. Several breathing retraining apps exist for iOS and Android smartphones. However, most have limitations including restricted customization options and a dependence on the user to remember to practice daily use of the breathing strategy. The innovation of wearable computer technology ("wearables") may offer some advantages for using some apps similar to those used on smartphones. Wearables may allow the user to access an app more quickly (without pulling out a smartphone) and to use it more discretely while in public. They are also likely to support behavioral and health monitoring more broadly through the incorporation of biosensor technology. Further, users, particularly those with memory deficits, may be less likely to lose or forget to bring a wearable with them in the community as it is worn on the body.

Discussion

The development team began developing a breathing coach for wearables in 2014 on Google Glass. When Google stopped offering that platform to consumers in early 2015, the team decided to complete the Glass-based version in order to gather as much user feedback as possible. Results showed sufficient positive feedback for a breathing coach on a wearable platform. Consequently, a new development project for BreatheWell on Android Wear smart watch devices was undertaken.

Development of the BreatheWell app

BreatheWell was designed for a specific set of users with specific needs following a user-centered design philosophy. User-centered design is a participatory design process that engages the user in design decisions whenever feasible, placing input from user research as the focal point of the design decisions (Luna et al. 2010; International Organization for Standardization 2010). It is also a highly iterative process, involving multiple versions with ongoing tests and revisions and refinements based on user input. This participatory process focuses on understanding the specific needs of the user in context and attempts to take into account the environment and other people the user may interact with while using the technology (Luna et al. 2010; International 2010).

Target users for BreatheWell are military service members with PTSD and TBI as well as healthcare professionals that support them. This target user population could be expanded to other populations that would benefit from stress management and cognitive aids. Nineteen military service members with PTSD and TBI and four healthcare providers (a speech-language pathologist, two clinical psychologists, and one clinical social worker all whom specialize in TBI and/or PTSD) contributed to the design process through initial design conceptualization, focus groups, interviews, questionnaires, feasibility testing and clinical testing.

Initial discovery of user needs was derived from input from the speech-language pathologist and one of the clinical psychologists, both of whom regularly supported service members with PTSD and TBI in using breathing for relaxation. Their input was used to inform the initial prototype of the app for Glass. The novelty of Glass made it necessary to build a working prototype of the app first in order to be able to demonstrate how a Glass-based breathing app would function. This prototype, along with several leading smartphone breathing apps, were demonstrated in a focus group with five service members living with PTSD and mild to moderate TBI for greater than twelve months. The focus group participants made recommendations that influenced the features, settings and display of the app. Specific suggestions regarding the use of calming background images and relaxing sounds were gathered. Participants also requested customizability of the voices providing guidance on inhalation and exhalation – choice of male and female voices, and option to mute voice guidance.

Focus group participants suggested the user be provided with several options for calming background images, such as tropical scenes, snow or mountains. Sixty-four photos matched to their suggestions were collected and shown to eight people, four of whom had a diagnosis of PTSD and TBI; the other four were healthcare providers and research scientists. Each used a five-point scale to rank how relaxing they felt the scene was. The top eight photos ranked most relaxing scenes were selected (see Figure 1). Focus group participants also suggested the user be given the option to select from a variety of preloaded songs and ambient noise tracks. Twenty-five songs and ambient noise tracks matched to their suggestions were collected and played for six people, four of whom had a diagnosis of PTSD and TBI while the other two were healthcare providers. Each were asked to use a five-point scale to rank how relaxing the music and sounds were, resulting in a set of seven songs and ambient noise tracks including two meditation melodies, as well as sounds of rain, a stream, a fan, the ocean and a rainforest.

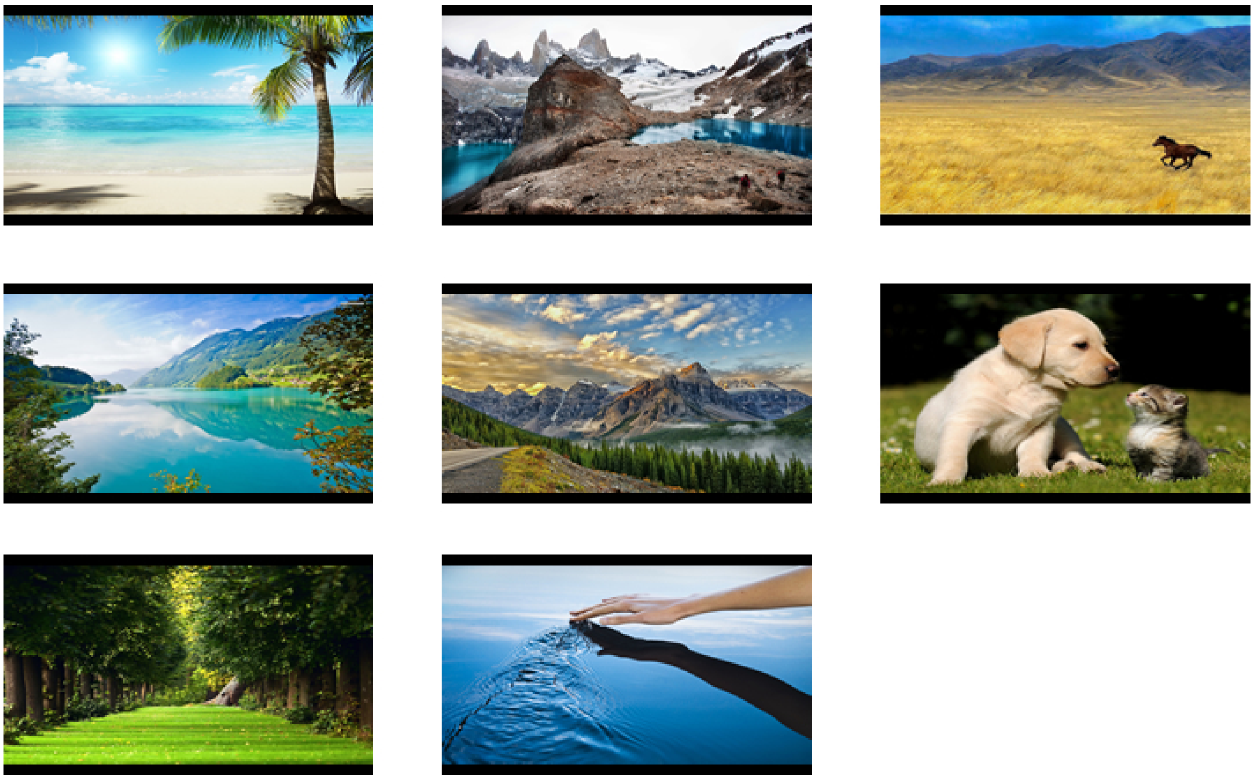

Fig. 1. BreatheWell Screenshots of User Selected Background Images (Glass Version).

Fully functioning prototypes of BreatheWell were then developed for Glass and Android Wear based on target user input. Both versions provided the user with the ability to toggle on/off a stress rating at the start and completion of the breathing exercise, user programmable reminders to practice, in-use adjustment of the rate of inhalation and exhalation, voice guidance options to guide the user to perform the breathing technique (including the choice of a male or female voice and the ability to toggle the feature on or off), and a selection of seven relaxing songs and sounds as well as the ability to add custom music selections from the user's personal library and the option to use the app without playing music at all. Both versions have an instructional video of a person with PTSD and TBI demonstrating the breathing technique, although the video plays directly on Glass in the Glass version but is played through the companion app residing on the smart phone or tablet paired with the Android Wear smartwatch for the Android Wear version. Both also have a graphical element to show the pace of inhalation/exhalation. The breathing pace bar on the Glass version is light green and transparent so that the photo behind it can be viewed, and it is at the bottom of Glass' rectangular screen (see Figure 2). The breathing pace bar on the Android Wear version is blue and runs along the perimeter of the watch face (see Figure 3). The Android Wear device also vibrates at the end of each inhalation and exhalation to provide a tactile cue to the user.

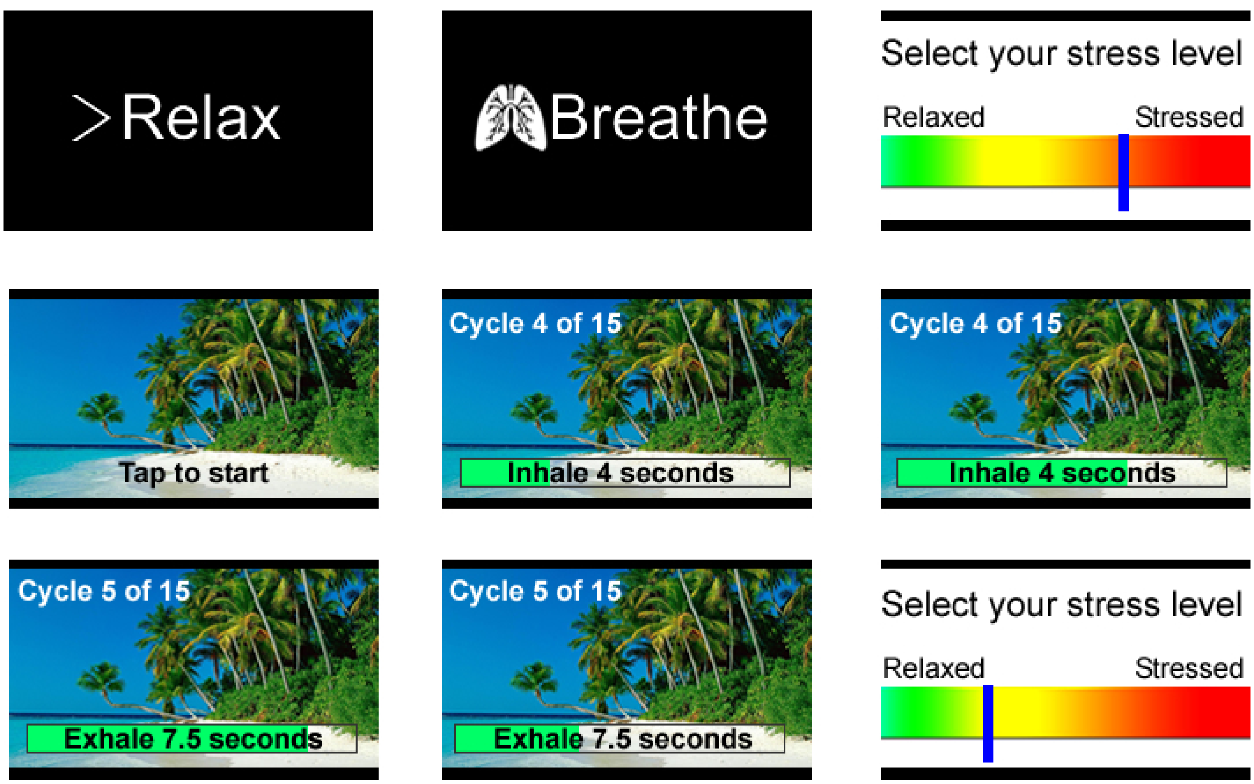

Fig. 2. BreatheWell Screen Flow (Glass version).

Fig. 3. BreatheWell on Wear Screen Flow (Displayed on LG Urbane).

Both versions allow the user to adjust the number of breathing cycles; only the Android Wear version allows that to happen while in use. Additionally, the Android Wear version allow the user to program a pause in breathing after inhalation and/or after exhalation, an optional element of breathing retraining incorporated by some but not all users. This feature was added after additional research and feedback from user testing.

Several design decisions were made in response to the opportunities and limitations of the two platforms. Background images are displayed only on the Glass version. Additionally, users can also choose to add calming photos, such as pictures of their children or pets, from their own library. The Android Wear version does not display calming images because the smartwatch platform would require too much visual attentiveness relative to Glass. Instead, the Android Wear version displays the user's heart rate (not available on Glass, but built into many smart watches) providing real time biofeedback (Figure 3). (Demo of the Android version)

Usability and Clinical Testing

Enhancements to the initial prototypes during in-house testing and usability testing with stakeholders resulted in eight “builds” of the app on Glass and six on Android Wear. Fourteen military service members living with PTSD and TBI participated in the usability testing of BreatheWell, seven provided user input into the Glass version and seven provided user input into the Android Wear version. Participants were recruited from the SHARE Military Initiative at Shepherd Center in Atlanta, Georgia, where they each were receiving treatment for PTSD and TBI. The participants were primarily male (13 of 14) with ages ranging from 26 to 42. Time since injury ranged from 1.5 years to 12 years. All reported experiencing significant stress, anxiety and/or emotion dysregulation and described symptoms of memory impairment and/or executive dysfunction.

Sit-by interviews were completed with each participant during which either the Glass or Android Wear version of BreatheWell was demonstrated, and all participants spent time wearing the device and testing the app. Comments on user experiences and structured interview responses were recorded for qualitative analysis. Participants provided input on the display of information, ease of use, usefulness and other design preferences. Additionally, information about service members’ experience with and attitudes towards these emerging technologies was gained in the process (see Tables 1-5). Some initial responses to experiencing BreatheWell included, “It’s pretty cool”, “I really like it”, and “I’m very impressed with it.” All fourteen participants reported they felt the BreatheWell app could help them. Favorite features identified included the wearable format (users stated they would be most likely to use a breathing app in wearable form because it is more accessible, meaning they would not have to fetch their phone from a pocket or another location in their home when needed); user customization options including turning features on or off and adding personal photos (Glass version only) and music; the ability to set reminders to practice; and the biofeedback provided by the heart rate display (Android Wear version only). Concerns reported included worries about eye strain and limitations for users with vision problems (Glass version only), as well as the potential difficulty operating the small screen on the Android Wear version, particularly for those with fine motor deficits.

Table 1. Participant Experience with and Use of Technology (n = 14).

Do you use any of the following on a regular basis? (Device)	**Percentage**
Laptop of desktop computer	79%
Tablet	71%
Regular cellphone	0%
Smartphone	100%
Mp3 player (separate from another device)	29%
Fitness or tracker	21%
Smartwatch	7%
Google Glass	0%

Table 2. Participant Use of Breathing Apps – Device type (n = 14).

Do you use a relaxation breathing app on any of your devices?	**Percentage**
Smartphone	88%
Tablet	25%
Fitness Tracker	0%
Smartwatch	0%

Table 3. Participant Use of Breathing Apps – Frequency (n = 14).

How often do you use apps to assist with breathing for relaxation?	**Percentage**
Every time I breathe for relaxation	14%
About half of the times I breathe for relaxation	7%
Very few of the times I breathe for relaxation	36%
I never use an app when I breathe for relaxation	43%

Table 4. Participant Experience While Using Google Glass (n = 7).

Ease of use and comfort using Google Glass	**Percentage**
It would be easy or very easy for me to use Google Glass	57%
It would be easy or very easy for me to use BreatheWell on Glass	100%
I would feel very comfortable wearing Google Glass out in the community	86%

Table 5. Participant experience while using Android Wear (n = 7).

Ease of use and comfort using Android Wear devices	**Percentage**
It would be easy or very easy for me to use Android Wear	86%
It would be easy or very easy for me to use BreatheWell Wear	71%
I would feel very comfortable wearing Android Wear in the community	100%

Participants also provided information about their experience using breathing retraining. Fifty-seven percent of the participants reported it was hard or very hard to remember to practice breathing for relaxation daily and 57% also reported practicing one or more times daily. This indicates that nearly half of the participants may have the potential to benefit from reminders to practice. Participants were also asked about whether they felt it would be helpful if the app or wearable could detect when the user is becoming stressed and suggest they try some deep breathing to relax. All 14 participants responded “yes”. Several participants stated they sometimes either do not remember to use the breathing strategy when stressed or do not recognize their stress and anxiety is increasing until it is escalated so high that the breathing strategy is less effective. One participant remarked he felt such an innovation could have had a positive impact in his life, stating, “I think other situations could have gone differently if I had one. Like maybe I’d still be able to see my wife and kids.”

Feedback gathered through this process was incorporated into the beta version, the ninth build of the app on Glass and seventh on Android Wear. End-user testing of the finalized beta versions was performed with three healthcare practitioners with specialization in PTSD and TBI, contributing to additional enhancements. Each version is now undergoing clinical testing which will likely contribute to additional refinements. Thus far each version has been tested outside of the clinic and "in the wild" by one target user, each of whom had different clinical experiences. Preliminary information is favorable and supports continued testing.

Future directions

Future directions include full clinical testing of BreatheWell as well as further development of the app to allow integration with a wireless sensor to detect physiological indicators of stress through ecological momentary assessment. Integrating with a biosensor will allow provision of cues to support the user in use of breathing for relaxation at optimum times. A consumer market product review revealed most currently available stress detection products are not wearable and few work with mobile apps. Those that do work with mobile apps seem to have limited user defined settings and are not well validated. Further, a review of the literature revealed many existing methods of stress detection either are not well studied or have a high rate of error, primarily due to false positive readings.

Continued exploration into the efficacy of using multiple modes of stress detection, such as galvanic skin response and heart rate variability, in a wearable format is needed to identify which combination of stress detection methods will work best for this purpose. Several prefabricated sensors under development by technology companies are expected to become commercially available in early 2017 and may help foster this development. Once a stress detection sensor is effectively integrated with BreatheWell, the next steps will be to identify whether machine learning and/or context awareness can further increase accuracy and functionality as well as to determine user preference for cueing methods.

Conclusion

BreatheWell for Glass and Android Wear may meet the needs of some users with PTSD and TBI. Further clinical testing is still needed. It will be important that user needs and preferences are well matched to the features of both the BreatheWell app and the device on which it resides in order for the user to gain the most benefit. Military service members with PTSD and TBI who prefer wearables, have functional use of their right eye and right hand may prefer to use Glass because of its hands-free interface. However, Glass is not currently available (at the time of this publication) for consumer purchase. Until a new Glass-like product is released, Android Wear devices and similar wrist-worn devices are the most viable platforms for wearable breathing support apps. Some users may prefer the Android Wear version due to their comfort with wearing Android Wear in the community and the biofeedback feature (heartrate display). Continued advancements in sensor technology should eventually offer the ability to connect BreatheWell to a biosensor that detects physiological signs of increased stress. This will enhance the functionality of the app by alerting users to onset of stress episodes.

Wearables may offer some advantages over smartphones for some users, depending on needs and preferences. Preliminary user experience data indicate that wearables appear to be well accepted by military service members living with PTSD and TBI. Consequently they should continue to be explored as assistive technology (AT) for this population, especially as new forms with increased functionality enter the consumer marketplace.

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Works Cited

American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorder*. 5th ed. American Psychiatric Publishing, 2013, pp. 271–280.

Brown, Richard P., et al. “Breathing Practices For Treatment of Psychiatric and Stress-Related Medical Conditions.” *Psychiatric Clinics of North America,* vol. 36, no. 1, 2013, pp. 121-140.

Cooper, D.B., et al. “Association between Combat Stress and Post-Concussive Symptom Reporting in OEF/OIF Service Members with Mild Traumatic Brain Injuries.” *Brain Injury*, vol. 25, no. 1, 2011, pp. 1-7.

International Organization for Standardization. ISO FDIS 9241-210, Ergonomics of human-system interaction – Part 210: Human-centered design for interactive systems. ISO, 2010.

Jansen, A. S., et al. “Central Command Neurons of the Sympathetic Nervous System: Basis of the Fight-or-Flight Response.” *Science*, vol. 270, no. 5236, 1995, pp. 644-646.

Luna, D., et al. “User-Centered Design to Develop Clinical Applications. Literature Review.” *Studies in Health Technology and Informatics*, vol. 216, 2015, p. 967.

O’Donohue, W. T. and Fisher, J.E. *General Principles and Empirically Supported Techniques of Cognitive Behavior Therapy*. John Wiley & Sons, 2009.

“Take a Deep Breath.” *The American Institute of Stress*, 12 Aug. 2012, www.stress.org/take-a-deep-breath/. Accessed 11 Nov. 2016.

Tschiffely, A.E., et al. “Examining the Relationship between Blast-Induced Mild Traumatic Brain Injury and Posttraumatic Stress-Related Traits.” *Journal of Neuroscience Research*, vol. 93, no. 12, 2015, pp. 1769-1777.

Ursano, Robert J., et al. "Practice Guideline for the Treatment of Patients with Acute Stress Disorder and Post-Traumatic Stress Disorder." *The American Journal of Psychiatry*, vol. 161, no.11, 2004, pp.3-31.

VA/DoD. "VA/DoD Clinical Practice Guideline for Management of Post-Traumatic Stress." *Department of Veterans Affairs, Department of Defense*. (2010). www.healthquality.va.gov/PTSD-Full-2010c.pdf. Accessed 22 Nov. 2016.

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ICTs to Support Persons with Disabilities in Global Policy Development

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Abstract

This study explores the development of the Disability Inclusive Development (DID) Policy Collaboratory. The DID Collaboratory is an accessible virtual organizational environment created in 2016 to support the effective participation of the global disability community in the UN Habitat III conference and the subsequent implementation of the New Urban Agenda (NUA). Using simultaneous mixed-methods (i.e. surveys, interviews, participant observation), this paper assesses the socio-technical factors influencing engagement with the Collaboratory and its effectiveness in supporting the participation of persons with disabilities in Habitat III. It is clear from this research that the global network of disability advocates participating in the Collaboratory benefited from its cyberinfrastructure, which in turn enhanced their effectiveness in Habitat III. This suggests that the prototype created for this project could serve as a model for promoting the participation of persons with disabilities in future global governance processes.

Keywords

ICTs; Emerging Assistive Technologies; Global Governance; Participation.

Introduction

With the adoption of the *2030 Agenda for Sustainable Development* and the Sustainable Development Goals (SDGs), persons with disabilities were finally placed more prominently on the international development agenda. The SDGs have been a notable achievement for inclusive development, with 11 references to persons with disabilities. This is in stark contrast to the Millennium Development Goals (MDGs), which excluded persons with disabilities despite their making up approximately 15% of every country's population (World Health Organization and The World Bank 27). There is also an historic confluence of several development and human rights policy initiatives that support the social and economic development of persons with disabilities, including the Convention on the Rights of Persons with Disabilities (CRPD), the outcome document of the World Summit on the Information Society (WSIS) +10, and the Internet Governance Forum (IGF). However, during the negotiations for another major global initiative, the *United Nations Conference on Housing and Sustainable Urban Development (Habitat III),* key disability issues had not been included in the New Urban Agenda (NUA).

Excluding persons with disabilities from this process would have been detrimental to the inclusion of persons with disabilities in cities and urban environments for the next twenty years. In order to better enable the global disability community to participate in the final negotiations for this important UN conference and beyond, the Institute on Disability and Public Policy (IDPP) at American University worked with stakeholders including the United Nations Secretariat for the CRPD located within the Department of Economic and Social Affairs Division for Social Policy and Development (UN DESA/DSPD), The Nippon Foundation, and The Pineda Foundation/World Enabled to create an accessible virtual organizational environment – a "Collaboratory" (Finholt 74) – to support persons with disabilities in this policy initiative and subsequent implementation of the NUA.

Information and Communication Technologies (ICTs) may be able to provide potential solutions to the numerous barriers that prevent persons with disabilities from participating effectively in global governance processes (Cogburn, "Partners or pawns" , "HCI in the developing world" 84, "Accessibility in Global Governance" xi-xiv). However, thus far, this potential remains largely untapped and under-studied. This paper addresses this issue by analyzing the policy-oriented Collaboratory created to support the effective participation of disability rights advocates to the UN Habitat III process. The successes and lessons learned from this initiative are discussed with a view to enhancing the involvement of the global disability community in the implementation of the NUA, as well as in other future global policy-making processes.

Purpose

The purpose of this study is to understand the accessible socio-technical infrastructure required to enhance participation of the global disability community in global governance processes. It explores the development and evaluation of a virtual organizational platform, the Disability Inclusive Development (DID) Policy Collaboratory, designed to support the *Global Multistakeholder Network on Disability Inclusion and Accessible Urban Development (DIAUD) Network*. This network, which was formed in May 2016 under the imprimatur of UN DESA, involves a variety of groups and organizations distributed globally, including: grassroots disabled people's organizations; global umbrella disability organizations; inter-governmental organizations; governments; foundations; and academic institutions.

Conceptual Framework

To better understand the DIAUD network, we draw on the concept of Transnational Advocacy Networks (TANs). These are defined as "networks of activists, distinguishable largely by the centrality of principled ideas or values in motivating their formation" (Keck and Sikkink 1). TANs are expected to have a collection of participants working internationally on policy issue(s) who have: (1) shared values; (2) a common discourse; (3) a dense exchange of information; and (4) seek to influence policy.

In addition, this type of networks are characterized by three key components, including (Keck and Sikkink 1):

1. Networked Organizational Form: "forms of organization characterized by voluntary, reciprocal, and horizontal patterns of communication and exchange."
2. Advocacy-Based: "plead the cause of others or defend a cause or proposition." These networks are organized to promote causes, principled ideas, and norms…."
3. Transnational in Scope: Not limited to any one country, but are fluid between domestic and international realms."

TANs have been shown to use varying degrees of information and communication technologies. In this study, we explore the degree to which ICTs can be integrated into a Collaboratory to support a TAN, foster its expansion, and promote its success. While the specific ICT components can vary, our approach to cyberinfrastructure typically includes the following broad categories of social and technical resources:

1. People-to-People (e.g. photo directories of members and constituent relationship management services);
2. People-to-Resources (e.g. background resources, paper archives, and document

repositories); and

3. People-to-Facilities (e.g. synchronous accessible audio-video webconferencing and application sharing).

The DID Collaboratory's cyberinfrastructure is designed to support all these three elements.

Research Questions

This paper is part of a larger project studying transnational advocacy networks in the information society (Cogburn, "Accessibility in Global Governance" 4) and asks four grand tour questions, including: (1) What is the evolution and structure of the DIAUD network?; (2) To what degree does the DIAUD Network reflect the model of a Transnational Advocacy Network (TAN)?; (3) What is the level of "Collaboration Readiness" within the DIAUD Network?; and (4) What has been the impact of the DIAUD Network and the DID Policy Collaboratory?

Methodology

The project has three major phases taking place between 1 June 2016 and 31 May 2017. Phase One, the subject of this study, focuses on the rapid prototyping and development of the DID Policy Collaboratory. While the DID Collaboratory is designed to support various networks, this phase focuses on supporting the DIAUD Network, whose original members were appointed by UN DESA, and included blind and visually impaired, deaf and hard of hearing, and mobility impaired people. DIAUD focuses on developing and integrating disability-inclusive contributions into the outcome document for Habitat III (October 2016) and post-conference implementation of the New Urban Agenda.

In addition to subject-matter expert interviews and participant observation, we administered a web-based baseline survey (O-1) of all DIAUD network participants (N=55) in May 2016. Following the Habitat III conference on 17-20 October 2016, a follow-up survey

(O-2) is planned for late fall 2016. The survey has 85 items divided into six sections: (1) Demographic Information; (2) Participation in UN Conferences; (3) Participation in non-UN conferences; (4) Collaboration within the DIAUD Network; (5) Experience with ICTs; and (6) Trust and Social Capital.

After the baseline data collection, we began building the prototype cyberinfrastructure for the DID Collaboratory (http://disabilityinclusivedevelopment.org/) and introduced the DIAUD Network to its mechanisms. In Phase Two, the project will broaden participation in the DID Collaboratory to support other disability-related networks engaged in global governance. Formative evaluation will facilitate iterative development of the socio-technical infrastructure of the DID Collaboratory. Phase Three focuses on summative evaluation and potential recommendations for further institutionalization of this Policy Collaboratory approach.

Discussion

Evolution and Structure of the DIAUD Network

The idea of facilitating greater involvement of the disability community into Habitat III processes emerged from a number of different quarters. First, some of our previous work on Accessible Global Governance, done in conjunction with and supported by The Nippon Foundation [49], pointed to the need for the principled and strategic use of ICTs to support these processes. Second, UNDESA and its CRPD secretariat wanted to support greater disability content in Habitat III. Fortunately, Dr. Victor Pineda, a globally recognized expert on inclusive cities based at the University of California-Berkeley, was already laying the groundwork for this substantive effort. Dr. Pineda was trying to mobilize interest amongst the disability community in contributing to Habitat III, which had previously been unrealized. IDPP, UNDESA, and The Nippon Foundation were able to support this nascent effort with the DID Policy Collaboratory.

DIAUD as Transnational Advocacy Network

Given that DIAUD was initiated by UNDESA, its organizational and substantive interests have shaped the network in significant ways. However, unlike some of the other networks UNDESA supports, there was no formal appointment letter to this network from DESA. As a result, the original 55 members were able to invite other partners and the network grew organically during preparations for Habitat III in summer 2016 to include over 110 participants. In broad terms, the structure of the DIAUD network reflects the concept of a TAN as defined above.

While several members are located in New York, Washington, DC, and California, the network covers all five continents with particularly large groups of members in the Latin America, Western Europe, and the Asia-Pacific region. This makes it scope inherently transnational. In addition, there seems to be a high level of shared values amongst the DIAUD network as all its members are focused on integrating and implementing disability content in the NUA, which in turn also makes this a primarily advocacy-oriented network. Shared knowledge about processes and procedures at UN and non-UN international conferences provide DIAUD with a common language as 95% of its members said they were at least ‘moderately knowledgeable about both.

The baseline survey highlighted that the preferred method of communication among network members was email lists, which 77% of respondents used at least “sometimes” in a typical month to communicate with other DIAUD members. Building on this finding, the DID Collaboratory promoted the use of repositories and webconferencing, which were the second and third most popular communication methods in DIAUD as over 40% of survey respondents said they used each of them to connect with other network members in a typical month. These media, coupled with a common language and shared values, fostered a dense exchange of information among DIAUD members throughout summer 2016, including background information about Habitat I and II, deadlines about the registration for Habitat III, submission of side events, comments on the draft conference outcome document, and other information related to the Preparatory Committee meetings.

Collaboration Readiness in the DIAUD Network

Previous research on scientific collaboratories has shown that one of the most important indicators of potential success of a collaboratory is ‘collaboration readiness’ (Olson and Olson 139; Olson et al. 44). This concept has three key dimensions: (1) Collaboration *Orientation* Readiness; (2) Collaboration *Infrastructure* Readiness; and (3) Collaboration *Technology* Readiness. In general, *Collaboration Orientation* refers to the willingness and desire on the part of Collaboratory participants to work together. *Collaboration Infrastructure* readiness tries to identify the degree to which the network has some existing tools and techniques for collaboration. Finally, *Collaboration Technology* readiness tries to measure the degree to which participants are experienced in various kinds of ICTs. These skills could be utilized or built upon in the Collaboratory, so the pre-existing skills are also an important predictor of success. Based on our baseline data collection, DIAUD Network has a high degree of collaboration readiness.

Most DIAUD members (62%) said they felt moderately or extremely confident in their ability to collaborate with colleagues in other parts of the world using technology, particularly email and web conferencing tools. This provided DIAUD with a valuable foundation upon which to build an intense flow of both synchronous (weekly coordination virtual meetings) and asynchronous (email discussion list, document repositories, collaborative online drafts) communications. These collaboration patterns were further strengthened by high levels of trust among DIAUD members. 92% of respondents somewhat or strongly agreed that the group has an open relationship and can freely share ideas and feelings with the group, and 76% of respondents somewhat or strongly agreed that they can talk freely about difficulties and know another group member will listen to them. Corroborating this impression of openness, only approximately half of the respondents (53%) agreed that they would feel a sense of loss if a team member left the network, which provides an indication of the potential resilience of the DIAUD network.

Impact of the DIAUD Network and the DID Policy Collaboratory

Although the DID Collaboratory is still new, emerging usage patterns of the DIAUD network can be observed in relation to the main Collaboratory components. This sheds light on how the Collaboratory infrastructure informs further strategic choices as DIAUD continues to evolve. Besides email lists, the Internet-based tools with which network members were very experienced or somewhat experienced included document repositories (50%), group calendaring (80%) and web conferencing applications (64%). Correlation analysis found no noteworthy relationships between the most popular technologies in the network and levels of technological expertise. Instead, accessibility is a factor. While all respondents indicated sufficient support for ICTs needs, with participation in a Collaboratory such technology needs may increase.

Overall, the DIAUD network was very successful in influencing the Habitat III process. The New Urban Agenda (NUA) adopted in Quito in October 2016 includes fifteen references to persons with disabilities, one of these a stand-alone paragraph (increased from only 6 references in the original zero draft of the NUA). DIAUD is also ideally positioned to participate in the NUA implementation, having submitted a successful proposal to add Persons with Disabilities as the 16th Partner Constituency Group (PCG) within the Habitat III General Assembly of Partners (GAP), which acts as the main organizing forum for civil society.

Conclusions

This pilot project has enabled the DIAUD network of global partners to explore the potential of accessible cyberinfrastructure to enable persons with disabilities to collectively organize to influence global governance. As demonstrated by the successful outcome of the Habitat III process, by providing the global disability community access to accessible ICTs and the policy Collaboratory model, persons with disabilities will be more effective in advancing disability rights in relation to the SDGs. Technology can facilitate engagement in global governance for persons with disabilities, but alone it is unlikely to catalyze participation. Having a concrete short-term goal was essential to build momentum and encourage increased collaboration in the DIAUD network. Going forward, it seems important for the disability community to be able to focus on similarly tangible goals in order to be able to maximize the affordances of collaboratory cyberinfrastructure.

Works Cited

Cogburn, Derrick L. "*Accessibility in Global Governance: The (In)visibility of Persons with Disabilities*." American University Institute on Disability and Public Policy: Washington D.C., 2016. Web. 12 November 2016.

---. *Transnational Advocacy Networks in the Information Society: Partners or Pawns?*. Palgrave-Macmillan, 2016.

---. "HCI in the developing world: What's in it for everyone?." *Interactions*, vol. 10, no. 2, 2003, pp. 80-7.

Finholt, Thomas A. "Collaboratories." *Annual Review of Information Science and Technology*, vol. 36, 2002, pp. 74-107.

Keck, Margaret, and Kathryn Sikkink. *Activists Beyond Borders*. Cornell University Press, 1998.

Olson, Gary M., and Judith Olson. "Distance Matters." *Human-Computer Interaction,* vol. 15, no. 2-3, 2000, pp. 139–79.

Olson, Gary M., and Stephanie Teasley, Matthew J. Bietz, Derrick L. Cogburn. "Collaboratories to support distributed science: The example of international HIV/AIDS Research." In Kotze, Paula, Venter, Lucas, and Barrow, John, editors. *SAICSIT '02 Proceedings of the 2002 Annual Research Conference of the South African Institute of Computer Scientists and Information Technologists on Enablement through Technology*, Port Elizabeth, South Africa, pp. 44-51.

World Health Organization and The World Bank. *World Report on Disability*. World Health Organization, 2011.

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Introduction of Cognitive Support Technologies (CST) for Job Seekers

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Abstract

Research shows that adults with cognitive impairment can benefit from cognitive support technologies (CST), and combined with good coping strategies, these technologies can help facilitate inclusion in the labour market. Experience from our rehabilitation work in Norway shows that introducing CST to persons with Asperger's syndrome and/or attention-deficit hyperactivity disorder (ADHD) can be challenging. This study describes and discusses factors that can promote or inhibit the introduction of CST in vocational rehabilitation services. These descriptions are based on twelve months of ethnographic fieldwork in two vocational rehabilitation programmes in Norway. We describe how adequate time, mandatory integration of technology in activities, recognition of and faith in the individual's ability to eventually find a job as part of a professional strategy, and the use of the job seekers' own technologies, are intertwined and interdependent factors that promote the introduction of CST. The inhibiting factors we describe may be related to the diagnosis of the typical challenges faced by adults suffering from ADHD and/or Asperger's, such as organizational challenges, procrastination or general difficulty in doing things in a new way.

Keywords

Vocational rehabilitation services, cognitive support technologies (CST), resistance, procrastination, practice studies and recognition.

Introduction

Job seekers with cognitive challenges, such as Asperger's, ADHD or mental disorders, are under-represented in employment (Steindal; Bø; Shattuck et al.). These job seekers are often skilful in the performance of the actual work, but have problems organising themselves in a job situation and coping with the social demands that they encounter on the job (Hawkins; Nadeau).

In some vocational rehabilitation programmes in Norway, technology is being introduced (Cognitive Support Technologies, CST) to improve this group's ability to cope with demands at work regarding organisation and communication, and to help give the job seekers a better organised and more predictable job situation. One challenge that was experienced in practice was that it could be problematic to persuade job seekers with Asperger's and/or ADHD to make use of technology to help them cope with on-the-job challenges.

This study describes and discusses factors that promote and inhibit the introduction and implementation of technology in vocational rehabilitation services. It is based on an ethnographic multiple-case field study, which follows two public-sector vocational rehabilitation programmes for twelve months, with a focus on describing the introduction of CST as cognitive support. The participants in the rehabilitation programmes are job seekers, primarily young men, with formal IT competence or an interest in IT, who have Asperger's or ADHD and additional difficulties, and who want to find work in the IT industry. Experience has shown that these participants are in a category of people who experience cognitive challenges, such as procrastination and executive difficulties (Barkley, Murphy and Fischer). In this paper CST refers both to the IT tools for production and communication that are used professionally in the companies and to the IT solutions that the individual job seeker uses in order to maintain or improve his/her competitiveness, or that help participants to be or to become more motivated to try to cope with an activity or life situation (De Jonge, Scherer and Rodger). Examples of CST in this study are smartphones, and social skills, organisation and communication apps. In this context, the introduction and facilitation of CST is based on a combination of empirical knowledge and professional discretion (Bodine).

The usefulness of CST for employees and students with cognitive disabilities is described in numerous case studies and effect studies (Hill et al.; Gentry, Kriner, et al.). In general, the research suggests that the use of technologies can potentially improve the opportunities for people with cognitive challenges to cope with everyday life, increase their independence and improve their chances of finding a job (Chen et al.; Westbrook et al.; Erickson; Gentry, Lau, et al.). The literature also describes and discusses the phenomenon whereby persons with cognitive challenges have a certain amount of resistance to utilising technology to cope with challenges involving memory or personal organisation (Baldwin and Powell). It is suggested that this resistance may be explained by the failure of the proposed or available technology to correspond with the person's identity, or because it makes them feel uncomfortable, or because the technology reminds them so much of their impairment that they avoid making use of it (Baldwin, Powell and Lorenc). Other studies have shown that persons who use technologies that are referred to as consumer technology associate this use to a lesser extent with their being impaired (Parette and Scherer). One possible explanation for this reluctance, especially among persons with autism spectrum disorders, is that they are not fully aware that they lack the skills that are needed in order to obtain employment or to hold a job (Hansen).

Method

This study is an ethnographic multiple-case field study that followed two public-sector rehabilitation programmes for twelve months. The selection of these two rehabilitation programmes was a strategic one. The selection criteria were that the programmes should be conducted by rehabilitation companies that specialised in, and had expertise in the use of CST in their vocational rehabilitation work, that had recruited employees with interdisciplinary expertise – i.e. pedagogical, supervisory, social work and IT expertise – and that for the most part provided a service to adults with cognitive impairment who wanted to enter the IT industry.

Both rehabilitation programs took place at IT companies developing software and web solutions for commercial and public sectors. Participants and staff worked together IT projects. The work consisted in designing and program the web pages, write program code, write documentation and testing programs

The fieldwork resulted in observation notes, summaries of spontaneous interviews in connection with the observed situations (interactive observation) (Tjora) and transcripts from interviews with 13 participants, two groups of interviews with the employees, interviews with the two managers, and interviews with the two supervisors who were especially responsible for the introduction and training of the participants in the use of individual support and assistive technologies (CST). The semi-structured interviews were based on the observation notes that were submitted to the interview subject.

The admission requirement for the rehabilitation programme that was followed was that the job seeker had impaired working capacity and was assessed as having especially uncertain vocational prospects and a need for broad and close follow-up for up to two years (NAV). For example, between 50 and 100% of the total of 25 participants had a diagnosis of Asperger’s. The fieldwork was cleared with the management six months before the first observation period, and management obtained consent from all employees and participants to take part in the study.

Researchers participated in all arenas and activities. No personal data was gathered. The study was approved by the Norwegian Centre for Research Data (NSD).

The identification of significant factors in the introduction of CST is based on a grounded theory approach with a systematic and inductive method for gathering, categorising and analysing data from the fieldwork (Glaser). A systematic iterative research process served as a response validation and as a process for dealing with the research ethical challenge in this project by helping to promote transparency and participation (Fangen).

Discussion

The factors we found that inhibited the introduction of CTS were associated with general challenges confronted by adults suffering from ADHD and/or Asperger's, such as procrastination, organisational challenges or general difficulty in doing things in a new way. One of the observed challenges that the supervisors encountered in the introduction of technology was that the participants were reluctant or resistant to making use of technology that could potentially be used as CST. One of the supervisors said, "*There are so incredibly many people with Asperger's who have what I call 'grandfather's telephones', i.e. they don't like to talk on the phone and don't like to send text messages, so why do they need a smartphone? True enough! So we have spent a great deal of time trying to get them to use smartphones and to get them to realise that there are functions on this kind of phone that they may want to use.*" Observations from the fieldwork and conversations with participants confirm that many had older touch-tone or flip phones. The following episode illustrates how severe this resistance could be:

"We gave one of the participants a new smartphone, which was supposed to constitute part of the infrastructure in the future job in which he was supposed to start. It took fully three weeks to persuade him before he so much as touched the phone. During those three weeks, it lay unused

on his desk. He would not use it, but he graciously let it lie there. Among other things, he refused to use an app that we recommend for better coping with the social aspects of various social settings." (By the conclusion of the rehabilitation period at the company, the supervisor described the situation as follows: *"Now he uses this phone for "everything".)*

All the participants in both of the vocational rehabilitation programmes owned a mobile phone and used it daily, but the supervisors perceived a reluctance on the part of many of them to talk on the phone. Interaction with the phone seemed to be social challenging, for example very few of the participants used the phone to be active on social media. When the participants started on their two-year vocational rehabilitation programme, only a few had a digital calendar or any other form of self-organising aid. Therefore, the main impression was that most participants did not see the benefits of using mobile phones for social interaction or self-organising.

The factors we found that promote the introduction of CST are intertwined and interdependent. During the fieldwork it was observed that the supervisors used several strategies and arrangements to introduce and arouse interest in the functionality of CST: arranging small-group workshops where participants assessed and wrote critiques of apps, insisting on including technology in the daily interactions at the companies, holding courses in setting up user accounts and organising apps, offering long-term loans or financial support for the purchase of a smartphone, and making training in the use of a social skills app mandatory. In the interactions with the participants, the supervisors ascertain what their interests are, what arouses their curiosity and what they find challenging. Through a number of observations and conversations with the participants, an impression was formed that this was a group of people who did not like to do anything "pretend" or as a drill. Therefore, it is a challenge for the supervisors to find situations that inspire or motivate the participants to make use of technology, and for them to adapt it to the needs of the participants.

It was observed that both of the companies insisted that the technology should be a part of the daily interactions. At Company 2, the participants were required to send important messages to the management, for example in the event of illness, through an instant messaging (IM) solution. The participants were allowed to choose which IM solution they wanted to use. The following IM solutions were used: Text messaging, Messenger, Facebook, Google Chat, and Email. The supervisors responded via the same IM solution with a confirmation that the information had been read and understood, often in an empathetic tone and with practical messages. In the course of the rehabilitation programme, the supervisors also began to use this established IM communication channel to send important messages to the participants. They informed them about changes in upcoming job tasks and the specific consequences of these changes for the participants. The supervisors explained that the participants would benefit from this practice because they now had specific messages stored on their own mobile phones and in each participant's preferred IM solution. For their part, the participants said that they dealt with these specific messages and found it useful that the information could be called up again when they had a need for it. The fact that the digital interactions between the company and the participants took place on apps and platforms that the participants made use of before they began the rehabilitation programme was described by the supervisors as reassuring. The strategy of making use of an interaction channel that each participant was familiar with and had a knowledge of before the rehabilitation programme was a factor that helped ensure that the technology would also be put to use in work-related contexts. The supervisors stated that they were more flexible in their choice of an interactive solution and that had no problems with making use of all available IM solutions.

At company 2, the supervisor insisted that all work schedules, memos, to-do lists and all other information that the participants needed should be entered into the participants own mobile phones. The supervisor sat down with the participant and said, "*You MUST enter this in your phone. You must enter this information in the phone because you MUST have the phone as your multi-tool for solutions.*"

The supervisors explained that by insisting that the mobile phones be included in the participants' everyday life in this way, they ensured that the participants had a better overview, more predictability and more structure in their working day, but also that they had established the mobile phone as a channel for communication. Insisting that they make use of technology in this way does not preclude the same procrastination and executive difficulties with which the participants otherwise struggle in their daily lives. This was a slow process, which took place throughout the twelve-month period of the fieldwork. Having time to undergo this process was a crucial factor here, which promoted the introduction of technology. The success of mandatory integration of CST in activities, and the insistence on using mobile phones was contingent on the relationship between the job seeker and the supervisor. In the interviews, the participants stated that their confidence that the supervisors wished them well and regularly expressed faith that they could do an excellent job when they entered employment made them more willing to try out the technology that the supervisor insisted they should use. The participants also stated that they felt that they were given recognition for their IT expertise and could share their fascination with technology with the supervisors. Recognition (Honneth and Holm-Hansen) thereby became a factor that increased the employees' reliability in matters concerning the use of technology and encouraged the development of a trusting relationship between the participants and the supervisors, which in turn promoted the introduction of technology that could be useful to the participant.

In the situations involving “face-to-face communication”, where the participant and supervisor sit facing each other and enter information in the mobile phone, the technology also has another function. The supervisors stated that they use an iPad, a screen or a mobile phone in these situations in order to reduce the stress that many people with Asperger’s feel with eye contact or with not knowing where to look in these situations involving face-to-face communication. The use of a screen determines where the participant should look. The supervisor found that this helped to increase their perseverance and reduce stress in these interactive situations. This is also a practical interaction technique that introduces technology without encountering major resistance.

Conclusion

In this study we have observed and documented that some job seekers with cognitive impairment are reluctant to make use of CST. Job seekers have behaved elusively and tried to postpone their use of assistive technology. These inhibiting factors may be related to the diagnosis of the typical challenges confronted by adults suffering from ADHD and/or Asperger’s, e.g. organisational challenges, procrastination or general difficulty in doing things in a new way. The intertwined and interdependent factors we describe that promote the process of adopting CST are: adequate time, mandatory integration of technology in activities, recognition and faith in the individual's ability to eventually find a job as part of a professional strategy, and the use of the job seekers’ own technologies. Since the introduction of CST for this group is a process that takes time, it is advantageous for the rehabilitation professionals to have patience, supervisory competence and insight into the nature of the problems that adults with cognitive impairment struggle with every day. This was a multi-site case study of a particular vocational rehabilitation professional practice based on strategic selection. It was not possible to draw any generalised conclusions from this exploratory study, but the identification and description of the challenges, and the identification of promoting factors, can be useful in dealing with other rehabilitation practices involving assistive technology, and in future research.

Works Cited

Baldwin, V. N., and T. Powell. "Google Calendar: A Single Case Experimental Design Study of a Man with Severe Memory Problems." *Neuropsychol Rehabil 25.4* (2015): 617-36. Print.

Baldwin, V. N., T. Powell, and L Lorenc. "Factors Influencing the Uptake of Memory Compensations: A Qualitative Analysis." *Neuropsychological Rehabilitation 21* (2011): 484–501. Print.

Barkley, Russell A., Kevin R. Murphy, and Mariellen Fischer. *Adhd in Adults : What the Science Says*. New York: Guildford Press, 2008. Print.

Bodine, Cathy. *Assistive Technology and Science*. 2013. Web.

Bø, Tor Petter. *Funksjonshemma På Arbeidsmarknaden I 2014 (the Disabled in the Labour Market in 2014)*. Ed. Håland, Inger. 2014. Web.

Chen, June L., et al. "Trends in Employment for Individuals with Autism Spectrum Disorder: A Review of the Research Literature." *Springer Science+Business Media* (2014). Print.

De Jonge, Desleigh, Marcia J. Scherer, and Sylvia Rodger. *Assistive Technology in the Workplace*. St. Louis, Mo.: Mosby Elsevier, 2007. Print.

Erickson, Kelly. "Evidence Considerations for Mobile Devices in the Occupational Therapy Process." *The Open Journal of Occupational Therapy 3* (2015). Print.

Fangen, Katrine. *Deltagende Observasjon (Participant Observation, 2nd Edition)*. 2. utg. ed. Bergen: Fagbokforl., 2010. Print.

Gentry, T., et al. "Reducing the Need for Personal Supports among Workers with Autism Using an Ipod Touch as an Assistive Technology: Delayed Randomized Control Trial." *J Autism Dev Disord 45.3* (2015): 669-84. Print.

Gentry, T., et al. “The Apple Ipod Touch as a Vocational Support Aid for Adults with Autism: Three Case Studies.” *Journal of Vocational Rehabilitation 37.2* (2012). Print.

Glaser, Barney G. *The Discovery of Grounded Theory : Strategies for Qualitative Research. Observations*. Ed. Strauss, Anselm L. Chicago New York: Aldine, 1967. Print.

Hansen, Rebecca S. “Understanding Employment Preparedness Needs for College Students with Asperger's Disorde.” *Marshall University,* 2015. Print.

Hawkins, Gail. *How to Find Work That Works for People with Asperger Syndrome : The Ultimate Guide for Getting People with Asperger Syndrome into the Workplace (and Keeping Them There!)*. London: Kingsley, 2004. Print.

Hill, Doris Adams., et al. “The Apple Ipadtm as an Innovative Employment Support for Young Adults with Autism Spectrum Disorder and Other Developmental Disabilities.” *Journal of Applied Rehabilitation Counseling 44.1* (2013). Print.

Honneth, Axel, and Lars Holm-Hansen. *Kamp Om Anerkjennelse : Om De Sosiale Konfliktenes Moralske Grammatikk*. Kampf Um Anerkennung Zur Moralischen Grammatik Sozialer Konflikte. Oslo: Pax, 2008. Print.

Nadeau, Kathleen G. *The Adhd Guide to Career Success : Harness Your Strengths, Manage Your Challenges*. Adhd Guide to Career Success. 2nd ed. ed: Taylor and Francis, 2015. Print.

NAV. *Kravspesifikasjon for Tiltak I Skjermet Virksomhet (Norwegian Labour and Welfare Administration (NAV). Specifications for Measures in Sheltered Workshops)*. 2016. Print.

Parette, P., and M Scherer. “Assistive Technology Use and Stigma.” *Education and Training in Developmental Disabilities 39.3* (2004): 217-26. Print.

Shattuck, P. T., et al. "Postsecondary Education and Employment among Youth with an Autism Spectrum Disorder." *Pediatrics 129.6* (2012): 1042-9. Print.

Steindal, K. . *Arbeidstakere Med Asperger Syndrom. Metodeutvikling Og Kompetanseheving I Nav. Et Samarbeidsprosjekt Mellom Nav Og Nasjonal Kompetanseenhet for Autisme. Sluttrapport.(Employees with Asperger's. Methodological Development and Competence Building in the Norwegian Labour and Welfare Administration [Nav]. A Collaborative Project between Nav and the Norwegian Resource Centre for Autism, Adhd, Tourette Syndrome and Narcolepsy. Final Report). :* Nasjonal kompetanseenhet for autisme, Oslo Universitetssykehus, 2010. Print.

Tjora, Aksel Hagen. *Kvalitative Forskningsmetoder I Praksis (Qualitative Research Methods in Practice. 2nd Edition.).* 2. utg. ed. Oslo: Gyldendal akademisk, 2012. Print.

Westbrook, J. D., et al. "Transition Services for Youth with Autism. A Systematic Review." *Research on Social Work Practice January 2015 vol. 25 no. 1 10-20* (2014). Print.

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A Business Case: Accessibility Preferences on Mobile Computing Devices

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Abstract

The business case for universal design of mobile computing devices is assessed from a market prospective using descriptive statistics. Survey data from consumers with sight impairments and active seniors are compared to determine if similarities exists between the perceptions and the accessibility preferences of the two groups. A total population of 300 respondents (150 per group) across the United States completed a Survey Monkey questionnaire. The survey instrument consists of categorical, behavioral, and perceptual questions where the latter two sections employ 7-level Likert items to quantify responses of subjective and objective statements. Results revealed a significant misconception seniors have regarding accessibility features and their use on mobile technology.

Keywords

Aging, blind/low vision, research and development

Introduction

The accessibility of mobile computing devices has grown in importance worldwide over the past decade. Though substantive progress has been made to ensure equal access to mobile technology, there continues to be a persistent digital divide between the access enjoyed by the general market and that given to persons with disabilities. The passage of the 21st Century Communications and Video Accessibility Act (2010 in the United States was transformative with its mandate to device manufacturers to make their products accessible to all consumers. However, the level of device accessibility continues to vary industry wide. For example, there is a limited selection of smart phones and tablets that are universally accessible to consumers with disabilities. With the exception of Apple, with its IOS platform, few manufacturers develop mobile computing devices that are universally accessible out of the box. Google's Android, the most widely used mobile OS in the world, powering 80% of mobile devices worldwide (Tozzi), is often customized by manufacturers in a manner that either minimizes or eliminates the accessibility API in their versions. Moreover, accessible apps available for Android, Fire, and Windows-based mobile platforms are severely limited given the tens of thousands available in their online stores. The concept of accessibility typically implies that minimal access be given to persons with disabilities as required by law. Since regulations have not kept pace with innovation, mobile computing devices are often adapted post-market release to comply with applicable regulations. The principle of universal design, on the other hand, states that products should be usable by most people regardless of their level of ability or disability when the product is launched. This study seeks to examine the inclusive approach to mobile device development through the lens of the business case - the justification for universal design based on potential market profitability. Moreover, it will be determined if a business case exists given the population surveyed and if so, using descriptive statistics, assess its strength from a market perspective.

Discussion

An avenue to explore this topic is to compare the user preferences of consumers with sight impairments, whose reliance on accessibility features is obvious, to those of active seniors, who may experience changes in vision as a normal part of the aging process. A total of 300 consumers were surveyed – 150 seniors age 60 - 69 and 150 consumers with sight impairments. The requirements for participation in the study were that each respondent must 1) owned a mobile device such as a smart phone or tablet and 2) used their device on a daily basis. The respondents with sight impairments were segmented into three distinct subgroups, each consisting of a third of the category. The subgroups included 1) low vision, persons with vision loss that cannot be corrected with regular eyeglasses or surgery (Duffy 11), but vision may be improved by the use of magnification aids, 2) visually impaired, persons with a wide range of visual function, from low vision to total blindness (Duffy 11), who generally use speech output and voice recognition), and 3) blind, persons with a complete lack of light perception (Duffy 11), most rely on Braille, speech output, and voice recognition. Active seniors surveyed did not have a diagnosed visual disability.

Table 1a. Gender

Gender	**Sight Impaired**	**Seniors**
Female	56%	54%
Male	44%	46%
Total	100%	100%

Table 1b. Ethnicity

Ethnicity	**Sight Impaired**	**Seniors**
American Indian/Alaska Native	1%	1%
Arab	1%	0%
Asian	5%	1%
Black/African American	19%	11%
Hispanic/Latino	6%	3%
Hawaiian/Pac Islander	1%	0%
White/Caucasian	67%	83%
Total	100%	100%

Table 1c. Work Status

Work Status	**Sight Impaired**	**Seniors**
Employed	37%	41%
Retired	13%	51%
Self-employed	19%	7%
Student	20%	0%
Unemployed	11%	0%
Total	100%	100%

The total population of respondents were recruited from all regions of the U.S with an emphasis on diversity of gender, ethnicity, and work status. The group of respondents with sight impairments were recruited through disability organizations. Participants were compensated with entry into a lottery for $50 Visa gift cards, where Three drawings were held and each winner received one of the prizes. Survey Monkey's Target Audience was used to obtain responses from active seniors at a cost of $2 per participant. As a control, the group of respondents with sight impairments were unaware of the participation of active seniors in the study and vice versa. This was an effort to eliminate 'the sympathy factor', especially among active seniors, that may arise given knowledge of the other group's participation. Responses were collected in the first quarter of 2015.

Data was collected from a brief, 10 question survey designed to capture the perceptions and behaviors of study participants regarding accessibility features and universal design of mobile devices. The first question was used to determine participant eligibility for the survey. Next, behavioral questions were asked which include the likelihood that respondents would use certain accessibility features on their mobile devices. The purchase preference of respondents and their likely recommendations regarding accessible devices were also assessed. Consumer perceptions were explored next through a series of statements designed to determine to what extent the respondents agreed or disagreed with sentiments expressed. The survey concluded with categorical questions to record respondent characteristics such as age, gender, work status, ethnicity, and disability. The survey completed by both groups were identical with the exception of question 10 on disability which was not included when distributed to active seniors. Respondents were asked to answer each quantitative question by selecting Likert-scale items ranked from 1 to 7, where 1 reflects extreme weakness or negativity and 7 reflects extreme strength or positivity. The survey instrument is viewable at https://www.surveymonkey.com/r/JQRF783.

Two statistical tools were used to describe the relationship between the attitudes of respondents with sight impairments and active seniors regarding universal design of mobile devices: analysis of variance (ANOVA) and regression. Calculations were computed by using the Analysis Tool Pack add-in available in Microsoft Excel 2016.

The objective in ANOVA is to test the equality of the means of two or more groups by using variance to draw conclusions regarding the relationship among data sets. In this study, one-way ANOVA is used, a hypothesis test where there is a single independent variable (i.e. a perception/behavior) and two or more dependent variables (i.e. respondent groups). In ANOVA, it is assumed that the groups represent populations whose values are randomly and independently selected, follow a normal distribution, and have equal variances. Therefore, the null hypothesis, H0, states that there is no difference between the means of the groups. The alternative hypothesis, H1, states that a difference exists. Thus, when ANOVA is used, the null hypothesis is rejected at a selected level of significance α (usually 0.05) only if the computed fSTAT value is greater than fCRIT, the upper-tail critical value of the Distribution with -1 and n-degrees of freedom (Levine et al. C10). There were five ANOVA tests conducted to determine if there is a difference in perceptions and behaviors of respondents with sight impairments and active seniors:

1. $H0_a$ = there is no difference in the likelihood between consumers with sight impairments and those who are active seniors in purchasing mobile devices with accessibility features
2. $H0_b$ = there is no difference in the likelihood between consumers with sight impairments and those who are active seniors in recommending accessible mobile devices to others.
3. $H0_c$ = agreement exists between consumers with sight impairments and seniors in whether extensive accessibility features on mobile computing devices will increase product costs
4. $H0_d$ = agreement exists between consumers with sight impairments and seniors in whether the addition of more accessibility features on mobile devices will complicate usage.

5. $H0_e$ = The agreement exists between consumers with sight impairments and seniors in whether ease of use will be enhanced with more accessibility features on mobile devices.

The alternative hypothesis, H1, for all cases is that there is a difference between the perceptions and behaviors between the groups.

Table 2a. Expected Value of the Mean, μ

Hypotheses	P/B	Sight Impaired	Seniors
H0a	Purchasing	6.5867	4.6733
H0b	Recommendations	6.5400	4.8267
H0c	Device cost	3.2267	5.1333
H0d	Complicate use	2.0933	4.8733
H0e	Ease use	6.3667	4.4933

Table 2b. Variance, σ^2

Hypotheses	P/B	Sight Impaired	Seniors
H0a	Purchasing	1.425	2.168
H0b	Recommendations	1.391	1.742
H0c	Device cost	3.841	2.103
H0d	Complicate use	2.367	2.474
H0e	Ease use	1.227	2.010

Table 2c. ANOVA – One Way

Hypotheses	P/B	Fstat	P-value	Fcrit	A	Result
H0a	Purchasing	152.830	1.28E-28	3.873	0.05	Reject H0
H0b	Recommendations	140.564	8.01E-27	3.873	0.05	Reject H0
H0c	Device cost	91.744	4.04E-19	3.873	0.05	Reject H0
H0d	Complicate use	239.474	4.71E-40	3.873	0.05	Reject H0
H0e	Ease use	162.617	5.11E-30	3.873	0.05	Reject H0

All hypotheses were rejected; there is a difference in how respondents with sight impairments and active seniors perceive the universality of mobile devices. The result of one test, $H0_{c,}$ is noteworthy: seniors are more likely to believe that more accessibility features will increase device cost with an expected value (μ) of 5.133 on a Likert scale of 1 to 7. Out of all factors examined, this observation solicited the strongest response from seniors surveyed.

Regression analysis is used to build upon ANOVA by exploring the interaction between variables. It explains how the typical value of the dependent variable changes when any one of the independent variables is altered, while other independent variables remain constant. In this study, multiple linear regression is used to 1) examine the relationship between perceptions of active seniors to the likelihood they will purchase a universal device and 2) determine to what extent accessibility features contributes to the likelihood seniors will purchase universal devices. In the first test, the following perceptions are independent variables: 1) more accessibility features will increase device cost (x1), 2) more universal features will complicate device usage (x2), 3) more universal features will improve usage (x3), and 4) it is important for manufacturers to develop mobile devices accessible to all (x4). The dependent variable is the likelihood seniors will purchase a universal mobile device (y_i).

Table 3a. Regression Statistics

Test	**1**	**2**
Multiple R	0.9582	0.9630
R Square	0.9182	0.9275
Adjusted R Square	0.9096	0.9186
Standard Error	1.4204	1.3418
F	409.495	370.774
Significance F	6.62E-78	2.44E-80
Observations	150	150

Three methods are used to evaluate the overall merit of the regression model: Coefficient of Multiple Determination (R^2), Adjusted R^2, and the f Test for the significance of the overall regression model. The Coefficient of Multiple Determination (R^2) measures the proportion of variation in the dependent variable that is explained by the variation in the set of independent variables (Levine et al. C14). The closer R^2 is 2 1, the more appropriate the regression model given the set of variables. In the first test, $R^2 = 0.9182$ which indicates that 91.82% of variation in the likelihood seniors will purchase universal mobile devices is explained by perceptions quantified in the set of independent variables. Adjusted R^2 differs slightly to R^2 in that it takes in consideration sample size and number of independent variables. The Adjusted $R^2 = 0.9096$ which means that 90.96% of variation in the likelihood seniors will purchase universal mobile devices is explained by the multiple regression model, adjusted for the number of independent variables and the sample size. Lastly, the f test of the significance of the overall regression model is used to determine whether there is a significant relationship between the dependent variable and the entire set of independent variables. If fSTAT is greater than f(α) where α = 0.05, then at least one of the independent variables impacts the dependent variable (Levine et al. C14). Since fSTAT = 409.495 which is larger than a fCRIT of 0, it is evident that at least one of the x variables are related to y.

Table 3b. Multiple Linear Regression – Test 1

	Coefficients	**Standard Error**	**t Stat**	**P-value**	**Lower 95%**	**Upper 95%**
Intercept	0.000	#N/A	#N/A	#N/A	#N/A	#N/A
x1	0.334	0.086	3.864	0.000	0.163	0.505
x2	-0.045	0.078	-0.580	0.563	-0.201	0.110
x3	0.524	0.076	6.882	0.000	0.374	0.675
x4	0.129	0.082	1.575	0.117	-0.033	0.292

Net regression coefficients are determined by corresponding values of tSTAT which are used to determine which independent variables are significant to the regression model taking the others in account. If the confidence interval does not include 0, it can be concluded that the given net regression coefficient has a significant effect (Frost). With intervals containing 0, more universal features will complicate device usage (x2) and the importance of universal devices for all consumers (x4) can be omitted from the regression model which will minimize error. Therefore, the Multiple Linear Regression Equation can be expressed as:

$y_i = 0.334x1_i + 0.524x3_i$

The y intercept is not included because it is held constant at 0. Since the value of x is never 0 (the Likert scale is from 1 to 7), the y intercept is of no inherent value. The net regression coefficients, 0.334 and 0.524, are slopes that correspond to perceptions regarding device cost and ease of use respectively. The slopes represent the change in the mean of y per unit change in x1 taking into account the inclusion of x3 and vice versa. Using the expected values (μ) from Table 2a regarding perceptions on device cost and ease of use, the Regression Equation can be used to predict the overall likelihood seniors will purchase universal devices:

$y_i = (0.334*5.133) + (0.524*4.493) = 4.069$

This indicates that, according to the Likert scale, active seniors are neutral in whether or not they are willing to purchase universal mobile devices.

In the second test, voice recognition (x1), speech output (x2), screen magnification (x3), color contrast (x4), and Bluetooth accessories for navigation (x5) are independent variables. The dependent variable is the same as in the previous regression model.

As with the first test, R^2, Adjusted R^2, and the F test are used to evaluate the overall merit of the regression model. The Coefficient of Multiple Determination $R^2 = 0.9274$ which indicates that 92.74% of variation in the likelihood seniors will purchase universal mobile devices is explained by the behaviors quantified in the set of independent variables. The Adjusted R^2 = 0.9186 which means that 91.86% of variation in the likelihood seniors will purchase universal mobile devices is explained by the multiple regression model, adjusted for the number of independent variables and the sample size. Moreover, the f test of the significance of the overall regression model yields a fSTAT of 370.774 which is larger than a fCRIT of 0 which indicates at least one of the independent variables is related to the dependent variable.

Table 3c. Multiple Linear Regression – Test 2

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.000	#N/A	#N/A	#N/A	#N/A	#N/A
x1	-0.037	0.075	-0.494	0.622	-0.186	0.112
x2	0.223	0.084	2.663	0.009	0.057	0.388
x3	0.502	0.062	8.149	0.000	0.381	0.624
x4	-0.027	0.074	-0.363	0.717	-0.173	0.119
x5	0.322	0.064	5.005	0.000	0.195	0.449

Regarding the net regression coefficients, with confidence intervals containing 0, the likelihood that active seniors will use voice recognition (x1) and color contrast schemes (x4) can be eliminated from the regression model as they are not significant. Therefore, the Multiple Linear Regression Equation can be expressed as: $y_i = 0.223x2_i + 0.502x3_i + 0.322x5_i$

The net regression coefficients, 0.223, 0.502, and 0.322 are slopes that correspond to usage of speech output, screen magnification, and aids for remote device navigation respectively. The expected values (μ) are speech output (3.893), screen magnification (5.280), and remote device navigation aids (3.940). Using the values of μ, the Multiple Linear Regression Equation can be used to predict the overall likelihood seniors will purchase universal mobile devices based on their usage of these three accessibility features:

y_i = (0.223 x 3.893) + (0.502 x 5.280) + (0.322 x 3.940) = 4.787

It can be inferred from this result that active seniors are somewhat likely to purchase universal mobile devices based on their usage of speech output, screen magnification, and Bluetooth aids for remote device navigation.

Conclusions

There is a difference in how respondents with sight impairments and active seniors view the concept of universal mobile devices. According to ANOVA, seniors are more likely to believe that more accessibility would increase the cost of devices. However, the perceptions regarding the cost of mobile devices can be debunked. According to comments submitted, many of the seniors surveyed owned Apple products, IPhones and IPads, universal devices, yet they were unaware of the accessibility suite which is standard, included at no additional cost. Additionally, regression analysis produced interesting results. Active seniors are neutral in their likelihood to purchase universal mobile devices when considering their perceptions on the possibility of an increase in cost and potential increase in ease of use. Seniors are also somewhat likely to purchase universal devices based on their usage of speech output, screen magnification, and Bluetooth accessories to aid remote device navigation.

According to descriptive statistics used in this study, there is some justification for universal design based on potential market profitability by targeting not only seniors age 60 – 69 but also those who are active, in their 50s, who will enter retirement over the next decade. However, the business case will strengthen only if 1) the perception of increased product cost is dispelled, 2) increased ease of use is promoted, and 3) the availability of speech output, screen magnification, and remote navigational accessories are marketed to active seniors by industry manufacturers. Also, issuing a mandate that the accessibility API be implemented into software designs prior to their release in App stores by all 3rd party vendors, including companies that develop mobile apps, would be especially useful. This ensures that if or when seniors begin to consciously purchase universal devices, their favorite mobile apps on which they rely, are accessible to them despite any changes in vision, dexterity, or hearing that may arise with age.

"I almost always say I don't need something and then after experiencing it, I realize it's *valuable."* - Senior respondent, ID 3787790019

In 2007, when Steve Jobs, co-founder of Apple, famously introduced the first IPhone, he convinced millions of consumers that it was a device they could not live without. In increasing awareness of accessibility features, it is possible seniors could be convinced that universal mobile devices and accessible apps are essential to their own active lifestyles; thereby bolstering profitability for companies that provide products that increase their quality of life.

Works Cited

Duffy, Maureen. *Making Life More Livable: Simple Adaptations for Living at Home After Vision Loss*. AFB Press, 2015, pp. 11.

Frost, Jim. "How to Interpret Regression Analysis Results: P-values and Coefficients", The Minitab Blog, 1 July 2013, Blog.minitab.com/blog/adventures-in-statistics/how-to-interpret-regression-analysis-results-p-values-and-coefficients. Accessed 30 November 2016.

Levine, David, et al. *Business Statistics: A First Course Student Value Edition with PHStat*. 6th ed. PDF, Pearson, 2012, Ch. 10, 14.

Tozzi, Christopher. "Open Source and Android: A History of Google's Linux-Based Mobile OS." The VAR Guy, 25 April 2016, www.theVarGuy.com/open-source-application-software-companies/open-source-and-android-history-googles-linux-based-mobil. Accessed 4 September 2016.

THE JOURNAL ON TECHNOLOGY AND PERSONS WITH DISABILITIES

PDF/UA Structure Elements and the User Experience

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Abstract

There is a direct correlation between the experiences of people with disabilities and the correct implementation of PDF structure elements in PDF documents.

Keywords

Government, Information and Communication Technology, Research and Development.

Introduction

In 2015 the *PDF and the User Experience Survey* was conducted to quantify the experiences of those with disabilities who use adaptive technology to access PDF documents (McCall). The results provided qualitative confirmation of what those of us in the field have known since Tags were introduced in 2001:

- There is a lot of inaccessible PDF content out there, either because it isn't tagged or it is tagged incorrectly.
- That many people using adaptive technology are using third-party tools to take PDF content out of the PDF format in order to access it and ensure that it is *portable*.
- That a "properly tagged PDF document is a pleasure to read."

The following are only a few comments from the 146 respondents who took part in the PDF and the User Experience Survey in 2015:

- "The viewing tools on Mac and iPhone don't allow [me] to navigate through properly tagged PDF by heading, bookmarks and so on. The structure of the document is not rendered." (Respondent 4427724923)
- "Any time I try [to read a PDF document] it usually says blank document, or if it does read it there's no tags, and when there's no tags its hard to figure out what's what. Then you've got words that are either split up or have errors, like to the point you cant figure out what it is." (Respondent 4426566325)
- "For work most PDFs are complex layouts including equations. If I try to reflow to increase the zoom level etc., then it destroys the equations. There is inadequate control of font, font size, interline spacing and layout. In a Word document I would control all of these for easier reading. Sometimes you can't search properly and this is

annoying as this is how I most easily locate information (scanning through is harder). Sometimes you copy and paste and get rubbish.” (Respondent 4398401216)

These are only a few of the frustrations reported by people using adaptive technology in trying to access PDF documents, even those that are tagged.

Discussion

Structure Elements and Content

PDF documents are prevalent because they can be opened on any platform or device and they retain the integrity of layout. They are a visual representation of a physical page/document. How does this visual representation of a page/document become something that can be read and comprehended by someone using adaptive technology (PDF Association)? At the root of a tagged PDF document is a Tag called <Tags>. This is also known as the Tags Root. From the parent <Tags> root, all other structural elements of the document are nested. The relationship of Tags is defined using a parent/child analogy. Nested under the <Tags> root is the child <Document> Tag.

A PDF document can have Heading Tags. These are represented with Tags such as <H1> for a Heading level 1, <H2>, <H3> and so forth. It is essential that Headings, which denote topic changes and the structure of the document, be sequential and not skip levels. For example, a document can’t skip from an <H1> to an <H3> without an <H2> between them. Headings are the primary means of navigating through a PDF document for those of us using adaptive technology. Most adaptive technology can either list Headings or move from Heading to Heading (topic to topic).

Tagged PDF documents use <P> Tags for content on a page that should be read as a paragraph. All lines in a paragraph must be under a single <P> Tag so that the lines are read as a continuous stream of information as opposed to being read as individual paragraphs.

Fig. 1. Sample Tags Tree with Heading and Paragraph Tags.

Another structure element that is prevalent in the visual representation of a page is a **list**. Lists have several structure elements that signal to adaptive technology that a list is being encountered, how many items are in the list, each list item, and that the person is leaving the list and returning to “normal” text.

The list structure has a parent <L> Tag under which are child <LI> or List Item Tags. There is one <LI> Tag for each item in the list. Nested under each <LI> Tag is a child <Lbl> Tag representing a bullet or number and a child <LBody> Tag representing the text or content of the List Item. The <Lbl> Tag is optional and is dependent on whether there is a bullet or number associated with the list. As long as there is a list structure, the “content” will be read as a list of related items.

Many documents have tables. The structure elements for tables are similar to those of lists in that there are a prescribed sequence of Tags that create a table structure. The parent <Table> Tag signals that a table has been encountered. The <Table> has a series of child <TR> Tags representing Table Rows and each Table Row has either a child Tag of <TH> Tag for a Table Header (column or row title) or a child Tag of <TD> for a Table Data cell. Tables can also have child Tags of <THead> for a Table Header (not a Heading) And a <TFoot> for a Table Footer.

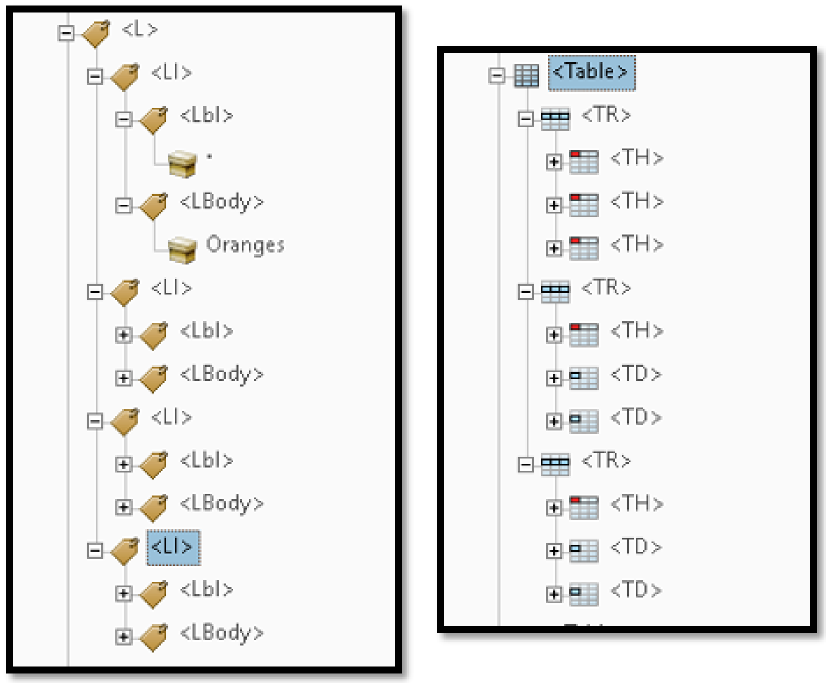

Fig. 2: Sample List structure (Left) and Table structure (right).

The correct semantic structure for accessible hyperlinks is equally important; A person must be able to activate a link using the keyboard. The <Link> Tag is used to identify links in tagged PDF documents but the <Link> Tag must have a “Link-OBJR” or *Link Object* nested under it along with the web address or text on the visual representation of the page that is the link.

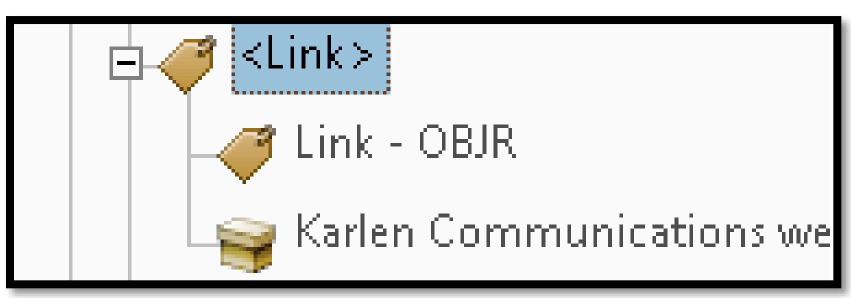

Fig. 3. Sample Link structure.

This brief summary of some basic Tags demonstrates the importance of using the correct structural elements in tagged PDF documents; Tags control how the information is rendered to the end user, and provide a method of searching and navigating the PDF document.

How Did We Get to This Point?

The ability to Tag PDF documents for accessibility began with the introduction of PDF Specification 1.4 in Adobe Systems Acrobat 5 in 2001. This capability set the stage to begin examining how we work with and create accessible digital content. The first publication to address the needs of document authors and remediators working with content that would eventually become tagged accessible PDF documents was published in October 2005 (Karen McCall, Accessible and Usable PDF Documents: Techniques for Document Authors).

In response to this publication and in an attempt to answer the question "what can we do in a native application to alleviate the amount of repairs in Acrobat", a follow-up book on creating more accessible Microsoft Word documents was published in 2005 (Karen McCall, Logical Document Structure Handbook: Word 2003). As Section 508 awareness expanded in the United States, document authors and remediators asked how non-HTML content could be mapped to the Section 508 legislation. In November 2006 one of the first attempts to map general document accessibility to Section 508 was published (Karen McCall, Mapping Section 508 to Digital Document Accessibility).

In 2004 an international working group was established to create a standard for PDF documents. The group was incorporated into the ISO (International Standards Organization) and AIIM (Association for Information and Image Management) in 2009. In 2012 the first PDF/UA or ISO 14289 international standard for accessible PDF was published (PDF Association). ISO 32000 was published in 2008 and put the PDF format in the public domain, no longer proprietary to Adobe Systems. PDF/UA builds on chapter 14 of ISO 3200 which identifies the Tag set used to make a PDF document accessible (International Standards Organization). This paper uses examples of structural elements/Tags to demonstrate the necessity to correctly Tag PDF documents.

As we move toward PDF/UA 2, there is still confusion about syntax/structure elements, how to Tag a PDF document and a lack of tools to do so efficiently, as well as a lack of support for accessible document design and creation in applications that output digital content. There are many PDF documents that are scanned images of pages and there are PDF documents for which there is no original document to refer to. The correct tagging of a PDF document is essential in providing access to content and structure of the visual representation of a page/document (PDF Association).

Conclusion

Some beneficial by-products of the need to remediate PDF documents are: an improvement in Acrobat's remediation tools, the development of best practices by the industry, the incorporation of accessibility checkers in many native applications used to create the original source documents, such as Microsoft Word, and the incorporation of PDF/UA into revisions of legislation for digital content (United States Access Board). It is critical to the user experience that PDF documents be tagged using the correct structure elements for the visual representation of the content on the page. We need the tools in all applications to make this easier and efficient, reducing labour and time costs and avoiding the purchase of expensive tools as add-ons to existing expensive ones.

Works Cited

International Standards Organization. *ISO 14289-1:2012 , Document management applications -- Electronic document file format enhancement for accessibility - Part 1: Use of ISO 32000-1 (PDF/UA-1)*. 2012. http://www.iso.org/iso/catalogue_detail.htm?csnumber=54564

International Standards Organization. *ISO 32000-1:2008 , Document management - Portable document format - Part 1: PDF 1.7*. Geneva, 2008. http://www.iso.org/iso/catalogue_detail.htm?csnumber=51502

McCall, Karen. *Accessible and Usable PDF Documents: Techniques for Document Authors*. First. Paris : Karen McCall, 2005.

McCall, Karen.. *Logical Document Structure Handbook: Word 2003*. Paris: Karen McCall, 2005.

McCall, Karen. *Mapping Section 508 to Digital Document Accessibility*. Karlen Communications. Oakville: Karen McCall, 22 November 2006.

McCall, Karen. "PDF and the User Experience." Karlen Communications, 2016. http://www.karlencommunications.com/PDFsurvey.html

PDF Association. *PDF/UA Competency Centre*. 16 June 2014. http://www.pdfa.org/publication/pdfua-reference-suite/

PDF Association. *PDF/UA in a Nutshell*. Ed. Duff Johnson. 16 June 2013. http://www.pdfa.org/2013/06/pdfua-in-a-nutshell/

PDF Association. *PDF/UA Structure Elements Best Practices 0.1*. 15 12 2015. http://www.pdfa.org/2015/12/announcing-the-structure-elements-best-practice-guide-0-1/

PDF Association. *The Matterhorn Protocol*. 2013. http://www.pdfa.org/wp-content/uploads/2014/06/MatterhornProtocol_1-02.pdf

United States Access Board. "Information and Communications Technology (ICT) Standards and Guidelines." 2015. *United States Access Board.* https://www.access-board.gov/attachments/article/1702/ict-proposed-rule.pdf

Eye Movements of Deaf and Hard of Hearing Viewers of Automatic Captions

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Abstract

To compare methods of displaying speech-recognition confidence of automatic captions, we analyzed eye-tracking and response data from deaf or hard of hearing participants viewing videos.

Keywords

Deaf and Hard of Hearing, Emerging Assistive Technologies, Research and Development

Introduction

Automatic Speech Recognition (ASR) may someday be a viable way to transcribe speech into text to facilitate communication between people who are hearing and people who are deaf or hard of hearing (DHH); however, the output of modern systems frequently contains errors. ASR can output its confidence in identifying each word: if this confidence were visually displayed, then readers might be able to identify which words to trust. We conducted a study in which DHH participants watched videos simulating a one-on-one meeting between an onscreen speaker and the participant. We recorded eye-tracking data from participants while they viewed videos with different versions of this “marked up” captioning (indicating ASR confidence in each word, through various visual means such as italics, font color changes, etc.). After each video, the participant answered comprehension questions as well as subjective preference questions. The recorded data was analyzed by examining where participants’ gaze was focused. Participants who are hard of hearing focused their visual attention on the face of the human more so than did participants who are deaf. Further, we noted differences in the degree to which some methods of displaying word confidence led to users to focusing on the face of the human in the video.

Discussion

Researchers have investigated whether including visual indications of ASR confidence helped participants identify errors in a text (Vertanen and Kristensson); later research examined ASR-generated captions for DHH users. In a French study comparing methods for indicating word confidence (Piquard-Kipffer *et al.*), DHH users had a subjective preference for captions that indicated which words were confidently identified. In a recent study (Shiver and Wolfe), ASR generated captions with white text on a black background; less confident words were gray. Several DHH participants indicated that they liked this approach; however, the authors were not able to quantify any benefit from this confidence markup through comprehension-question testing of participants after they watched the videos. Our study considers captioning to support live-meetings between hearing and DHH participants; so, we investigate ASR-generated captions for videos that simulate such meetings. We display captions in four conditions: no special visual markup indicating ASR word confidence (as a baseline), captions with confident words in yellow color with a bold font, captions with uncertain words displayed in italics, and captions with uncertain words omitted from the text (and replaced with a blank line, e.g. "______").

A recent study (Sajjad *et al.*) used eye-tracking data to predict how readers would rate the fluency and adequacy of a text. Other researchers used eye-tracking to investigate the behavior of DHH participants viewing videos with captioning, as surveyed in (Kruger *et al.*). Some (Szarkowska *et al.*) found that deaf participants tended to gaze at the caption to read all of the text before moving their gaze back to the center of the video image; whereas hard-of-hearing participants tended to move their gaze back and forth between the captions and the video image, to facilitate speech-reading or use of their residual hearing. Since we are interested in the potential of ASR-generated captions used during live meetings between hearing and DHH participants, it may be desirable to enable the DHH participant to look at the face of their conversational participant as much as possible. For this reason, we analyze the eye-tracking data collected from participants who watched a video that simulates a one-on-one meeting, to examine how much time users are looking at the human's face.

User Study and Collected Data

We produced 12 videos (each approximately 30 seconds) to simulate a one-on-one business meeting between the hearing actor (onscreen) and the DHH viewer. The audio was processed by the CMU Sphinx ASR software (Lamere *et al.*) to produce text output, along with numerical representation of the system's confidence in each word. This output was used to generate captions for the videos, which appeared at the bottom of the video. The text output had a word-error rate (WER) of approximately 60% depending on the individual video. Figure 1 shows the four display conditions in this study; all participants saw the 12 videos in the sequential order, but the assignment of the four display conditions was randomized for each participant.

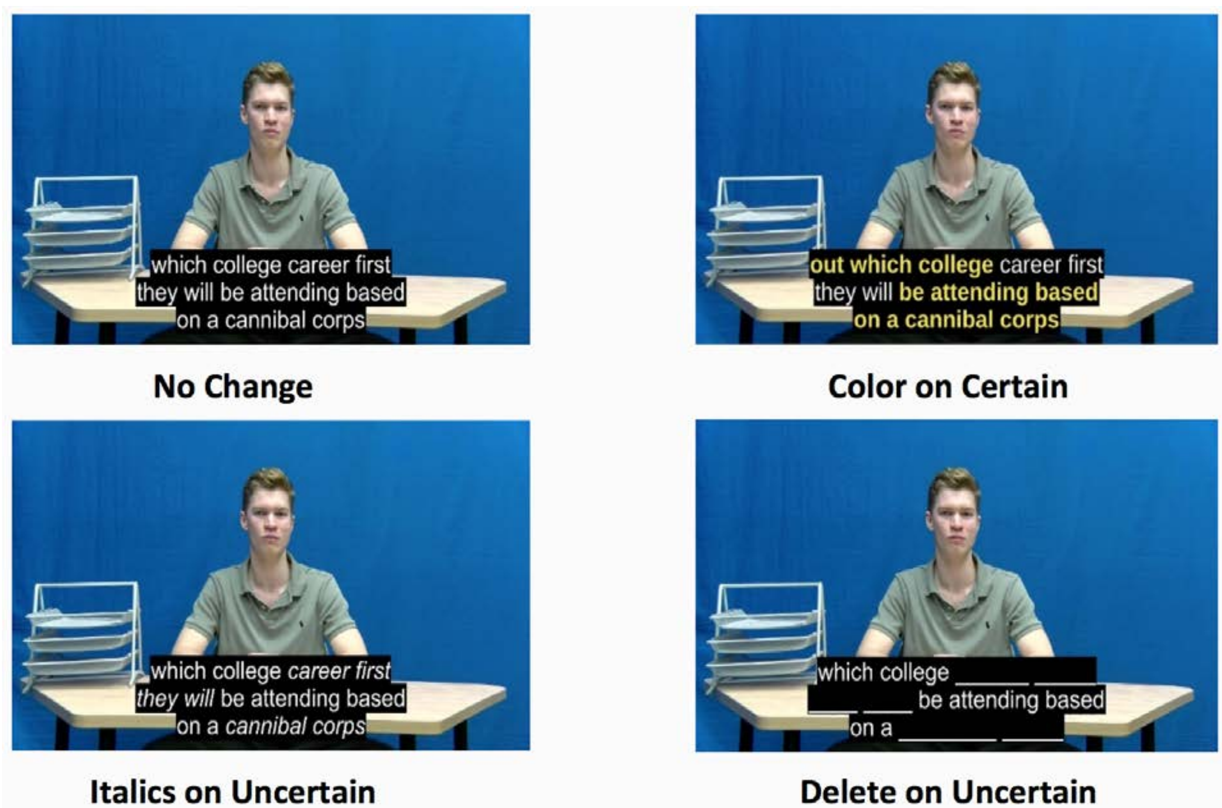

Fig. 1. Image of onscreen stimuli with the four captioning conditions in the study.

Ten participants were recruited using email and social media recruitment on the Rochester Institute of Technology campus: Six participants described themselves as deaf, and four, as hard of hearing. A Tobii EyeX eye-tracker was mounted to the bottom of a standard 23-inch LCD monitor connected to a desktop computer; the eye of the participant was approximately 60cm from the monitor. Software using the Tobii SDK was used to calculate a list of eye fixations (periods of time when the eyes remain within a defined radius), which include their location on the monitor, along with their start and stop times.

After the arrival of each participant, demographic data was collected, and the eye-tracker was calibrated. After displaying a sample video (to familiarize the participant with the study), all 12 videos were shown (with the sound on, to enable some DHH participants to use residual hearing along with speech-reading, as they might in a real meeting). Eye-tracking data was collected during this initial viewing of the 12 videos. Afterwards, the participants were shown the same 12 videos again, but after viewing each video this second time, participants responded to a Yes/No question asking “Did you like this style of captioning?” Participants also answered multiple-choice questions about factual content conveyed in each video.

Results and Analysis

For eye-tracking data analysis, the onscreen video was divided into several areas of interest (AOI), including (a) the face of the onscreen human and (b) the region of the screen where the captions were displayed, as shown in Figure 2. To analyze the eye-tracking data, we calculate the proportional fixation time (PFT) of that participant on each individual AOI during a video; the PFT is the total time fixated on an AOI divided by the total time of the video. In past studies, time spent fixated on captions usually correlates with the difficulty the reader is having absorbing the content (Robson; Irwin).

Fig. 2. Areas of interest monitored with eye-tracking.

To determine whether the overall patterns of eye-movement recorded in our study were similar to prior work examining the eye-movements of deaf and hard-of-hearing participants, we compared the eye movements of deaf and of hard-of-hearing participants. Significant differences in the "PFT on face" (Mann-Whitney test, $p<0.05$) were found, as shown in Figure 3. This suggests that eye-movement behaviors observed in this study were similar to those observed in prior work with DHH users (Szarkowska *et al*).

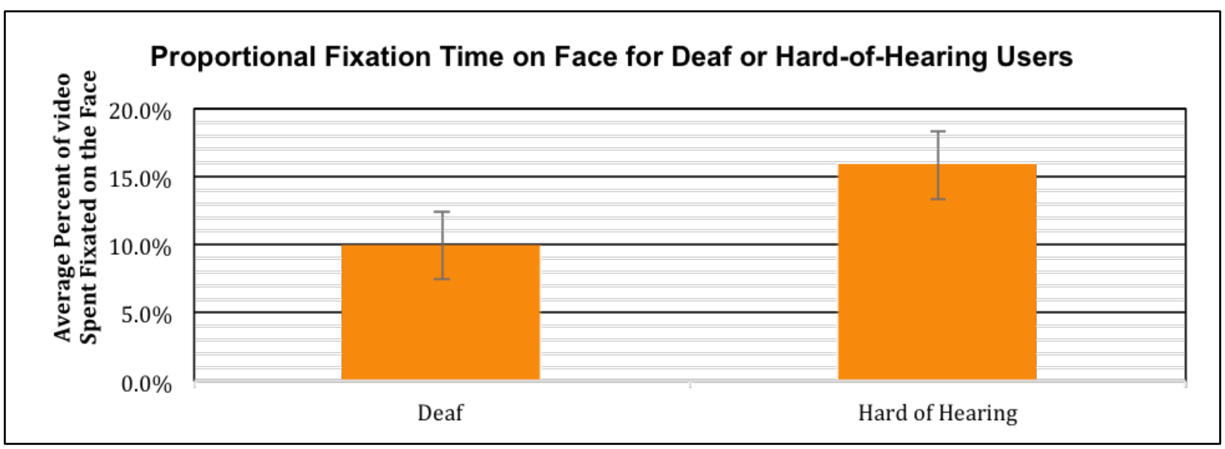

Fig. 3. PFT on Face for Deaf and Hard-of-Hearing Participants.

Figure 4 shows how differences in the display condition also led to differences in participants' time spent looking at the face (Kruskal-Wallis, $p<0.05$); post-hoc Mann-Whitney tests with Bonferroni corrected p-values revealed a significant pairwise difference between the "italics on uncertain" and "delete on uncertain" conditions.

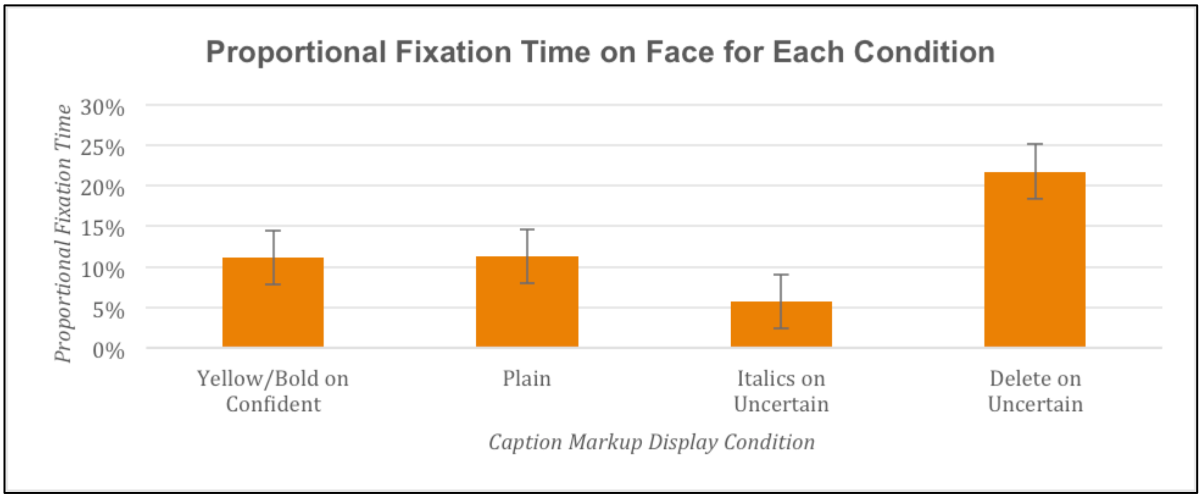

Fig. 4. Percentage of time participants looked at the human's face for each condition.

Participants spent the greatest amount of time looking at the face of the onscreen human when the "delete on uncertain" style of caption display was used. Under the premise that looking at the face of a conversational partner is desirable during a meeting, this might initially suggest that "delete on uncertain" is best. However, we must consider participants' responses to comprehension and preference questions to understand these eye movements. For instance, participants might have spent less time looking at the captions in the "delete on uncertain" condition because they found the captions less useful or simply because there were fewer words to read (since uncertain words were replaced with blank spaces). As indicated in Figure 5, most participants preferred the captions with "italics on uncertain," and as indicated in Figure 6, participants achieved the highest accuracy scores on comprehension questions for captions with "italics on uncertain." These differences between means, however, were not statistically significant. "Delete on uncertain" had the lowest accuracy scores.

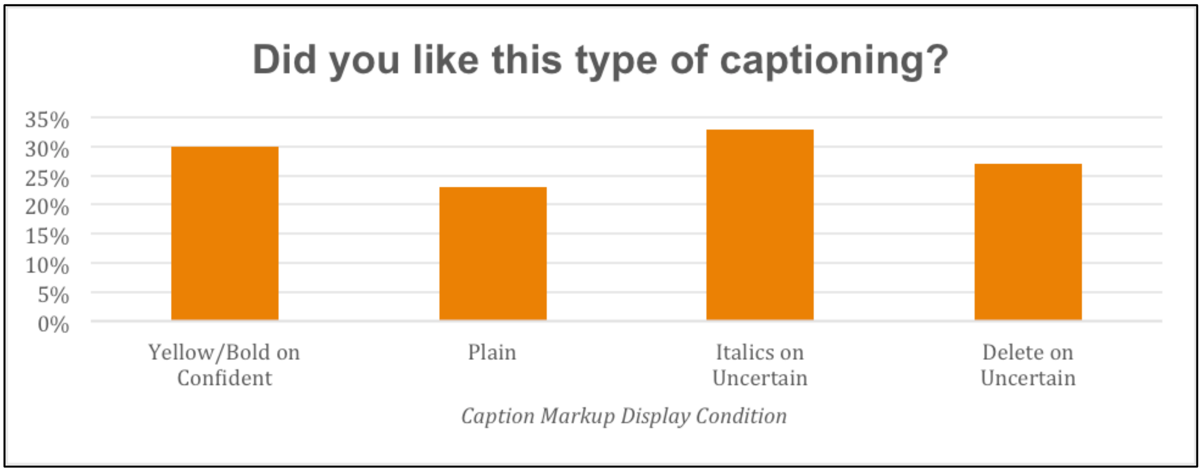

Fig. 5. Subjective preference for each condition.

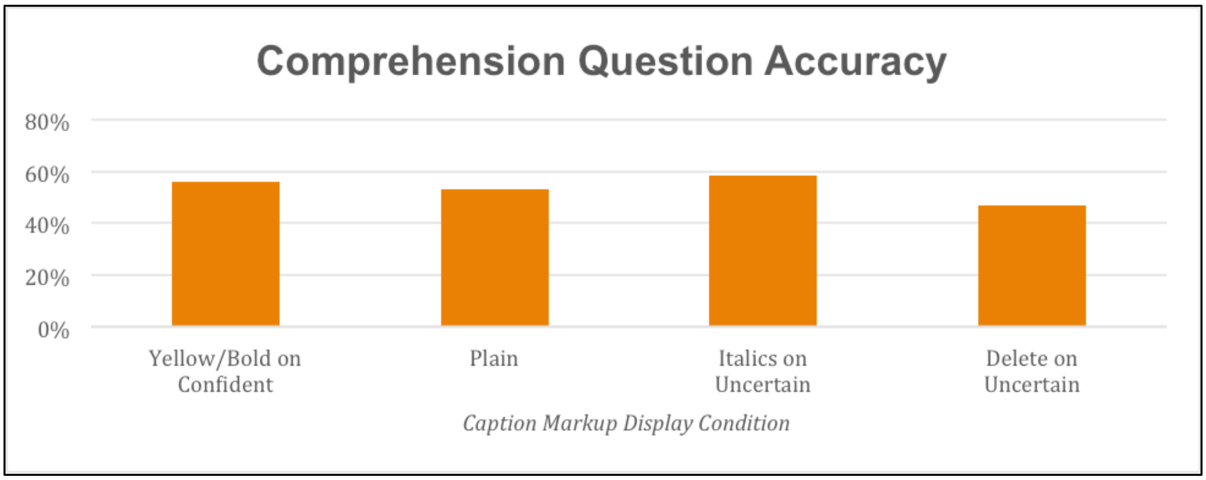

Fig. 6. Comprehension question accuracy for each condition.

Conclusions

This study examined how DHH participants used onscreen captions displayed during videos simulating a one-on-one meeting, with the text of the captions generated using ASR and various conditions of visual presentation of captions to indicate ASR confidence in each word displayed. Eye-tracking analysis revealed that changing the display condition led to differences in eye-movements of DHH participants. While we initially posited that we should seek to maximize the amount of time that participants look at the face of the human in the video, an analysis of the comprehension and subjective preferences of participants suggests that the relationship between this eye-metric and captioning success is not so straightforward. In future work, we intend to investigate a wider variety of caption display styles and evaluate these approaches with a larger set of participants, to further examine this relationship between eye movements, caption preferences, and methods of displaying confidence in automatic captions.

Works Cited

Irwin, David E. “Fixation location and fixation duration as indices of cognitive processing.” In J.M. Henderson & F. Ferreira (Eds.), The interface of language, vision, and action: Eye movements and the visual world, 105-133. New York, NY: Psychology Press. 2004.

Kruger, Jan Louis, Agnieszka Szarkowska, and Izabela Krejtz, “Subtitles on the Moving Image: an Overview of Eye-Tracking Studies” *Refractory* 25. University of Melbourne. 2015.

Lamere, Paul, Philip Kwok, Evandro Gouvea, Bhiksha Raj, Rita Singh, William Walker, Manfred Warmuth, and Peter Wolf. “The CMU SPHINX-4 speech recognition system.” *In IEEE Intl. Conf. on Acoustics, Speech and Signal Processing (ICASSP 2003)*, Hong Kong, vol. 1, pp. 2-5. 2003.

Piquard-Kipffer, Agnès, Odile Mella, Jérémy Miranda, Denis Jouvet, and Luiza Orosanu. “Qualitative investigation of the display of speech recognition results for communication with deaf people.” In *6th Workshop on Speech and Language Processing for Assistive Technologies*. 7. 2015.

Robson, Gary D. *The closed captioning handbook*. Amsterdam: Elsevier. 2004.

Sajjad, Hassan, Francisco Guzm´an, Nadir Durrani, Ahmed Abdelali, Houda Bouamor, Irina Temnikova, and Stephan Vogel. “Eyes Don’t Lie: Predicting Machine Translation Quality Using Eye Movement.” In *Proceedings of the 2016 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies*, San Diego, California, June. 2016.

Shiver, Brent, Rosalee Wolfe. “Evaluating Alternatives for Better Deaf Accessibility to Selected Web-Based Multimedia.” In Proceedings of the 17th International ACM SIGACCESS

Conference on Computers and Accessibility (ASSETS ’15). ACM, New York, NY, USA, 223–230. 2015.

Szarkowska, Agnieszka, Izabela Krejtz, Zuzanna Kłyszejko, Anna Wieczorek. “Verbatim, standard, or edited? Reading patterns of different captioning styles among deaf, hard of hearing, and hearing viewers.” *American Annals of the Deaf* 156 (4):363-378. 2011.

Vertanen, Keith, Per Ola Kristensson. “On the benefits of confidence visualization in speech recognition.” In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 1497–1500. 2008.

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Haptics for Guide Dog Handlers

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Abstract

Guide dogs have the important responsibility of connecting their visually-impaired users to their immediate surroundings. However, it is often difficult for guide dogs to accurately communicate information to their human partners. This experiment aimed to enhance the platform for communication between guide dogs and handlers by investigating the best vibration feedback methods for handlers to receive information from their guide dogs. We created four different prototypes to test a human's ability to distinguish between four randomly selected vibration patterns. A total of 12 users participated in this pilot study, each receiving 8 minutes of training for familiarization with the prototypes. The results of the pilot study were evaluated based on the users' ability to correctly identify the vibration patterns when prompted, and a questionnaire posed to the users at the end of the experiment. This pilot study yielded an overall accuracy of 97%. It was also found that the smart-watch prototype produced the highest accuracy, while the guide dog harness bar prototype was the most preferred design among the participants.

Keywords

Augmentative and Alternative Communications (AAC), Blind/Low Vision, Information & Communications Technology (ICT)

Introduction

Guide dogs, as defined by the international assistance dog organization ("Guide Dogs"), are trained to assist visually impaired people by guiding their partners and avoiding obstacles to ensure their safety. Although guide dogs are highly trained to respond to various obstacles in their environments, it is difficult for guide dogs to inform their handlers about the nature of these obstacles. For example, a bus going by would be a temporary, or "wait" obstacle, whereas a fallen tree would be a "go around" obstacle. Clear communication from a guide dog to a handler would allow for better decisions to be made on how to proceed. Our previous work on the FIDO project (Jackson et al. 1) explores the possibility of implementing wearable sensors that dogs can accurately activate in either a specific situation or on a command. This unlocks a new method of communication between guide dogs and their partners. Guide dogs can activate a sensor attached to their guide dog harness to let their human partners know that an obstacle is in their path. It is hence imperative that the human partner has a reliable method to receive this information as clear and unobtrusive. Since audio-based devices can be highly disruptive to a user's surroundings, vibrotactile interfaces are used instead to ensure that the communication remains solely between the dog and the handler. A vibrotactile interface also allows the dog to alert the handler without interfering with other audio-based devices such as navigation support.

The main goal of this initial study is to establish the most reliable design to deliver vibration feedback to a handler's hands, allowing guide dogs to better communicate with their handlers. Furthermore, we aim to find answers to the following questions: "Can people receive haptic signals with their hands and wrists?" and "What modality is the best for the handler?". There are three different phases in this study required to understand the designs. The first phase, described in this paper, is testing which haptic feedback mechanisms are most effective. The second phase will be understanding the dogs' perception and the influence of haptic feedback on dogs, if any. Lastly, the third phase will be conducting the end-to-end field study with the results of the previous two phases.

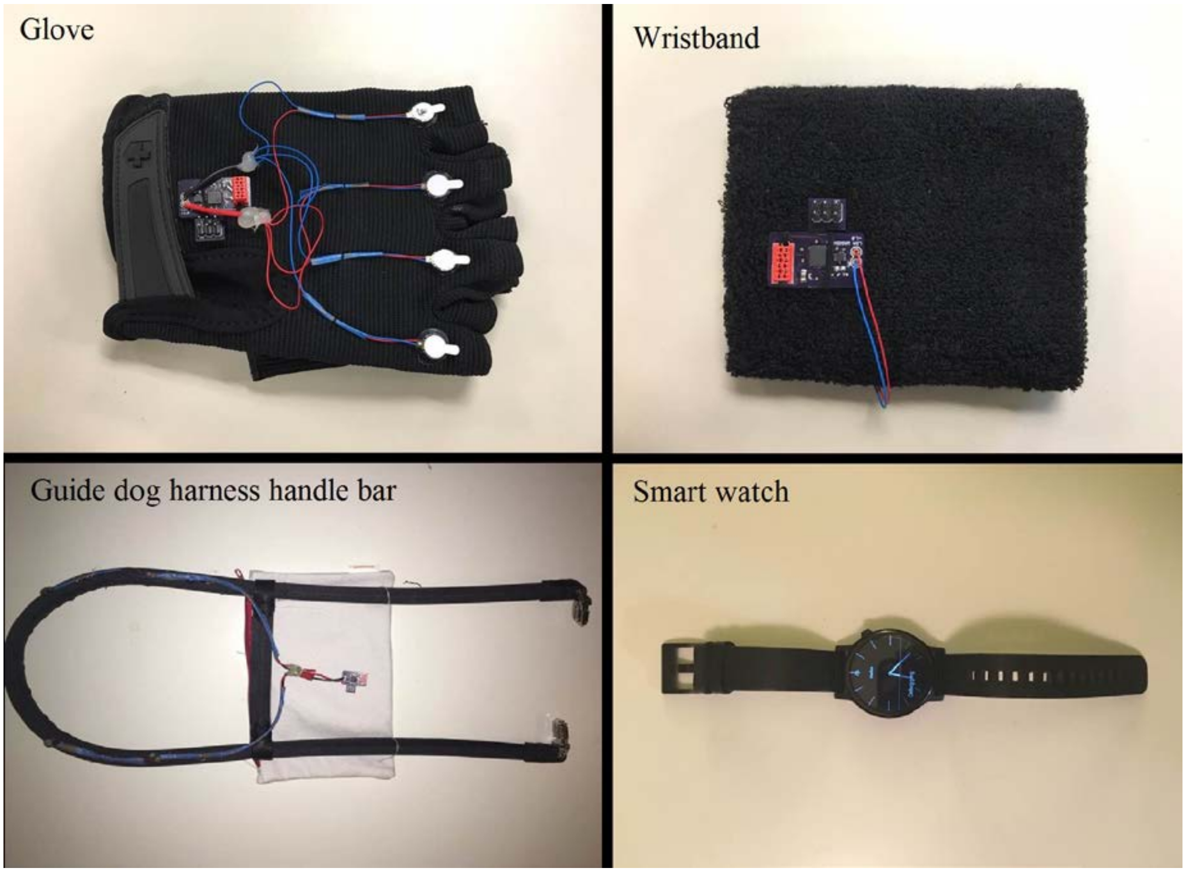

Fig. 1. The four prototypes (glove, wristband, guide dog harness handle bar, and smart watch)

We created four different prototypes for this study (Figure 1). Each prototype integrated vibration motors through different modalities consisting of: A glove, a wristband, a guide dog harness bar, and a smart watch. The effectiveness of each prototype was evaluated by testing the participants' ability to distinguish between four distinct vibration patterns (Figure 2).

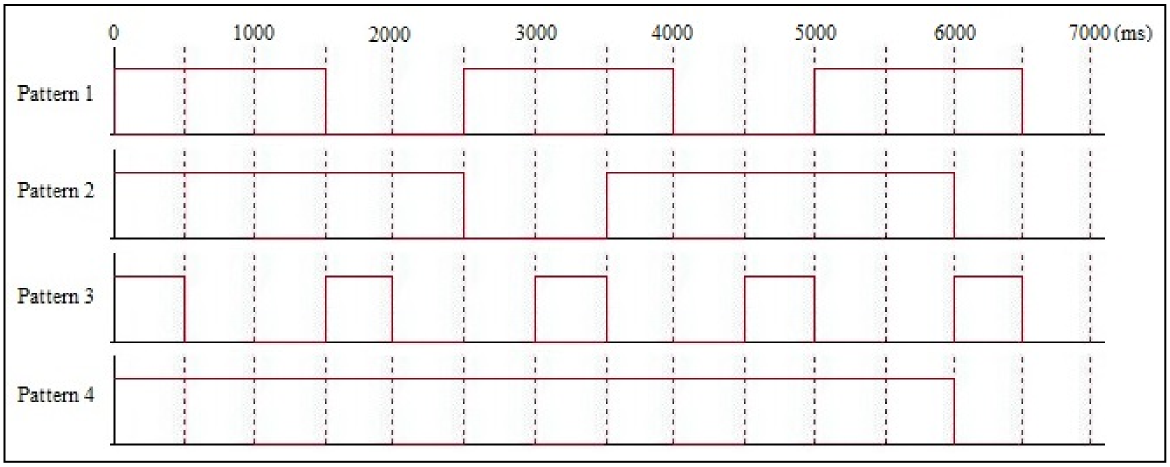

Fig. 2. Four vibration patterns.

Related Work

The applications of haptics signal wearable devices have been studied extensively in various fields. A study by Lee and Starner (2010) shows that temporal patterns are the easiest to distinguish among four parameters (intensity, starting point, temporal pattern and direction). Kajimoto, Kanno and Tachi (2006) explore the possibility of substituting a person's sense of sight with tactile displays. In addition, Lee and Starner (2010) reveal the possibility of wrist-worn wearable tactile displays to distinguish 24 tactile patterns.

Method

Materials

The main piece of electronics used in the study was a custom-designed vibration controller board (Figure 3). This board was used for three out of the four prototypes (the glove, wristband and guide dog harness handle bar). The vibration board used an ATmega328p chip (“ATmega328P”) as its central microcontroller. A DRV2603 haptic controller chip was used to control a LRA motor (“8mm Linear Resonant Actuator - 3mm Type”). Figure 4 is the schematic of the vibration board.

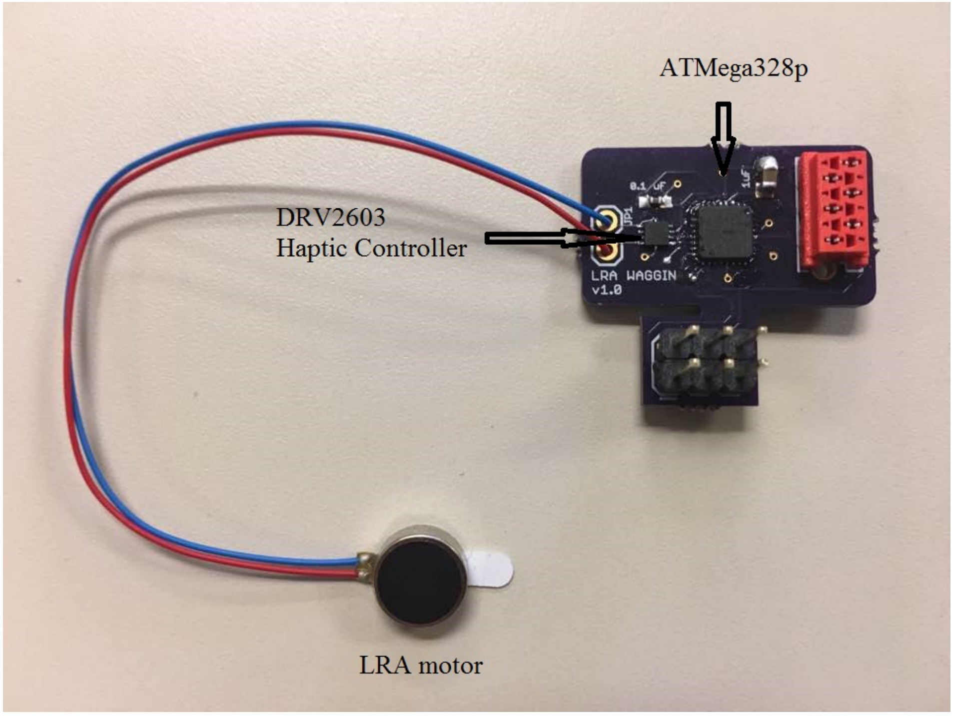

Fig. 3. Custom vibration board with a LRA motor.

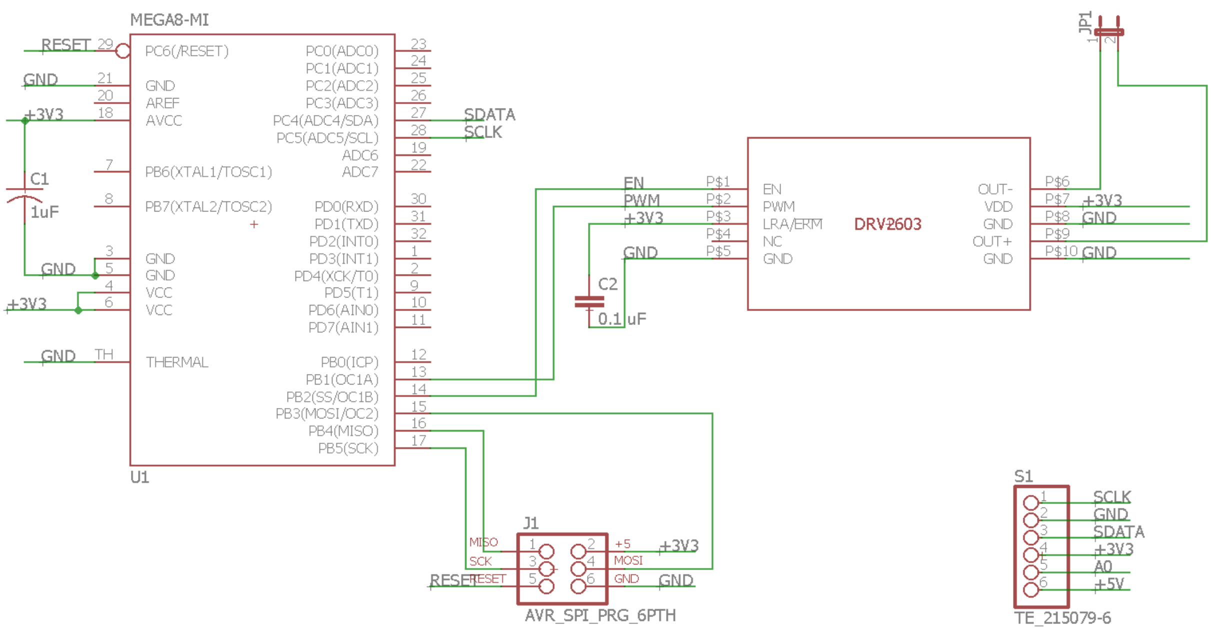

Fig. 4. Schematic of the custom vibration board.

The electronics consisted of four elements. The first was an Arduino UNO R3 with a customized shield. We built a custom Arduino shield, which allowed for quick and easy “plug and play” prototyping. The shield acted as a hub to handle power and communication protocols. This allowed us to plug and play a variety of different sensors, such as accelerometers and haptic sensors. The second component was a Bluetooth modem known as *BlueSMiRF Silver* manufactured by SparkFun (“SparkFun Bluetooth Modem - BlueSMiRF Silver”) to create a Bluetooth connection between a smart-device and an Arduino UNO R. The third and fourth components were a custom-designed vibration board and a 9V battery pack respectively.

Prototypes

The glove, wristband, and handle bar prototypes sensors were attached to an Arduino UNO board (Figure 5). As illustrated by Figure 6, the smart watch prototype and Arduino UNO board are connected to a smart device by Bluetooth connections, depending on the type of prototype used.

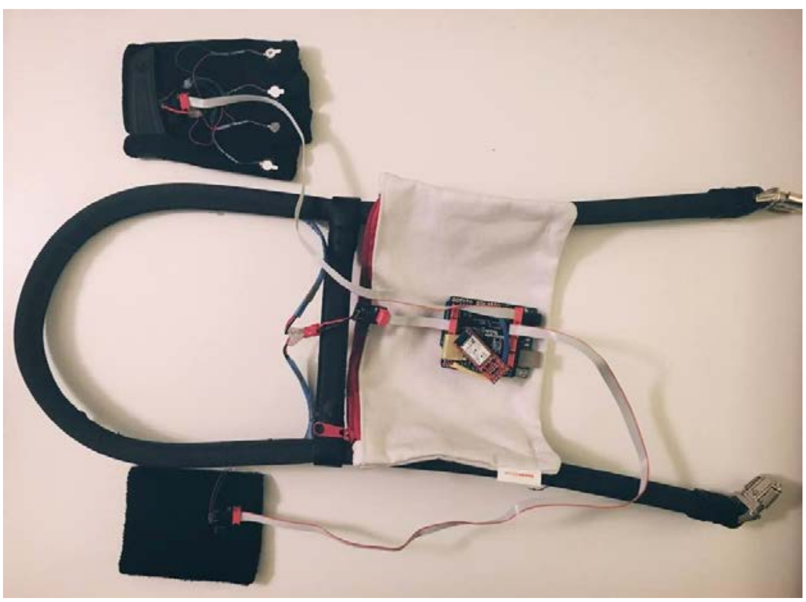

Fig. 5. Guide dog harness handle bar, glove and wristband prototypes connected to Arduino UNO board with a customized shield with a *BlueSMiRF Silver* Bluetooth Modem.

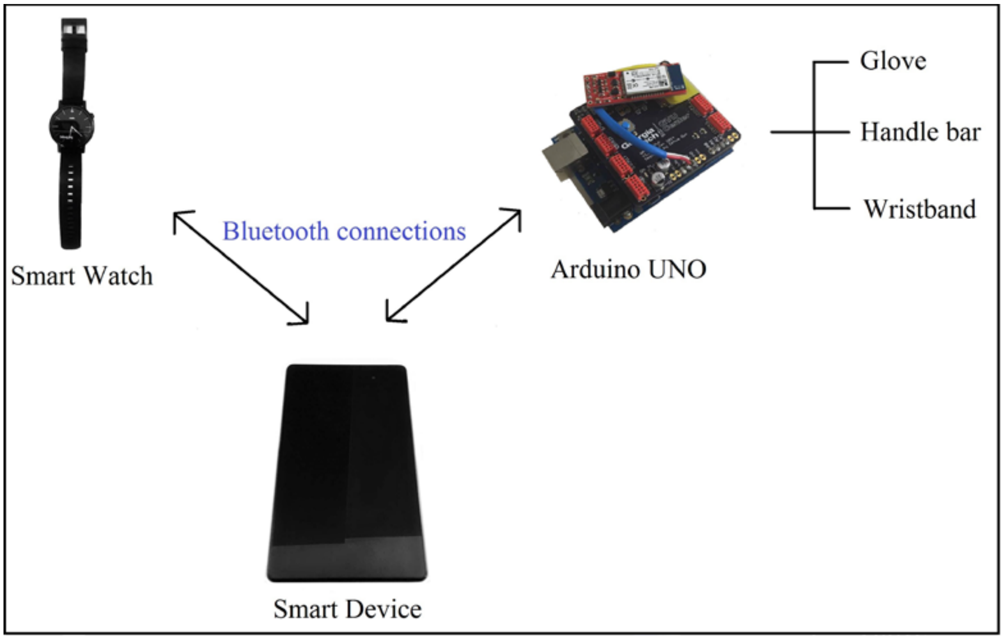

Fig. 6. Bluetooth connections between smart watch, smart device, and Arduino Uno.

Prototype 1–Guide Dog Harness Vibration Handle Bar

The guide dog harness handle bar prototype was the simplest prototype design used in this study because it did not require any additional components. The handlebar had one LRA motor located on each side (Figure 7). One major limitation of the handle bar design was that it required the user to place his/her hand on the handlebar to receive a message.

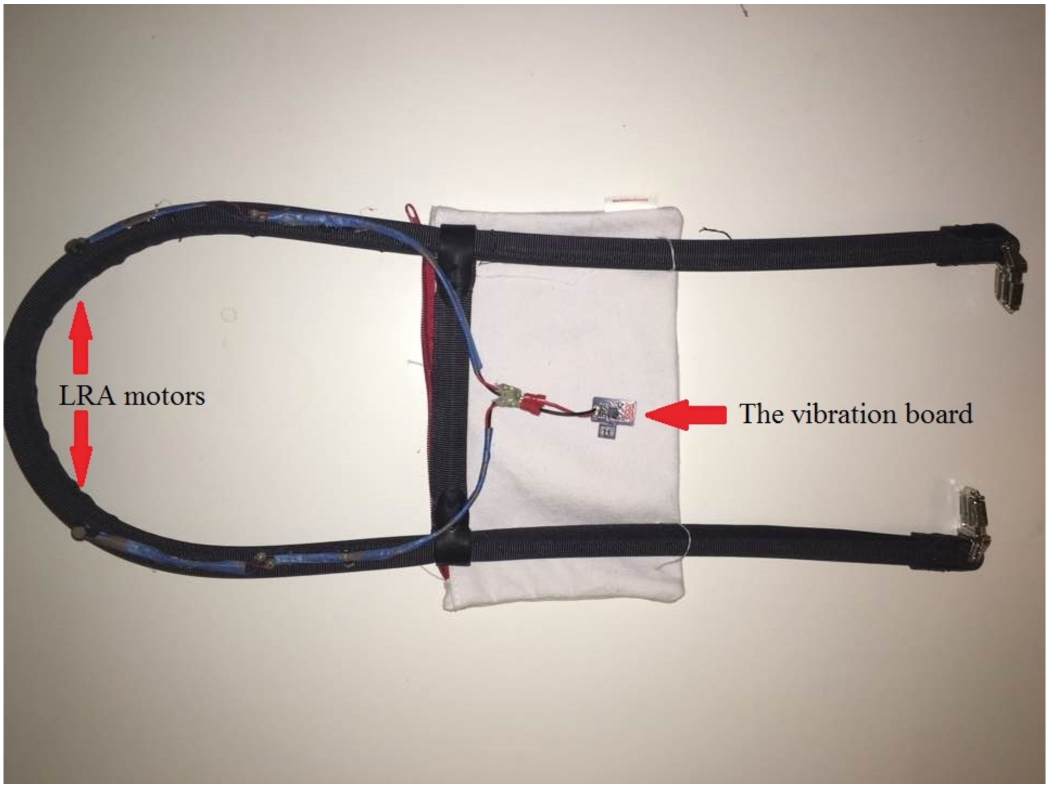

Fig. 7. Guide dog harness handle bar prototype with two LRA motors and one custom-designed vibration board.

Prototype 2–Glove prototype

The glove prototype had one custom-designed vibration board and four LRA motors (Figure 8). The glove was a commercial half-finger gym glove which had a leather palm protection layer and "StretchBack™ performance mesh" on the back of the hand. Every finger except for the thumb had one LRA motor placed between the knuckle and first finger joint.

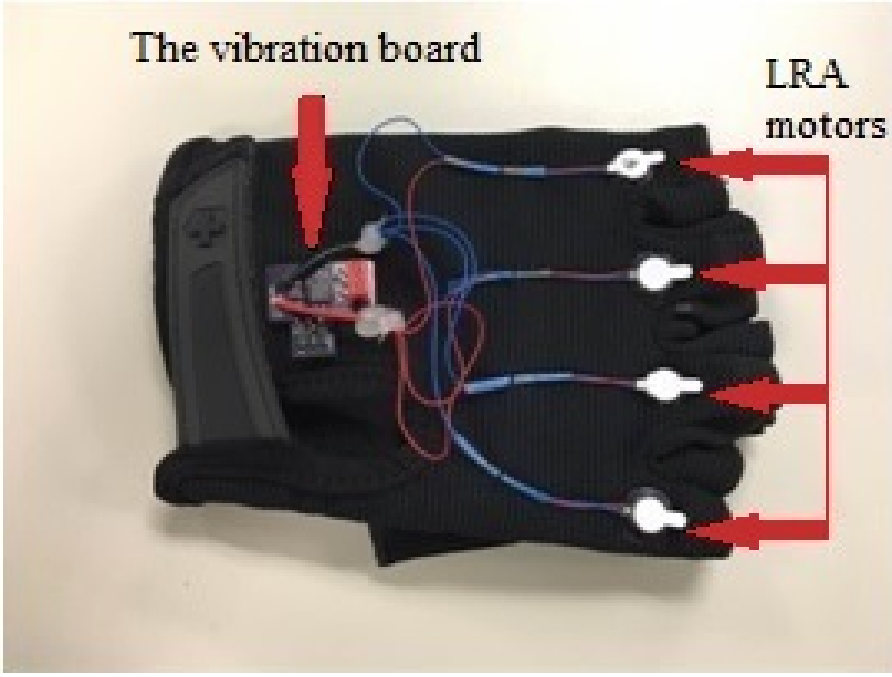

Fig. 8. Glove prototype with four LRA motors and one custom-designed vibration board.

Prototype 3–Wristband Prototype

The wristband prototype had one custom-designed vibration board and one LRA motor placed against the inner wrist (Figure 9). The wristband was a commercial cotton sports wristband. We asked the participants to place the motor on the underside of the wrist to increase their sensitivity to the haptic feedback (Lee and Thad).

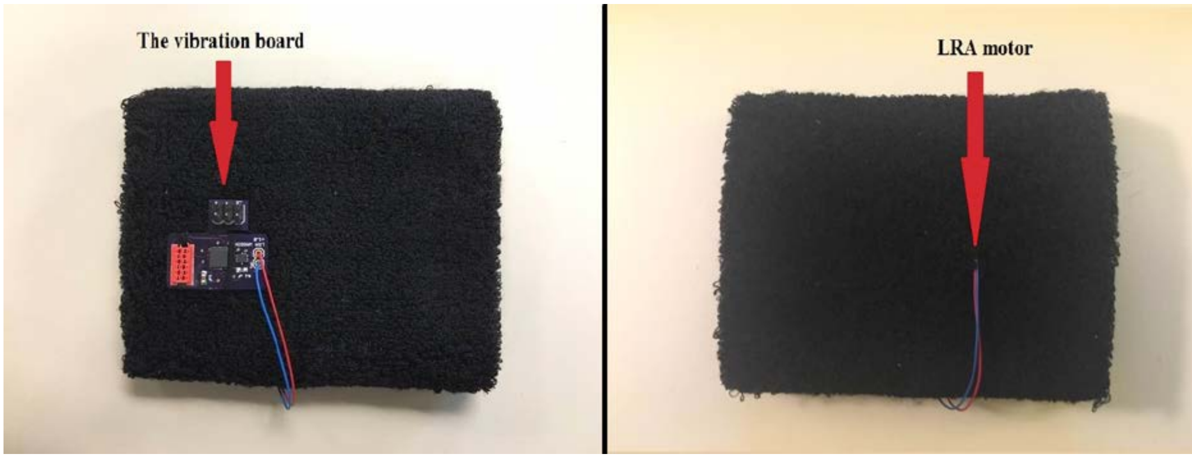

Fig. 9. Top and bottom views of wristband prototype with one custom-designed vibration board and one LRA motor inside of the wristband.

Prototype 4–Smart watch Prototype

The smart-watch prototype used a commercial smart-watch Moto 360. This product allowed for pairing with an Android smart-device using a default Moto 360 application. To send vibration signals, this pairing system created a Bluetooth connection between the smart-watch and an Andriod smart-device.

Participants

A total 12 number of participants were used for this pilot study. None of the participants were visually impaired, and were aged between 20 to 27. There were 5 female and 7 male participants. All participants are pursuing bachelor degrees or above and are right dominant.

Procedure

In our pilot study, each training session lasted 8 minutes, with approximately 2 minutes allocated per prototype. The initial training sessions allowed participants to familiarize themselves with each prototype and the four vibration patterns. Since most guide dog handlers place their left hand on the guide dog harness' U-shaped handle bar (Martin), all the prototypes were designed to test the participants' sensitivity to vibration feedback on the left hand. For consistency, all participants were required to hold the U-shaped handle bar regardless of the type of prototype worn (Figure 10).

Fig. 10. Testing position with a glove on (left) and with a wristband (right).

In the testing session, the participants received 30 randomized instances of the four vibration patterns for each prototype after their training session. Each prototype had its own distinct, pre-scripted set of 30 vibration patterns. Although each individual script did not contain an equal number of patterns, all the participants were given each pattern 30 times throughout the whole experiment.

To keep the experiment consistent, a specific test order was used to test all the prototypes. All participants were asked to use the guide dog harness handlebar prototype first, the glove second, the wristband third and the smart-watch last. However, it must be noted that we recognize that this uniform testing order was not an ideal procedure because of the learning effects introduced by the repeated patterns, thus possibly influencing the apparent effectiveness of the four prototypes (MacKenzie).

All participants were required to complete a questionnaire form at the end of each session for applications in the future design process. As illustrated by Table 1, the questionnaire contains five basic demographic questions and seven user experience questions. The feedback obtained from the questionnaire and the experimental data collected were used to determine the optimal design.

Table 1. Questionnaire questions.

Number	Question
1	Gender?
2	Age?
3	What is your dominant hand? (Right or Left)
4	Do you have a guide dog?
5	Do you have a visual disability?
6	How do you feel about cell phone vibration feedback?
7	Do you have any other device which gives vibration feedback?
8	Which prototype do you prefer?
9	How valuable do you find this feedback?
10	How likely are you to use this interface if it were created?
11	Which signal was the easiest to distinguish from the others?
12	What kind of message do you want to receive from your guide dogs?

Results and Discussion

Following this testing process, we analyzed the accuracy for each prototype using the total number of signals sent to the participant (N) and the number of correct responses (A) for the individual prototype. We also ranked the prototypes from the highest to the lowest accuracy for each participant. In addition, we calculated the overall accuracy of each prototype using the data obtained from all the participants.

Table 2 shows the accuracy of the participants' responses to the various vibrations for each prototype. The participants' ability to correctly identify the vibrations was the least accurate when using the wristband prototype. The overall accuracy average was over 97%.

Table 2. Accuracy results from the participants.

Prototype	**Accuracy (%)**
Smart watch	98.06
Guide dog harness handle bar	97.50
Glove	96.94
Wristband	95.83
Overall Average	**97.08**

The accuracy of each prototype was found to be over 95%. In order to explore the significant differences between all the possible pairs of prototypes, we used T-testing to obtain the T-value on the accuracy results of each prototype for each participant (see Table 3).

Table 3. T-Value of all possible pairs of two prototypes.

Prototypes compared	**T-value**
Handle bar and glove	0.279
Handle bar and wristband	0.842
Handle bar and smart watch	0.342
Glove and wristband	0.546
Glove and smart watch	0.658
Wristband and smart watch	1.330

Table 3 shows the T-test results of all possible pairs of the four prototypes. A significance level (known as alpha or α) of either 0.05 or 0.01 is commonly used to understand the results of a T-test. Since all six possible results were greater than both 0.05 and 0.01 alpha values, there is no significant difference between any pair of prototypes. However, it is hard to generalize the result because a sample size of 12 participants is too small to allow for any accurate generalizations of the overall significance level.

The participants did not use the full 8 minutes of training to familiarize themselves with the four distinct vibration patterns. Instead, most of the participants spent 2 minutes to learn the four vibration patterns for their first prototype but took less than 1 minute for their second, third and fourth prototypes.

From the questionnaire, we found that 10 out of the 12 participants displayed a preference for the guide dog handle bar as the most effective method to receive haptic feedback. The participants reflected that the vibration from the guide dog harness handle bar “Feels the most distinct and direct” and “gave the strongest vibration”. Although the guide dog harness handle bar prototype had the 2nd highest accuracy rate among the four prototypes, this prototype was the most preferred design for the participants. With the questionnaire answers and the accuracy results, we could argue that the learning effect took place during the pilot studying. In other words, if we had followed the Latin square method to randomize the order of prototypes for the pilot studies, the accuracy results might arguably mirror the questionnaire responses more closely.

As illustrated by Figure 11, the most confusing a pair of vibration patterns was pattern 1 and 2. The overall probability of confusion between patterns 1 and 2 was more than 7% and the probability of confusion for patterns 1 and 3 had the second highest rate of 3.6%. The length of the vibration intervals for the two patterns differed by 1000ms. In addition, the number of vibrations for pattern 1 was three, and the number of vibrations for pattern 2 was two. It is likely that the difference in the length of vibration intervals between these two patterns was not significant enough to be easily distinguishable. The results also show that the most distinguishable pairs of patterns were patterns 1 and 4, patterns 2 and 3, and patterns 3 and 4.

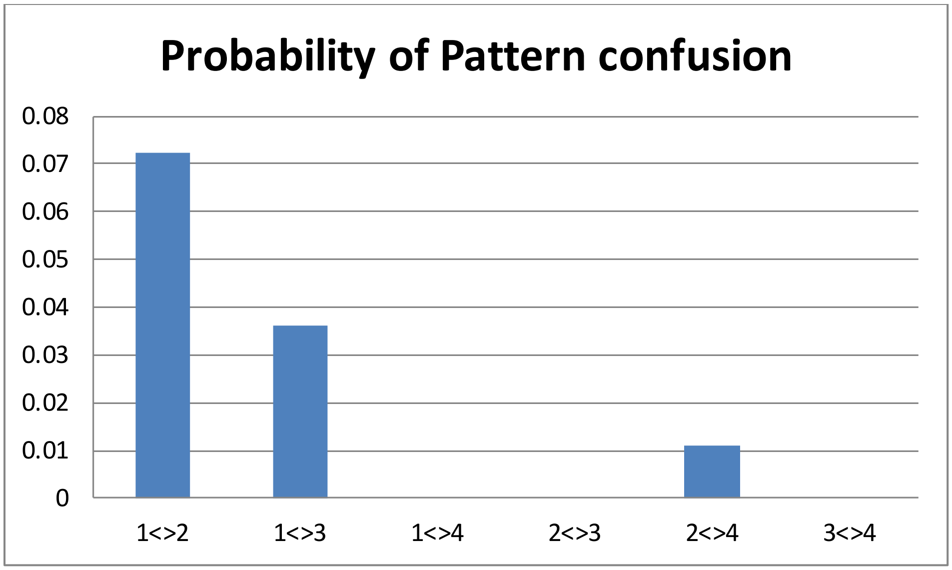

Fig. 11. Probability of pattern confusion from all participants for every possible pair of vibration patterns.

Each prototype displayed unique characteristic during the pilot study. The handle bar prototype shook the whole guide dog harness whenever it received any haptic feedback. It would be useful to consider the effect of haptic feedback on guide dogs for future work.

For the glove prototype, it was found that two out of the 12 participants had hands that were too big for the glove. This meant that the motors did not properly make contact with their skin, thus resulting in weaker haptic feedback.

The wristband had the weakest vibration force of the four prototypes. This was because the cotton material absorbed the vibration force, thus reducing the overall effectiveness of haptic feedback for the participants.

Lastly, we noticed that the smart-watch not only vibrated, but also created a loud buzzing sound whenever it received a signal. This allows the participants to identify the pattern of any given feedback solely through their sense of hearing.

Conclusion

This initial pilot study was a proof of concept for the first phase of our study. We wanted to explore the effectiveness of haptic feedback for guide dog handlers before moving on to the next phase of the study. This study achieved an overall accuracy rate of more than 97%. Even though the accuracy rate of each prototype did not reflect significant differences, the participants' experiences showed that the handle bar prototype was the most preferred design choice. In addition, the results showed that all four prototypes are equally usable for guide dog handlers to receive haptic feedback. However, this study was only conducted in a lab environment without any noise or distractions and all the participants were not visually impaired users. Furthermore, the accuracy rate results and the questionnaire answers showed that there was a learning effect during the pilot studies. Further studies should consider the Latin square method and field study environments. We also plan to study the effect of vibration signals on guide dogs to determine which interfaces are the least obtrusive for dogs.

Acknowledgements

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Works Cited

"8mm Linear Resonant Actuator - 3mm Type." *8mm Linear Resonant Actuator - 3mm Type | Precision Microdrives*. N.p., n.d.

"ATmega328P." *ATmega328P*. N.p., n.d.

"Guide Dogs." *About Us*. Assistance Dogs International. n.d.

H. Kajimoto, Y. Kanno, and S. Tachi. "Forehead electro-tactile display for vision substitution." In *Proceedings of the EuroHaptics,* 2006.

Jackson, Melody Moore, Yash Kshirsagar, Thad Starner, Clint Zeagler, Giancarlo Valentin, Alex Martin, Vincent Martin, Adil Delawalla, Wendy Blount, Sarah Eiring, and Ryan Hollis. "FIDO - Facilitating Interactions for Dogs with Occupations." Proceedings of the 17th Annual International Symposium on International Symposium on Wearable Computers - ISWC '13 (2013).

Lee, Seungyon "claire", and Thad Starner. "BuzzWear." *Proceedings of the 28th International Conference on Human Factors in Computing Systems - CHI '10* (2010): n. pag. Web.

MacKenzie, Scott. "Within-subjects vs. Between-subjects Designs: Which to Use?" *Within-subjects vs. Between-subjects Designs: Which to Use?* MacKenzie I. S., 29 Mar. 2013.

Martin, Vincent (visually-impaired Ph. D. student) in discussion with the author, March 2016.

"SparkFun Bluetooth Modem - BlueSMiRF Silver." *WRL-12577 - SparkFun Electronics*. N.p., n.d.

A Longitudinal Study of Reading Growth for Students with Visual Impairments

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Abstract

Little is known about growth in reading for students with visual impairments. Understanding reading development for students with visual impairments as they progress through school provides expectations for academic growth and informs instructional practices. Using data from Northwest Evaluation Association's Measures of Academic Progress assessment, reading achievement was analyzed from 224 students with visual impairments in grades 3 – 10, in four states over an eight-year time period. Reading growth for students with visual impairments were compared with a nationally normed group of students from the general population. Findings indicate students with visual impairments initial performance in reading achievement in third grade is lower than the national norm. While this population's growth trajectories in reading are trending upward at a steady pace, the gap between students with visual impairments and the national norm is wide. However, the initial review of the data suggests that the rate of growth for students with visual impairments is greater. In particular, the results indicate accelerated growth between 9th and 10th grade, whereas students at the same grade level in the nationally normed group tend to drop in reading growth at this time. Study limitations and recommendations for future research are discussed.

Keywords

Academic achievement, visual impairment, assessment, accessibility, reading

Introduction

With the reauthorization of Every Student Succeeds Act (ESSA), states will still need accountability systems that include subpopulations such as students with disabilities. In addition, with Common Core consortia, the use of growth measures for levels of proficiency on statewide accountability systems has grown. Measuring student growth is important information for an accountability system because it allows schools and teachers a more accurate understanding of student learning over time. According to the 2011 National Assessment of Educational Progress (NAEP), 33% of fourth grade students were below proficiency on basic reading assessment. Additionally, 24% of eighth grade students were below proficiency (National Center of Educational Statistics, 2011). The potential problem is data from the test results are interpreted with the assumption that all items are equal to all learners, all standards are assessed equally, and that all students with the right accommodations are all growing equally.

Unfortunately, little is known about the growth in reading achievement for students with visual impairments. Learning to read for students with visual impairments is very different than the majority of children. Some students with visual impairments learn to read Braille, which is a tactile language, others need the print to be enlarged or have field of vision issues. In general, students with visual impairments are delayed in reading development by two years (Edmonds and Pring 337) compared to their sighted peers. While there is a growing number of studies that focus on the acquisition of reading skills for students with visual impairments (Emerson et. al.; Gillon and Young), there are no studies that have determined academic growth norms in reading for these students. Currently, results on academic achievement for students with any disability are typically combined together because all students with disabilities make up about 10% - 15% of the total school population (Buzick and Laitusis 540; Wei 19; Wei et al. 90). Empirical data on subpopulations are not differentiated, thus making differences among each subpopulation unknown. Classroom teachers of students with visual impairments should have access to academic growth norms to ensure appropriate learning and instructional expectations.

Across the US, there are approximately 28,000 students in general education or residential settings who are visually impaired (American Printing House for the Blind). Section 300.8 of IDEA (Individuals with Disabilities Education Act) regulations states that “visual impairment including blindness means an impairment in vision that, even with correction, adversely affects a child's educational performance. The term includes both partial sight and blindness” (Individual with Disabilities Education Act). State Departments of Education define visual impairment specifically for their student population, for example, Kentucky’s regulations specify that a student’s visual acuity with prescribed lenses is 20/70 or worse, or the student has a condition that causes a functional loss of vision (Kentucky Department of Education 10).

The purpose of this study is to examine academic growth in reading for students with visual impairments in grades three through ten. This grade span was selected because by third grade, students who read Braille are starting to be fluent and potentially have experience with assessments on computers, and after tenth grade, reading growth is minimal. Differences between students with and without visual impairments will be examined to determine if the gap in reading achievement is increasing, decreasing or consistent across grade levels.

Methods

Data was collected from the Measures of Academic Progress (MAP) Reading tests administered for students with visual impairments through grades 3-10 from four different states: Arizona, Indiana, New Mexico, and South Carolina. The study used exploratory analysis of longitudinal data to discover patterns of score change over time across students with and without visual impairments. Conditional score distribution was examined across grade levels. Group means and standard deviations were compared to the MAP reading norm (Thum and Hauser 55) to examine if the two groups were growing in a similar or different fashion. The distributions of difference between two groups across time was examined.

1. For students with visual impairments, does their MAP score change over time? What is the pattern of change?
2. Do students with visual impairments have different growth over time comparing to students without visual impairments? How does the pattern differ?

Sample

Table 1 (Appendix B) presents student demographic information. The final sample included 511 test events that were collected from four schools for the blind and visually impaired in Arizona (N = 218), Indiana (N = 122), New Mexico (N = 97), and South Carolina (N = 74). These test events were completed by 224 students, including 101 females and 123 males. These students were from grades 3 to 10 and completed MAP reading test between spring 2008 and spring 2016. In the longitudinal data matrix, for all the students, there were 490 valid scores out of the total (N = 1792) across grades 3 to 10, containing 73% missing data.

Table 1. Sample Summary

State	Female	Male	Total Number of Students
Arizona	44	47	91
Indiana	23	35	58
New Mexico	19	21	40
South Carolina	15	20	35
Total	101	123	224

Measures

MAP is computerized adaptive assessments that schools typically administer at times between their high stakes accountability assessments and are often referred to as interim assessments. Specifically, MAP assessments are administered seasonally (fall, winter, and spring) as they were for the students in the study. MAP assessment items are calibrated on a vertical scale that is specific for each subject area, using a one-parameter item response theory model (Rasch) (NWEA 23; Barker 19). MAP assessments show high reliability and consistency attributable to following the AERA/APA/NCME Standards for Educational and Psychological Testing protocol. Since the tests are adaptive, each student experiences a different set of items. Items are selected from an item pool using an algorithm that searches for the most informative item, where $\hat{\theta}$ is the interim ability estimate and δ is the difficulty of the item required. The test taker's estimated ability is updated after each item response. The update is used to identify the difficulty of the next item to be presented. Because of this method, students have a roughly 50% probability of responding correctly to any given item, with their response (correct/incorrect) driving the selection of the next item presented.

Discussion

To address our research questions we computed group means and standard deviations for these 511 test events across grades 3-10, and compared results to the national MAP reading status norms that represent national performance in MAP reading test.

As seen from Table 2 (Appendix B) and Figure 1 (Appendix A), this group of students exhibits steady growth across grades. The curve follows a monotonic pattern. In general, students show larger growth in the lower grade levels (grades 3 – 6) than the upper grade levels (grades 7-10). Students with visual impairments show larger growth from grade 5 to 6 and grades 7 to 8.

Interestingly, the national norm student group shows no growth from grade 9 to 10, while the students with visual impairments accelerated growing from grade 9 to 10.

Table 2. Descriptive Statistics of Data Sample

Grade	Mean RIT Score	SD
3	181.52	23.28
4	187.73	22.62
5	190.71	21.19
6	196.43	20.39
7	197.38	20.22
8	201.32	21.97
9	201.76	21.45
10	207.96	18.79

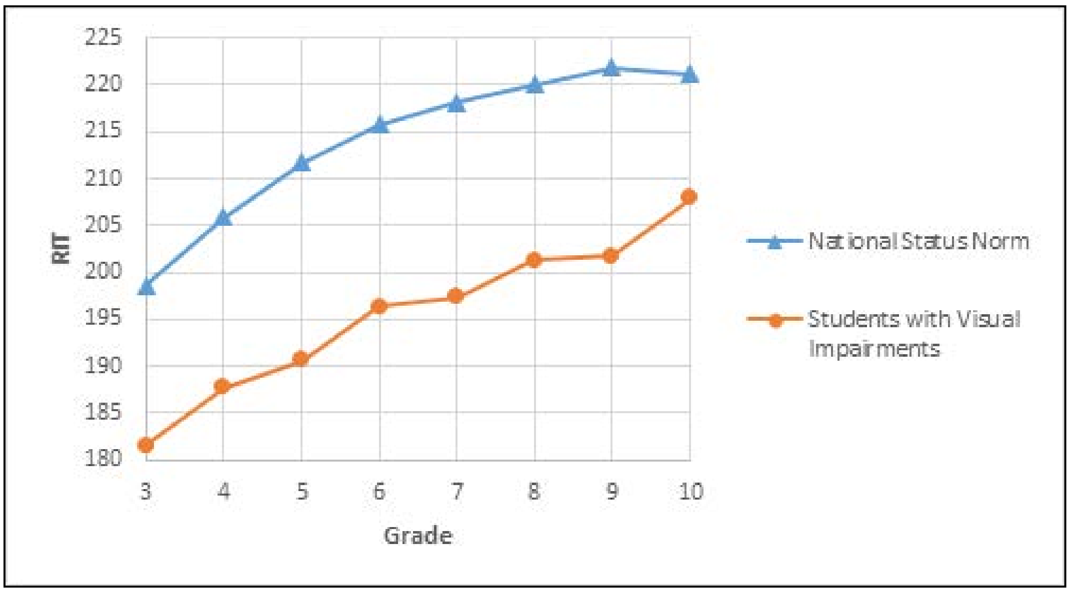
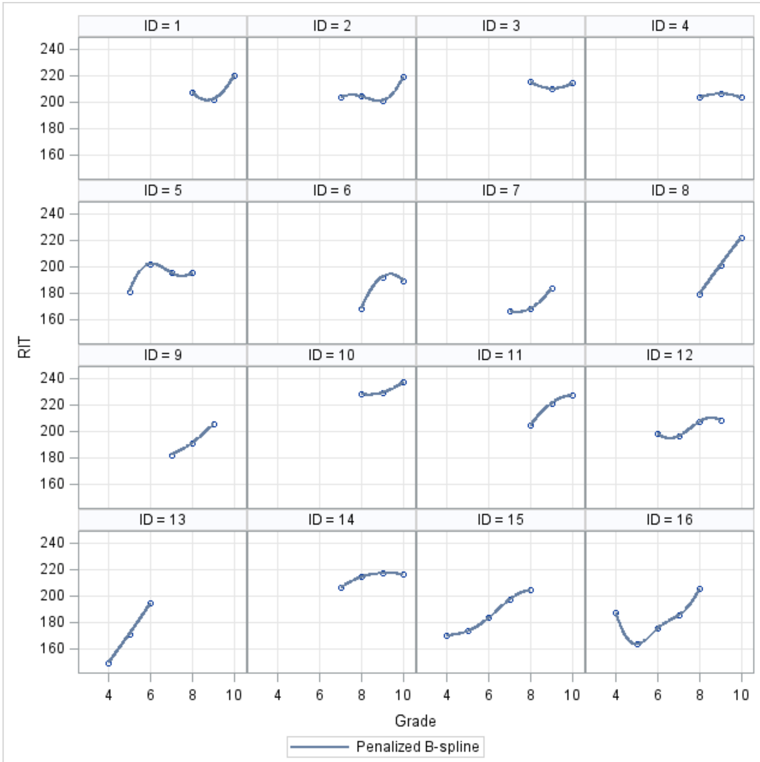
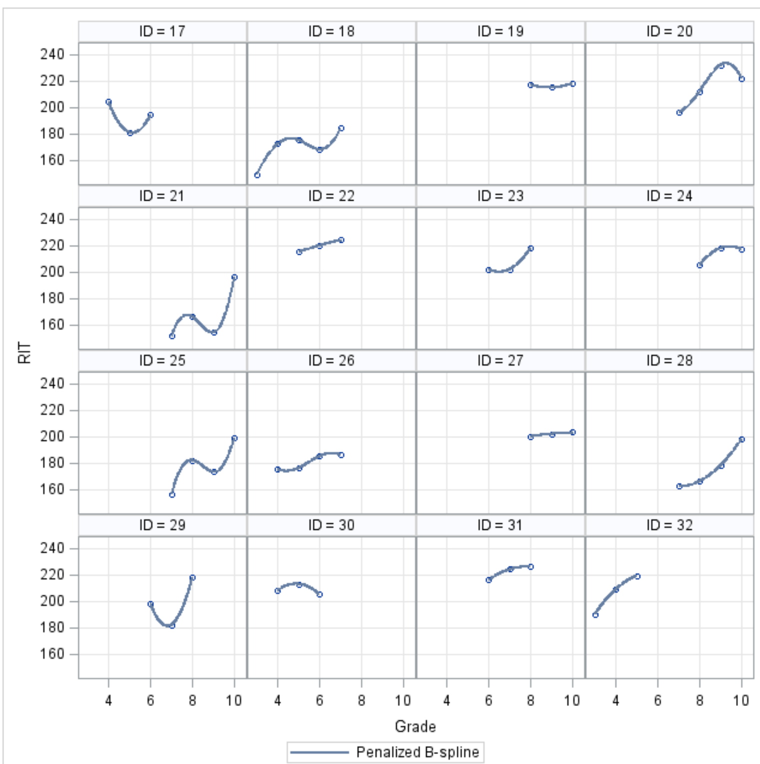


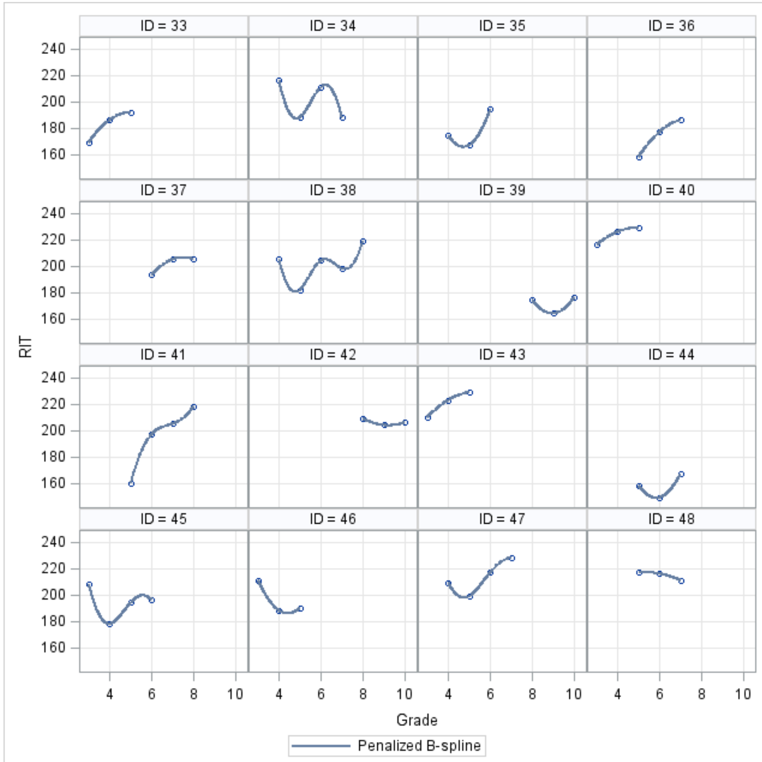
Fig. 1. Reading Score Group Mean Across Grade

On average, there is an achievement gap between students with visual impairments and the overall national sample. The achievement of this particular group is approximately 20 RIT points lower than the average MAP reading performance. This achievement gap could be explained by disparities in when students with visual impairments acquire literacy skills compared to students who are sighted. Research points to lack of incidental exposure to print as the reason that students with visual impairments are delayed in starting to read (Hatton et al. 744). “Children with normal vision encounter writing on walls, labels on food packages, directional road signs, and so forth. Because these opportunities are out of scope of children with low vision, they necessarily have less experience with written materials” (Bosman et al. 218). Another possible explanation suggests that deficits in general knowledge cause a difference between reading ability and age expectations (Gillon and Young 48), which may also be attributed to incidental learning.

In addition, we investigated the pattern of student growth. Due to the large amount of missing data, we examined individual student’s longitudinal profile. First, we included all students who have valid scores in more than two consecutive years (N = 64). Second, we included all students who have valid scores in more than three successive years (N = 28). To help explain these change patterns, repeated measurements of individual MAP reading scores obtained from 64 students and 28 students are plotted in Figures 2A and 2B (Appendix A), respectively. Figure 2A contains 64 students’ profiles that display a variety of growth patterns. For example, five students exhibit linear growth (e.g., ID = 8, 13, 26, 31, and 55) showing consistent growth over time. As can be seen from other students, changes in MAP reading scores are not adequately characterized by linear trajectories—individual growth is not linear. Figure 2B contains 28 students’ profiles that all display non-linear growth. The results indicate that, there is no uniform growth pattern for this group of students with visual impairments. Since our sample size is small, these patterns of growth, which include steeper gains and score drops, are easier to isolate. The NWEA national status norms represent the growth of the general school population and are based on tens of thousands of test results. The NWEA norms study does not isolate individual test results which could also show these irregular patterns of growth.







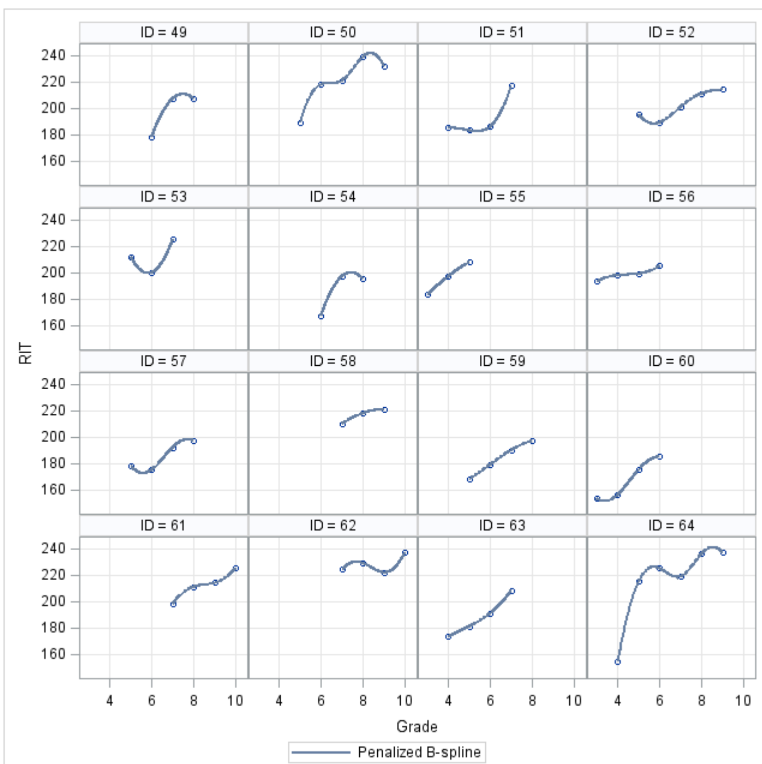


Fig. 2A. Longitudinal Observation of Individual Student (N = 64).

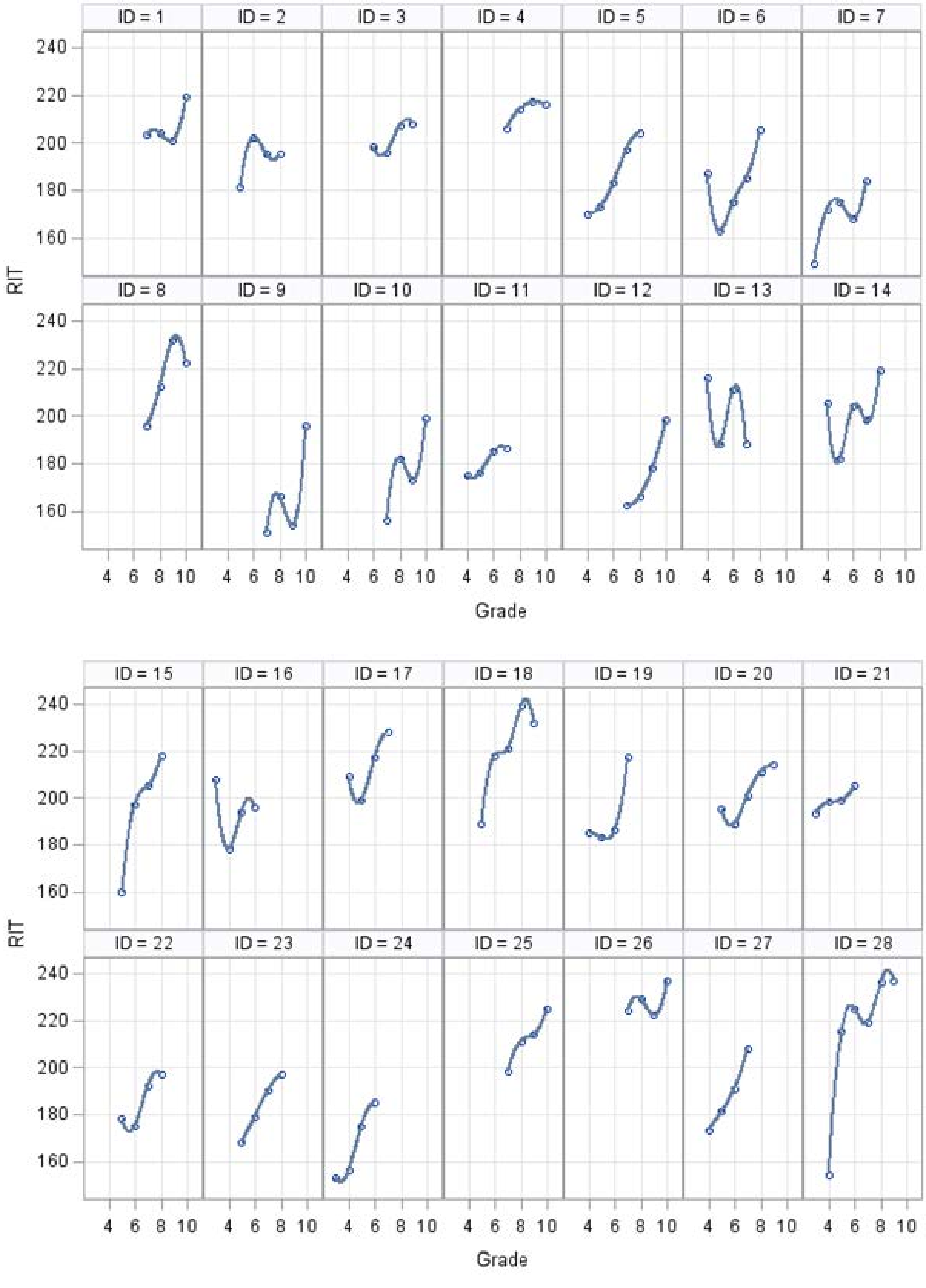


Fig. 2B. Longitudinal Observation of Individual Student (N = 28).

Conclusion

Students with visual impairments experience learning to read in a variety of ways, and understanding what this means in terms of student growth trajectories is important. Students with visual impairments are exposed to print and reading strategies at later age than their sighted peers. Our study revealed interesting findings regarding the differences between students with visual impairments and the national MAP reading normed group. While most of our findings support prior research, others findings provide a foundation for further longitudinal investigation.

The difference between initial performance for students in the nationally normed group and students with visual impairments in grade 3, is an important finding. This data seems to support previous research from Edmonds and Pring (337) indicating a two year delay in reading between students with visual impairments when compared to their sighted peers. Additionally, while there seems to be an accelerated rate in growth for students with visual impairments in upper grades compared to the national norms. Investigating how these students continue accelerating in reading growth is important for instruction and student learning.

Limitations

Findings from this preliminary study must acknowledge several limitations. First, this study is from eight years of student data, which offered a great amount of information relating to reaching achievement and growth overtime.

Generalizability

Missing data was significant within the dataset with 73% missing and, therefore, the ability to generalize the results may be compromised. Additionally, since data was collected over a broad number of years, 2008 through 2016, not all states or students have data available.

Measuring longitudinal growth in a more sensitive manner such as months or weeks is suggested as a more accurate approach.

Confounding Variables

In addition to the potential limited generalizability of the data with a small total population and extensive missing data, there are few other covariates that could have been incorporated into the analysis such as type of visual impairment for each student. For example, whether the student used a screen reader and refreshable braille, or whether the student used a magnification software device, could provide additional information. Also, the inability to account for school type (e.g., public or residential) makes it difficult to specify why some students may be accelerating in reading while others have score drops. More specifics about the student could help to explain some of the variation and making the data more generalizable.

Future Studies

This study was simply a launching point, hopefully, for more informative and extensive research analysis. After this year (2016-2017), NWEA will obtain growth data from nine schools for the blind, which includes three time points within each year. This information will not only be available for reading achievement, but in mathematics, science, and language usage. Conducting studies to examine the validity of tests for students using screen readers, braille devices, and accessibility will be investigated. Further studies investigating the nesting of students within school type (e.g., public vs. residential) will also be considered. Investigating these relationships between students with visual impairments and their sighted peers helps to understand learning development which will promote growth in all areas of academic achievement.

Works Cited

American Printing House for the Blind. “Annual Report 2014: Distribution of Eligible Students Based on the Federal Quota Census of January 7, 2013 (Fiscal Year 2014)”. http://www.aph.org/federal-quota/distribution-2014/.

Barker, Elizabeth. *To what extent do early literacy skills predict growth in mathematics for students with reading difficulties*. 2015. University of Oregon, PhD dissertation. ProQuest search.proquest.com.proxy.cc.uic.edu/docview/1727457107/1A496B7253034AC8PQ/1?accountid = 14552.

Bosman, Anna MT, et al. “Low vision affects the reading process quantitatively but not qualitatively.” *The Journal of Special Education* 39.4, 2006, pp. 208-219.

Buzick, Heather M., and Cara C. Laitusis. “Using Growth for Accountability: Measurement Challenges for Students with Disabilities and Recommendations for Research.” *Educational Researcher*, vol. 39, no. 7, 2010, pp. 537-544 doi:10.3102/0013189X10383560.

Edmonds, Caroline J., and Linda Pring. “Generating Inferences from Written and Spoken Language: A Comparison of Children with Visual Impairment and Children with Sight.” *British Journal of Developmental Psychology*, vol. 24, no. 2, 2006, pp. 337-351 doi:10.1348/026151005X35994.

Emerson, Robert W., M. C. Holbrook, and Frances M. D'Andrea. “Acquisition of Literacy Skills by Young Children Who are Blind: Results from the ABC Braille Study.” *Journal of Visual Impairment & Blindness*, vol. 103, no. 10, 2009, pp. 610-624.

Gillon, Gail T., and Audrey A. Young. “The Phonological-Awareness Skills of Children Who Are Blind.” *Journal of Visual Impairment & Blindness*, vol. 96, no. 1, 2002, pp. 38-49.

Hatton, Deborah D, et al. “Phonological awareness of young children with visual impairments.” *Journal of Visual Impairment & Blindness* 104.12, 2010, pp. 743-751.

“Kentucky Administrative Regulations (2008, August 6).” Kentucky Department of Education. http://education.ky.gov/specialed/excep/documents/kentucky%20administrative%20regulations.pdf

Northwest Evaluation Association (NWEA). “Technical Manual for Measure of Academic Progress & Measure of Academic Progress Primary Grades.” 2011.

Thum, Yeow Meng., and Hauser, Carl H.” NWEA 2015 MAP Norms for Student and School Achievement Status and Growth.” *NWEA Research Report*, 2015.

U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2011 Reading Assessment.

U.S. Department of Education, Office of Elementary and Secondary Education. *Individual with Disabilities Education Act*. Pub. L. No. 101-4760, § 104, Stat. 1142, 2004.

U.S. Department of Education, Office of Elementary and Secondary Education. *No Child Left Behind Act of 2001*. Pub. L. No. 107-110, § 115, Stat. 1425, 2002.

Wei, Xin. “Does NCLB Improve the Achievement of Students with Disabilities? A Regression Discontinuity Design.” *Journal of Research on Educational Effectiveness*, vol. 5, no. 1, 2012., pp. 18-42 doi:10.1080/19345747.2011.604900.

Wei, Xin, Jose Blackorby, and Ellen Schiller. “Growth in Reading Achievement of Students with Disabilities, Ages 7 to 17.” *Exceptional Children*, vol. 78, no. 1, 2011., pp. 89-106.

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Experience Report of a Blind Gamer to Develop and Improve the Accessible Action RPG ShadowRine for Visually Impaired Gamers

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Abstract

Computer games are becoming increasingly diversified. The lead author of this paper first encountered them early in elementary school. One of the authors recalls quite often having had fun playing games with his neighborhood friends, who were healthy individuals. He, however, was completely blind essentially from birth, which made it impossible to visually recognize screen displays or to play any game at a satisfactory level. Visually impaired persons, including him, have had to deal with barriers in computer games, which are extremely difficult to overcome, in order to play computer games. Therefore, our group decided to embark on the task of developing a game on their own that could be enjoyed to the satisfaction of everyone, regardless of visual impairment. This report describes the sequence of events that led to the development of an action role playing game (RPG) that can be played by sighted and visually impaired persons alike, as well as the development process and the details of the finalized game.

Keywords

Visually impaired persons; inclusive game; integrated game development environment for the blind

Introduction

Computer games are becoming increasingly diversified; they are popular in a variety of formats, such as commercial arcade games, home console games, and personal computer games. The lead author of this article first encountered computer games early in elementary school. One of the authors recalls quite often having had fun playing games with his neighborhood friends, who were healthy individuals. He, however, was completely blind essentially from birth, which made it impossible to visually recognize screen displays or to play any game at a satisfactory level. Sighted persons are able to visually recognize information displayed onscreen that indicates the status of the game, such as maps or text. Totally blind persons must instead rely primarily on auditory information to discern what is occurring onscreen. These circumstances made it necessary for us to devise means for understanding the status of a game by associating the sound effects and background music with game status or by memorizing the sequential arrangements and hierarchical structures of menus. Furthermore, one of the authors with visual impairment required the collaboration of sighted friends to play games that contained scenes where progress was not possible without obtaining visual information.

Despite all such playing tactics and published accessibility guidelines (Miesenberger et al. 247-260; Porter, and Kientz 3:1-3:8; Yuan, Folmer, and Harris Jr. 81-100) and studies to create accessible game for visually impaired people (Dobosz, and Ptak 523-529; Archambault, and Olivier 450-453), there were few games that gamers with blindness could play relying solely on sound. The determination of whether any given game could be played using solely auditory information could only be made by verifying each game in a painstakingly elaborate manner. The search for games required gamers with blindness to play the demonstration versions of the games, refer to official game websites, and rely on information provided by friends.

Furthermore, recent games have progressively higher visual resolution and enhanced definition, while there is an increasing trend in games of obliging players to acquire visual information. Visually impaired persons, including one of the authors, have had to deal with these barriers, which are extremely difficult to overcome, in order to play computer games.

However, there has also been progress in developing games intended for visually impaired persons. A report covering games that can be played by visually impaired persons, on their own or with assistance of others, was featured by the website AudioGames.net (AudioGames.net). Information on games for visually impaired persons that can be operated in a screen reader environment, primarily by using auditory information such as sound effect cues, and audio games was gathered from around the world. The author with blindness became aware of audio games and began playing them around the time he advanced to junior high school. At this point, he no longer simply played the games but started to develop them on his own, relying on information provided by more senior students at school, as well as by the Internet. In high school, the author established a computer club with friends and developed games with several people. These games were enjoyed via the Internet by users with visual impairments, but it was difficult for sighted individuals to actually enjoy playing games that could be played solely by relying on sound. The author therefore continued to play ordinary computer games with friends with normal or weak vision, in addition to playing and developing audio games.

Much ingenuity and effort are required of visually impaired persons to play ordinary computer games conversely (Miesenberger et al. 247-260; Porter, and Kientz 3:1-3:8; Yuan, Folmer, and Harris Jr. 81-100; Dobosz, and Ptak 523-529; Archambault, and Olivier 450-453), it is difficult for sighted persons to enjoy playing games that are developed for visually impaired persons. Therefore, it has been difficult for visually impaired persons like the author to play the same games as sighted persons and to share common topics of conversation. Therefore, we decided to embark on the task of developing a game on his own, that could be enjoyed to the satisfaction of everyone, regardless of visual impairment (Matsuo et al. 303-312; Matsuo et al. 537-544). This report describes the sequence of events that led to the development of an action role playing game (RPG) that can be played by sighted and visually impaired persons alike, as well as the development process and the details of the finalized game. The definition of role playing game in this paper is the game that players act the role of main characters in a fictional virtual world.

Discussion

Preparation of Development Environment

Sequence of events that led to development

One genre of games that visually impaired gamers had been unable to play without using visual information was action RPGs. Such games require instantaneous decisions based on information displayed on the screen; operations must be performed based on understanding on the field of the game and positional relationships with opponent characters. The leading author was unable to play action RPGs at will for this reason. This study, therefore, was intended to develop a real-time action RPG, which had in the past been difficult for visually impaired persons to play. We intended to create a game that incorporates elements belonging to the computer games that he had previously been unable to play, despite a strong desire to, and to create a novel system for arranging audio games such that visually impaired and sighted persons can play. Figure 1 shows the overview of the developed game. This figure includes a game screen, and a tactile display (KGS Corporation DV-2).

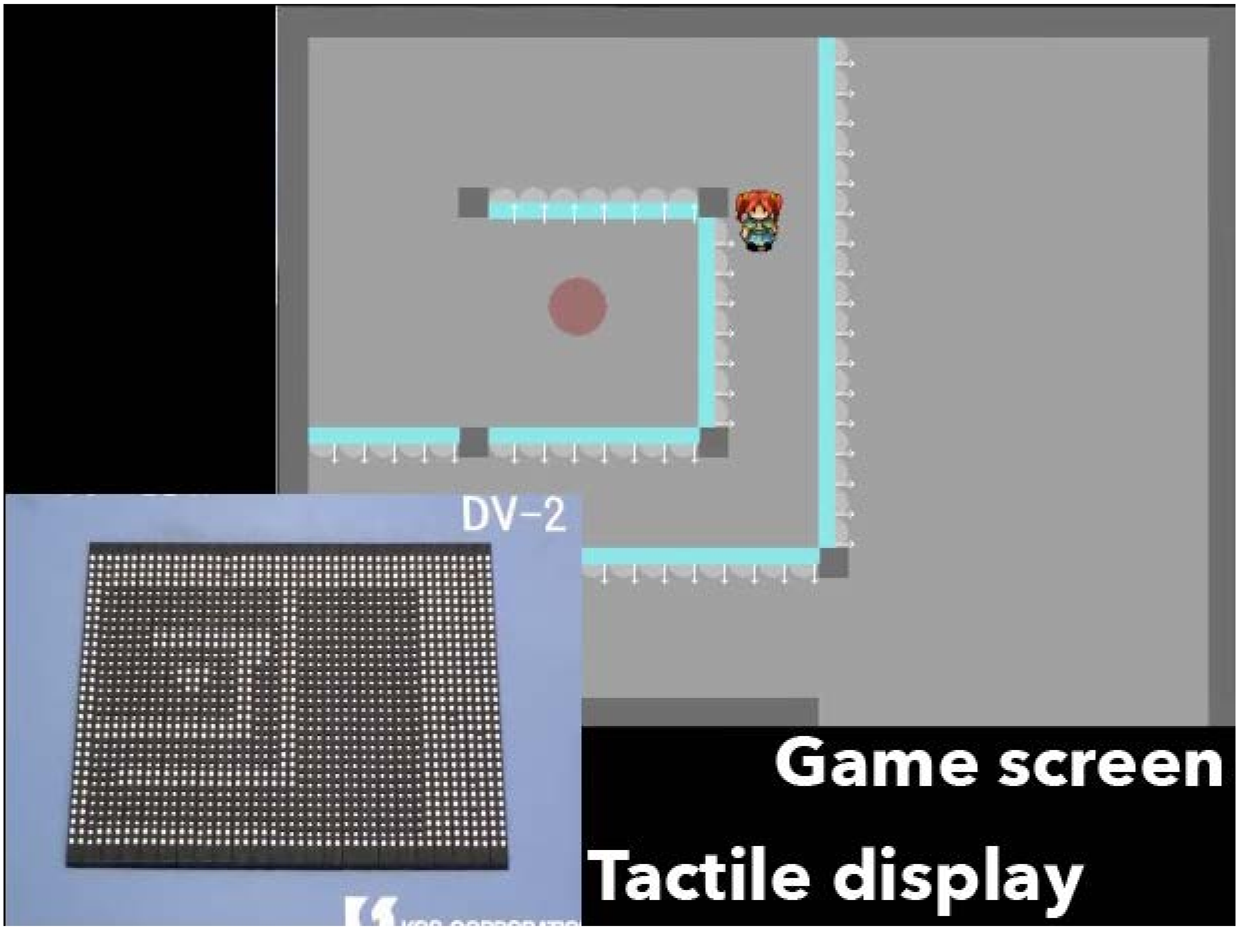

Fig. 1. Game View and Its Presentation on a Dot Matrix Display.

An environment designed to accommodate the development of an action RPG by a visually impaired person, however, did not exist. A decision was made to set up an environment intended for the development of an action RPG that could accommodate development by visually impaired persons. Of particular necessity was a map editor, necessary to prepare fields of the game, for visually impaired developers, which did not previously exist. Thus, a map editor that enables a developer to prepare two-dimensional maps by listening to sound was developed.

Summary of Development Environment

The implementation of the game development environment was conducted entirely by one of the author, who is a totally blind individual. The other authors played a role to mainly advise the design implication including user interfaces, and evaluation scheme of the game. The programming language selected for game development using a screen reader was the Hot Soup Processor (HSP) (HSPTV!). This programming language was used to develop the game's basic algorithm. Additionally, the text displayed by the game was prepared using Otonove (Otonove), which one of the authors had developed previously. This tool was developed using the HSP and can be used even by individuals who have visual impairments. Otonove makes it possible to prepare sound novel games (sound-based adventure games played primarily based on text information) by combining text information with available options, as well as sound effects. The development of text content for this RPG was simplified by incorporating such content into the algorithm for displaying portions of the story in the game.

Sound effects, background music, and graphical elements were selected from materials available on the Internet, either free or for a fee. We selected the processing methods and the allocation of background music and sound effects using free software that operates on the Windows operating system. Since there was a limit to the extent that game displays can be developed by a totally blind individual relying on a tactile display, collaboration was obtained from friends with weak or normal vision. Instances where the combination of background and character colors made it difficult to visually distinguish the two or where the character and wall positioning were misaligned were pointed out. Improvements were implemented together with visually impaired gamers. These people also provided their collaboration in selecting and assigning illustrations for characters and background images.

Furthermore, the Fullvoice Edition of the game, which is its latest version, incorporated human voice actors for conversations of characters in the game. Amateur voice actors were selected from among those who are active on the Internet.

Map Creation Tool AudibleMapper

AudibleMapper is a tool for creating fields that supports accessibility for totally blind persons. The programming language selected for development using a screen reader by totally blind persons was the Hot Soup Processor (HSP) (HPSTV!). This tool conveys the position of the cursor on the screen and two-dimensional fields are drafted through keyboard operations. The conditions under which a totally blind person drafts a map using this map editor is described in Figure 2. First, the map is surrounded on four sides by a wall (Figure 2, Left); then the walls are arranged according to the image of the map to be drawn (Figure 2, Center); and finally objects, such as treasures, are positioned (Figure 2, Right). The red circles in the figure are the cursor for editing. In Figure 2, Left, the field was surrounded by walls. In Figure 2, Center, a road was prepared by at the end of a branching road. In Figure 2, Right, additional road and a treasure were placed.

Fig. 2. An Example of Drawing Using the AudibleMapper.

Specific descriptions of the development operations are provided. Cursor positions were moved according to the directions of arrow keys on the keyboard using this editor, while the walls and waterfronts, as well as tiles such as a lava flow or objects such as treasure chests and doors, were freely arranged using alphanumeric keys. Types of tiles and objects can also be arbitrarily added, as needed. The range of cursor movements was also selectable and objects located within a selected area can be processed together. A range selection can be made within an area of a square shape, by moving the cursor while the Shift key is pressed down, starting from the starting point for the range selection and then releasing the key. Batch processes can be performed within a region; wherein identical objects can be added or deleted.

The sound for indicating the current position of the cursor was varied in order to enable the user to gain understanding of the current cursor position. The horizontal positional information indicator for the cursor utilizes the asymmetry in sound volume level between left and right, making it possible for a user to gain an understanding of the horizontal coordinates on the screen based on auditory localization. The vertical positional information indicator for the cursor utilizes the difference in the sound volume, making it possible for a user to gain understanding on the vertical coordinates on the screen. Understanding the entire map is possible with the help of sound effects alone, by tracing over the entire map by moving the cursor position. The change in sound pressure that occurs as the cursor position is changed was set to 2 dB or higher in the horizontal direction based on reports provided by Hafter et al. and Yost et al. (Hafter et al. 829-834; Yost, and Dye 1846-1851), while it was set to 1 dB or higher for movements in the vertical direction based on reports by Miller (Miller 609-619). The map tool was also set to replay various sound effects, depending on the positioning of the tiles. We employed not three-dimensional spatial acoustical presentation method but two-dimensional presentation method because the employed method was suitable for the purpose. Concretely, the 3D presentation method present surrounding acoustical field that a listener is virtually located at the center while 2D method can present absolute positions of a cursor and various objects on a map. Moreover, because 3D presentation method can be utilized by the head-related transfer function (HRTF), the position of localized sound image varies between individuals (Wenzel et al. 111-123).

An example of the game map, prepared according to the flow described in Figure 2, is shown in Figure 3. A map prepared with the assumption that players make intuitive movements (positioning and routes are easily understood) is depicted in Figure 3 (a) and a map prepared with the assumption that players perform searches (positioning and routes are difficult to understand) is depicted in Figure 3 (b), while Figure 3 (c) depicts a field prepared with the assumption that players must consider methods for acquiring the treasure chest. These are used in the game as a section of a town, a dungeon, or a field in which an item is hidden, respectively.

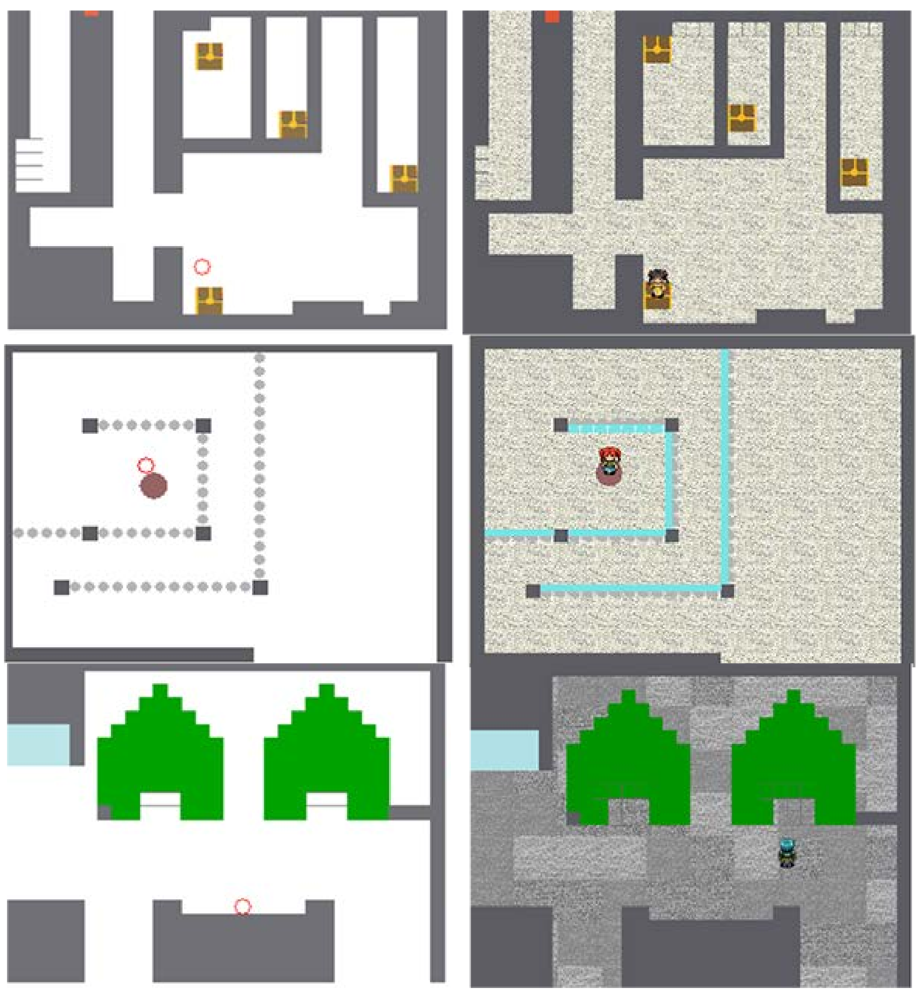

Fig. 3. AudibleMapper (Left) and Corresponding Game Maps (Right)

All game maps were drawn quickly and efficiently by a totally blind person using this editor. The conventional procedure involves entering numerical values directly into the program screen to prepare a map, which makes it difficult to achieve detailed placements of objects and complicates source code, requiring dozens of minutes to prepare a single map. Preparation time is shortened to just dozens of seconds or a few minutes by using this editor, however, which improved work efficiency. A totally blind person using this tool to develop an action RPG prepared about 500 sets of maps comprised of 32 horizontal and 24 vertical cells. A field viewer for verifying game screen details, based on the map editor, was also incorporated as a base component of the game. This function is intended for understanding the game status when it is being played solely based on sound. Visually impaired persons using this function, who are proficient with a variety of games, are now able to proceed with their game while gaining an understanding of the map and their current position.

The Developed Game, *ShadowRine*

Game summary

ShadowRine is a tactile action RPG that can be played by both sighted and visually impaired persons (Though the author firstly named it ShadowRun that meant "run in the dark," there was a game with the same name. He then alternatively chose "line" and called ShadowLine that meant "trace on lines in the dark." However, he wanted to leave subtle nuance of "run," decided to use "R," and finally named ShadowRine.). The game was developed with the aim of creating an action RPG that can be enjoyed by both visually impaired and sighted persons alike, for their satisfaction as well as to enable them to share conversations relating to the game. The game was designed in such a way that all information relating to the details of the screen can be obtained using sounds and tactile information (Figure 1). Sighted persons perform operations while visually verifying information displayed on the screen, much as in conventional action RPGs. Visually impaired persons, on the other hand, perform operations by relying on auditory information and tactile sensory information. A game that clearly secures accessibility of auditory and tactile sensory indicators while offering finely detailed visual scenes had not previously existed. The game operates on Windows and has been packaged to perform multimedia processes using Direct X. Text information provided by the game can be read out using a screen reader; the game also supports screen readers that are capable of automatically reading out clipboard contents, as well as such representative screen readers as NVDA or SAPI. The use of a tactile sense display makes it possible for a player to determine the status of the screen tactilely, in real time.

Game flow

The basic operation of the game involves the vertical and horizontal movement of a character, who represents the user, in a two-dimensional field, much like conventional action RPGs. Sites where progress is possible and those where it is not possible, as well as enemy characters that attempt to prevent the character's progress using a variety of meth- ods, are positioned on the field. Users proceed with the game by either avoiding such enemies or defeating them with weapons. New characters that have different functions or characteristics become operable as the game progresses. Such characters contribute to the expansion of the field in which adventures can unfold, as they are capable of performing such activities as jumping over valleys or swimming across rivers and lakes. The game contents include conversations between characters and the users can proceed with the game along the flow of the story.

Users may select from three levels of difficulty, ranging from beginner to advanced, so that all players can enjoy the game. As shown in Figure 4, a tutorial mode intended for beginners, which shows operations while explaining how to play the game, was also made available. The advanced level featured sub-events (elements that have no relevance to the main thread of the game, which can be pursued by a player) that involve discovering treasure chests hidden in various locations to accomplish achievements requested by a non-player character, as well as special elements that are added on depending on the player's performance in clearing game stages. The time required to clear all game stages is about ten hours. The situations of each view and the meanings of the Japanese texts in each view are as follows. a) Single road: Pass this field, and aim at the north. b) Branch road: This area has a branch. You should not get lost! c) A road that a player need to dash: Don't stop using the "dash" action to go to the opposite shore. d) A field with monsters and items: When you destroy objects or defeat enemies, items sometimes appear.

Fig. 4. Four Example Views of the Tutorial Mode.

Auditory and tactile information indicators

Information on the screen is indicated using a diverse range of sound and other effects, which are fed by connecting stereo speakers and headphones to the computer. Gaining understanding of the positional relationship between enemy characters, treasure chests, and the player's characters was made possible using the interaural difference of the acoustic volume between left and right to indicate range in the horizontal direction, as well as differences of sound pressure level to indicate range in the vertical direction. Furthermore, dedicated sound effects were incorporated to prompt the user about locations of objects, as well as a surround sound viewer function that conveys bending angles using the sound of the wind.

Connecting a tactile display to the computer makes it possible to perform operations while touching the game screen (tactile observation playing), as shown in Fig. 5. All screen information provided in the game —the positional relationships of playable characters and enemy characters, field locations where movement is possible and where it is not— are also provided by binary means that varies depending on whether the location is up or down in relation to the pin. Such information is indicated in real time, enabling the player to easily and immediately discern the status of the field. Using the dot matrix display, a player with blindness can selectively understand the positions of a) all the objects including monsters, items, the player's character, and the current field, b) only the player's character, c) only the monsters, and d) only the items. As shown in views b), c), and d), the dot matrix display always shows positioning indicators at the left edge.

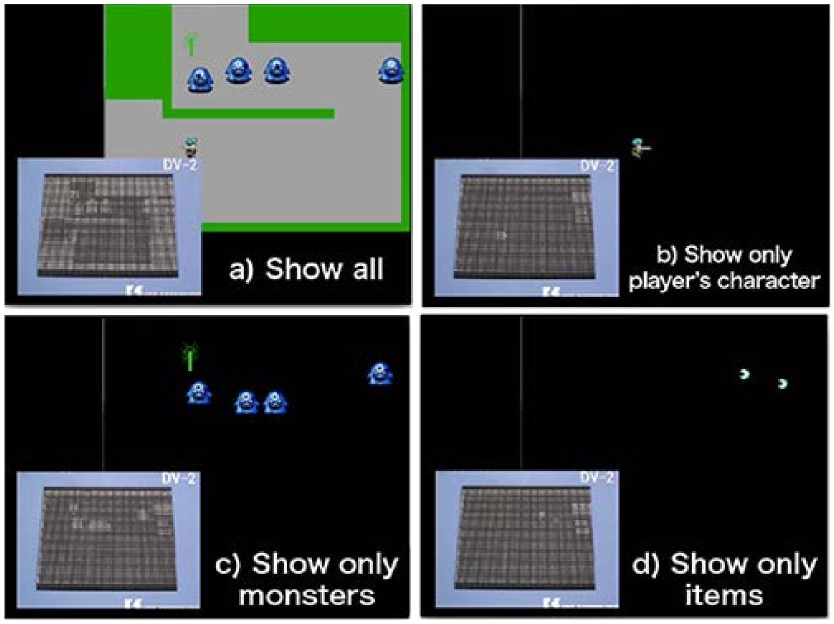

Fig. 5. Game Views and Corresponding Presentations on a Dot Matrix Display.

Number of Downloads and Reactions from Players

ShadowRine was freely distributed on a website beginning on February 9, 2014 (ShadowRine). The game became a focus of attention as an action RPG that visually impaired persons can enjoy playing and has been downloaded 2,508 times as of November, 2015. An anonymous survey addressing users that had played the game was conducted at the game's distribution site from June 11, 2014. The survey question items consisted of two formats: those that requested an overall evaluation on the fun and user-friendliness of playing the game rated on a five-point scale and those that requested free descriptions of the positive and negative aspects of the game. This resulted in responses received from 99 individuals, with 63 of those responding rating the game with a score of 5 (Extremely fun to play), and the average and median of the score were 4.6 and 5.0, respectively.

The free-form comments indicated that experienced game players that are visually impaired generally offered highly positive evaluations, indicating such positive aspects of the game as the broad range of fields, the long stories, the crossroads set up in the story, difficult dungeons, and the presence of deviating paths that include elements like item collection. Beginning game players that are visually impaired, on the other hand, offered opinions suggesting that the field being too broad causes the player to lose track of their present location, the unclear meaning of system sounds, or the difficulty in achieving such action movements as jumping over a valley. Issues derived in this manner were addressed by improving the field viewer through version upgrades, extending the tutorial mode, and adding a sound effect when a character jumps.

Although the survey was made available in Japanese only, there were still 38 responses provided by visually impaired persons from outside Japan. (This is based on tabulation that identified countries of origin for accessing the survey to be outside Japan.) Their comments included requests for future games, as well as a desire for an English translation of the game. Information relating to the game was also featured by AudioGames.net (Shadow line Full voice, AudoiGames.net), which made it evident that the game was also enjoyed by visually impaired persons in English-speaking regions. An opinion that expressed the pleasure of having disabled and able-bodied persons play a game together was also posted on the user exchange bulletin provided on the game distribution site.

Version upgrades of game

The game had been played by many people, as it was made available on the website and offered at exhibits. Improvements are still being made based on user feedback. The current version of the software, as of May, 2016 is 3.12; there have been 30 version upgrades so far. A summary of details of the version upgrades, in particular relating to the game system improvements made based on requests from users, is provided in this section.

This paper describes details of the Fullvoice Edition, which is the current version of the game software. The former version, released on September 29, 2012, had also undergone seven version upgrades. Two issues relating to playing the game by relying primarily on tactile observations were cited as for the development of the initial version of the Fullvoice Edition. These two aspects consist of the one regarding the fact that all displayed objects tend to become connected on the screen and become individually indistinguishable in fields where there is a concentration of locations through which movements are not possible, such as walls, as well as enemy and operated characters, which cannot be readily memorized by beginners of the game, causing them to lose track of their current position. These problems arose due to the fact that the game system did not support a blinking pin indicator or due to the low resolution of the dot diagram display. Improvements were made on these issues by incorporating a navigation function that is capable of individually indicating operated characters and enemy characters.

Issues relating to sound play were also mentioned. Opinions posted on the user exchange bulletin board included those that suggested that structures, such as positions of walls within fields, were difficult to understand. A field viewer was incorporated in the game to address this issue. This function is an application of the program used to prepare fields during the development of the game by a totally blind person. It notifies the user the positions of the walls and objects inside fields by indicating cursor position using sound. The opinion that suggested that the jumping operation for leaping across valleys was difficult to perform was addressed by extending the contents of the tutorial, combined with the improvement made by adding a sound effect that is emitted while the character is jumping to warn the player of the danger zone. The opinion that pointed out that it was difficult to keep track of what each sound effect meant because a lot of sound effects were played back from the initial stages of the game was addressed by adding a function for trial listening of sound effects while running the tutorial.

When this game was available only in Japanese, overseas users have indicated their desire to see this game translated into English. Currently, an English language translation of the game text had completed and English version of the game has just released on October 2016 (ShadowRine Official site; Matsuo et al. 2826-2827). Other than those described above, efforts are being made through the extension of the game by incorporating more sub-events and adding more elements, as well as implementing bug fixes.

Conclusions

One of the authors with total blindness developed an action RPG that can be played independently by either visually impaired or sighted persons, based on his experience as a player of games for visually impaired persons. This RPG can present various game information acoustically and tactually as well as visually. The game was released on the web and is being played by users around the world. This game has undergone several upgrades to implement improvements based on user feedback that modify the game to be more enjoyable and easier to play.

In the future, we intend to utilize the method for discerning game status through auditory and tactile senses that was achieved in the development of this game to develop action games with even faster indicator times that can promote collaborative playing between visually impaired and sighted persons. A field preparation tool for visually impaired persons to develop games on their own was developed and more improvements will be implemented to the map editor in the future, to make it possible for visually impaired persons to draw maps more efficiently. Verifications will be performed to ensure that visually impaired persons can use the map editor to prepare maps and gain an understanding on maps representing actually existing topographies as well as routes plotted to the intended destinations. Such efforts are expected to make it possible for visually impaired persons to gain understanding on information regarding two-dimensional planes such as maps relying solely on sounds. This should enable visually impaired persons to draw a variety of maps on their own.

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Works Cited

Archambault, D., Olivier, D.: How to Make Games for Visually Impaired Children. In: Proc. ACM ACE ’05, (2005) 450-453.

AudioGames.net, http://www.audiogames.net/ (last checked: 2016/09/06)

Dobosz, K., Ptak, J.: How to Control a Mobile Game: A Comparison of Various Approaches for Visually Impaired People. In: Lecture Notes in Computer Science, 9758, (2016) 523-529.

Hafter, E. R., Dye, R. H., Nuetzel, J. M., Aronow, H.: Difference thresholds for interaural intensity. In: J. Acoust. Soc. Am., 61, (1977) 829-834.

HSPTV!, http://hsp.tv/ (last checked: 2016/09/06)

Matsuo, M., Sakajiri, M., Miura, T., Onishi, J., Ono, T.: Accessible action RPG for visually impaired gamers: Development of a game software and a development environment for the visually impaired. In: Trans. Virtual Reality Soc. Jpn., 21, 2, (2016) 303-312 (in Japanese).

Matsuo, M., Miura, T., Sakajiri, M., Onishi, J., Ono, T.: Audible Mapper & ShadowRine: Development of Map Editor Using only Sound in Accessible Game for Blind Users, and Accessible Action RPG for Visually Impaired Gamers. In: Lecture Notes in Computer Science, 9758, (2016) 537-544.

Matsuo, M., Miura, T., Onishi, J., Sakajiri, M., Ono, T., “ShadowRine: Accessible Game for Blind Users, and Accessible Action RPG for Visually Impaired Gamers,” In: Proc. IEEE SMC 2016, (2016) 2826-2827.

Miesenberger, K., Ossmann, R., Archambault, D., Searle, G., Holzinger, A.: More Than Just a Game: Accessibility in Computer Games. In: Lecture Notes in Computer Science, 5298, (2008) 247–260.

Miller, G.: Sensitivity to changes in the intensity of white noise and its relation to masking and loudness. In: J. Acoust. Soc. Am., 19, (1947) 609-619.

Otonove, http://www.mm-galabo.com/soft/otonove/onvinfo.php (last checked: 2016/09/06)

Porter, J. R., Kientz, J. A.: An Empirical Study of Issues and Barriers to Mainstream Video Game Accessibility. In: Proc. ACM ASSETS '13, (2013) 3:1-3:8.

Shadow line Full voice, AudioGames.net, http://audiogames.net/db.php?action=view&id=Shadow%20line%20Full%20voice (last checked: 2016/06/23)

Shadow Rine, http://www.mm-galabo.com/sr/ (last checked: 2016/06/23)

ShadowRine Official site, http://www.mm-galabo.com/sr/index_en.php (last checked: 2016/12/01)

Wenzel, E. M., Arruda, M., Kistler, D. J., Wightman, F. L.: Localization using nonindividualized head-related transfer functions. In: J. Acoust. Soc. Am., 94(1), (1993) 111-123.

Yost, W. A., Dye, R. H.: Discrimination of interaural differences of level as a function of frequency. In: J. Acoust. Soc. Am., 83, (1988) 1846-1851.

Yuan, B., Folmer, E., Harris Jr., F. C.: Game accessibility: a survey. In: Universal Access in Information Society, 10, (2011) 81–100.

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Indoor Map Learning for the Visually Impaired

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Abstract

Trip planning is useful for every traveler, especially for visually impaired people because they can learn maps and routes prior to their upcoming journey. Research on trip planning for the visually impaired has been more attention in the past decade. However, past methods have some limitations: (a) the methods usually made use of special visualization interfaces that are costly; (b) the methods mainly focused on outdoor navigation due to existing online map and GIS databases. Although this approach could be extended to indoor navigation, it would need substantial additional effort to generate indoor maps. Therefore, the above limitations make trip planning unfeasible to most of visually impaired people. In this paper, we propose a novel trip planning framework by applying gamification concept, which particularly deals with indoor scenarios. First indoor accessible maps are automatically generated, and then, a mobile app will be designed and implemented for the visually impaired. This will allow users to learn building layouts and routes prior to their travel. The proposed trip planning method can be easily adapted to other indoor scenes, and it will encourage the visually impaired users to travel easily and independently.

Keywords

Assistive Technology, Accessible Map, Trip Planning, Visually Impaired, Gamification, Map Learning, Cognitive Map

Introduction

Traveling in unknown environments presents significant challenges for visually impaired people (VIP). Though a lot of efforts have been made to develop navigation systems and algorithms for VIP, many of them need additional infrastructures (Ganz et al. 33-44, Dias 1-20, Paisios 2012, Ahmetovic et al. 1). Hence, they are not easy to scale up. Methods using computer vision with mobile devices (Manduchi 9-12, Hu et al. 600-614) do not need infrastructure changes, but they are error-prone, especially in indoor environments. Therefore, they are unreliable for VIP to use for localization. As an alternative or supplementary solution, a trip planning approach allows VIP to learn spatial environments and plan route priors to their upcoming journey.

Research on trip planning for the visually impaired has been more attention in the past decade (Zeng and Weber. 54-60, 466–473 Kumar 1, Ivanchev 81-88, Meneghetti 165-178 and Poppinga 545-550). However, past methods have some limitations: (a) the methods usually made use of special visualization interfaces that are costly; (b) the methods mainly focused on outdoor navigation due to existing online map and GIS databases. Although this approach could be extended to indoor navigation, it would need substantial additional effort to generate indoor maps. Therefore, the above limitations make trip planning unfeasible to most of VIP.

In this paper, we propose a novel trip planning framework, particularly dealing with indoor scenes. Figure 1 shows the system work flow. First an indoor accessible map is automatically generated using AutoCAD architectural floor plan, and then a mobile app is designed and implemented for the visually impaired to learn maps and plan trip prior to their travels. VIP user can play the app, and learning progress can be evaluated and reported automatically. The app allows a VIP to play as many times as need to feel familiar with the building layout and build a cognitive map. The proposed trip planning method is easy to be applied to other indoor scenes and encourages the visually impaired to travel independently.

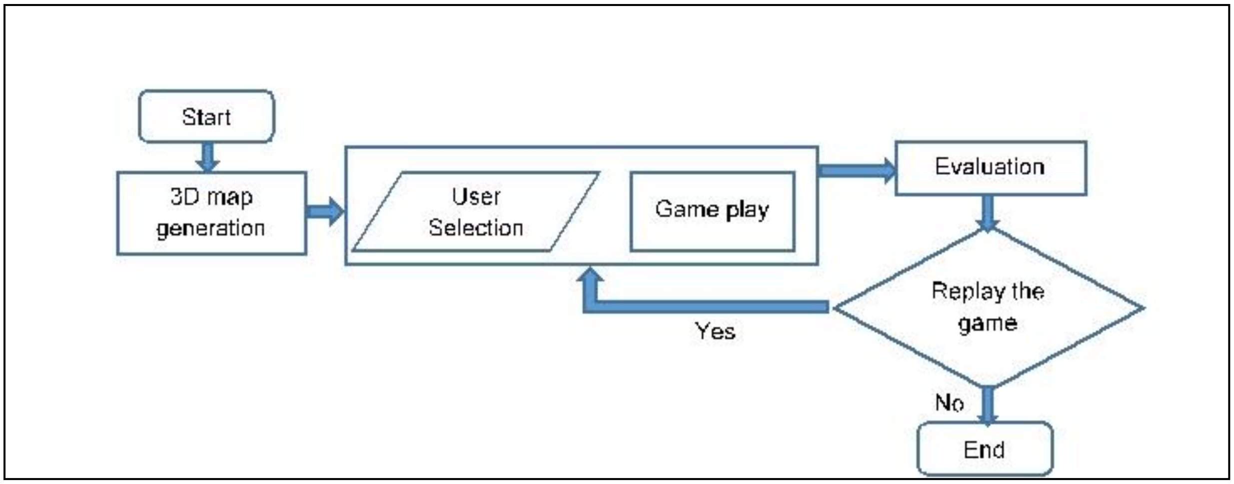

Fig. 1. Flow Chart of the Mobile App

Discussion

Related Work

Many efforts have been made to develop navigation algorithms and systems for VIP, however, most of them are GPS-based accessible navigation systems that aim at outdoor scenes, Example of such accessible systems are Ariadne GPS (Ariadne), BlindSquare (BlindSquare) and Sendero Seeing Eye GPS (Sendero). However, none of the aforementioned systems works in indoors due to the lack reliable and available GPS signals. However, research shows that on average people spend around 87% of their time in indoor environments (Klepeis et al. 231–252), and indoor spatial knowledge acquisition could play a very important role to improve the quality of daily life of VIP. In the last decade, researchers have been working on Wi-Fi or Bluetooth-based localization and navigation approaches, and a few public facilities have tested such approaches (e.g. SFO airport and The American Museum of Natural History). Most of the approaches, however, usually provide rough localization of users and cannot navigate them to their destinations. Ahmetovic (Ahmetovic et al. 1) proposed a method which navigates the visually impaired in a campus building, but it requires large-scale infrastructure changes and tedious sensor installations and calibrations procedures, thus making such kinds of requirements very costly and not easy to scale up.

VIP typically plan their routes prior to their journey, especially when they have to travel to an unfamiliar environment. As a result of the lack of reliable and accurate indoor navigation systems, any advances in safe and easy indoor trip planning could have significant impact on the quality of life for VIP. Many approaches (ClickAndGo and Das 1-20, Sánchez et al. 365-371 and Sanchez et al. 970-981, Ganz et al. 33-44) offering trip planning features provide narrative maps, which are verbal or text-based descriptions of the navigation instructions between two locations. However, trip planning feature only offers a step-by-step guidance between two pre-defined locations, and does not help the visually impaired to build a complete cognitive map. They will not work if temporary changes of building layout (renovation) or a special event cause a detour. Cognitive maps are part of our daily lives, as they are the basis for all spatial behavior (Downs and Stea 8–26). They contain knowledge about landmarks, route connections, distance and directions (Montello 14771–14775). Without the cognitive map, it's very difficult for VIP to travel independently, especially when they get lost from the route they planned in advance or need a detour. This need for a layout learning was emphasized in interviews we conducted with VIP. Therefore, building a cognitive map is important to enhance the safety and independence of VIP navigating unfamiliar indoor environments.

Although building a cognitive map for the visually impaired is important, it's not easy. (Brock 1-361) gave an excellent review of building spatial cognition for VIP. Some approaches build interactive maps (Zeng and Weber 54-60, 466–473, Kaklanis et al. 59-67, Brock et al. 117-129), and VIP can explore these maps to build up their cognitive maps. This requires special visualization interfaces and costly devices are usually needed. In addition, most of the systems focus on outdoor maps and are not easy to translate to indoor maps due to the lack of accessible maps for indoor environments.

In this paper, we proposed a map-learning approach that allows the visually impaired to learn indoor maps, by playing a simple mobile game. The game guides the users navigate between two locations in an indoor environment. Unlike other existing trip planning methods, our system not only provides VIP a narrative map that users can virtually travel in the unknown facility with turn-by-turn navigation guidance, but it also allows the users to build up their cognitive maps (including landmarks, route connections and distance and directions).

System Design and Implementation

The paper seeks to provide an easy map-learning framework through gamification concept (Werbach 1). The approach consists of three major modules, 3D map generation, a trip planning game and assessment. When the game starts, a VIP user is prompted to choose a facility and his/her starting and ending positions in the facility. He/she then follows step by step guidance in the game play section until reach the destination. The user is then evaluated in each round, and he/she can replay the game until becomes confident enough to start the actual journey (Figure 1).

3D Map Generation

In this module, an architecture floor plan map, which is available in most building built within the last three decades, is used to construct a 3D map. Algorithms developed in our previous work (Tang et al. 176-191) automatically process an architecture map and produce a 3D accessible map, in which rooms, corridors, landmarks, doors, exits, elevators and stairs are labelled (Figure 2a). This map is then transcoded into the game with all the physics and collision features. The virtual avatar through these features can localize itself in the game. The maps that have more than one floor are connected through stairs, escalators and elevators.

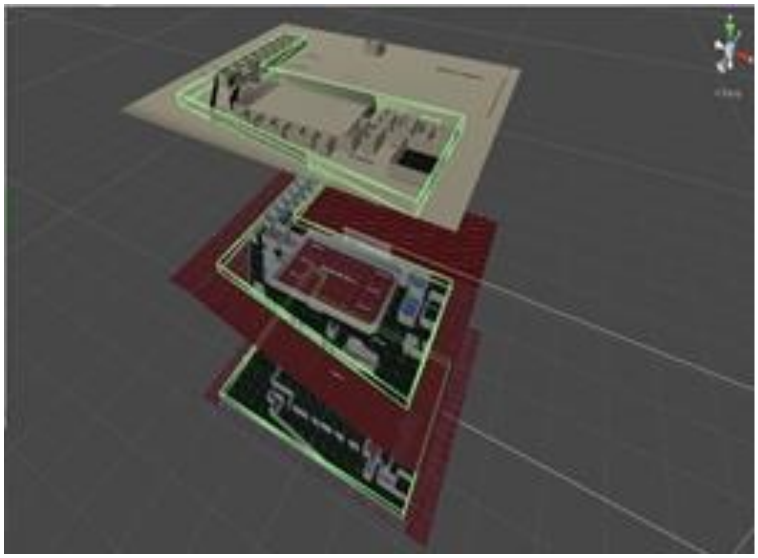

Fig. 2a. The Generated 3D Accessible Map of a Facility with Three Floors.

Fig. 2b. An optimal path in blue is calculated using a pathfinding algorithm. The path is connected by a few waypoints (best viewed in the electrical version).

Map Learning and Trip Planning

Fig. 3. Interface of Our Mobile App: (a) three campus buildings are listed in the map selection; (b) Room numbers of one building are listed; (c) a configuration and setting page; (d) the third person perspective is displayed

The game is designed for VIP to learn indoor maps and plan trips. In this module, we import the 3D accessible map generated in the previous module to create 3D game environment. The 3D map is geo-referenced and all the rooms, including exits, staircases and other landmarks in the map have known 3D locations. The current game design focuses on training, which allows users to plan their journey, for example, the user plans to transfer from E train station to R train station at 34 street, or from the entrance of a campus building to the room 8/210. The optimal route is generated using a pathfinding algorithm (ref). The user then starts his/her virtual journey, with location-specific guidance provided by the game, based on the optimal route. The user applies various finger gestures (up, down, left and right) on the mobile device to move the avatar in the virtual environment. The game can also correct user whenever he/she does not exactly follow the guidance and is off from the optimal route.

User Interface of the App

General User Interface

The app user interface (UI) is able to work with the accessibility feature of the Android (TalkBack). The UI also display images in high contrast for those VIP users with some sight while have contrast sensitivity losses. Figure 3 shows some UI design, including a map selection page, a room selection page and a configuration and setting page. In the map selection page, all facilities available in the app are listed, and currently there are three campus buildings available. Once a facility is selected, the app proceeds to the room selection page, which allows users to select a specific room, users need to select a starting room and destination room before the training game actually launches.

Configuration and Setting Page

VIP often perceives information based on measurement they can easily interpret, hence we prepared a configuration and setting page. This page will allow them to choose what type of distance and movement representation they preferred, including feet, meters or steps. The amount of audio feedback is also controllable, since in interviews some VIP wanted more information while others wanted less.

The game-play mode has an audible music background that is turned on by default. The music was included to signify that the game play is still active, but it proved to be distracting to some VIP users, and a function to disable it was provided in the game.

a) Menu color option: The display module shown above is the default look of the application. The color selection is white text on black background because of the stated contrast preference of our group of initial VIP users. The color can also be inverted for users with different contrast polarity preferences. The color choice selection can be made in this module depending on the preference of the user.
b) Distance option: Observations from preferences discovered during experiments led to the design a distance module. We observed that users preferred the distance information feedback in a certain unit. To address this issue, we created a way to change the distance settings under the settings UI module. Feedback on distance is provided in terms of meters, feet or steps.
c) Level of feedback option: This option allows users to choose the level of details provided by audio feedback in the training.

Game-Play Mode

There was a small change of view for one of our gameplay features; camera view to be exact. Switch from a bird's eye camera view to a third person perspective seemed to be more intuitive when giving instructions to the user. Previously implemented instructions gave the user directions from the perspective of the camera view (top down view), such as "Go Down" and "Go Up", which were not very user friendly. The third person camera view had a more egocentric perspective for more intuitive directional instructions like "Go forward", "Turn left", etc. Partially sighted VIP users benefit from this change of perspective (Figure 3d).

Implementation

The mobile app is implemented by integrating Unity 3D game development engine and Android Studio. The user Interface is implemented in Android Studio because of its provision of accessibility features. The game development is implemented in Unity 3D game development engine and therefore, requires an integration of both platforms. The rationale behind this is because of the TalkBack accessibility feature is not available on Unity 3D. Once the game part is completed, we export the project from the Unity platform and import it to Android Studio and complete the user interface design.

Assessment

The map learning is a self-learning process, so it is very important to include a self-assessment module. The game collects the statistics of game playing, including the time spent, the number of wrong turns and collisions that the user made during trip planning between two locations. The performance statistics allow the users to know how well they learned the map, and their learning progress. They can play many times to enhance their learning. They can select different sources and destinations, in order to construct a complete cognitive map of a facility.

In order to evaluate the effectiveness of the trip planning app, we conducted preliminary evaluations. The first prototype was tested with five blind users, who were all smartphone users. Two were totally blind, and three had low-vision. We asked them to complete a pre-test survey and a post-test survey.

In the pre-test survey, we ask general questions about their experiences using mobile app and independent travels, such as: Do you navigate alone indoors? Do you have trouble navigating alone? Do you use any app to get around/navigate or map learning? If so, how do you like the app? What places/facilities do you think should have an indoor accessible map made first? The survey results reveal they all have trouble navigating indoors. One participant used Google map before, but none of them used any indoor navigation app or map learning software. Their suggestions included making accessible maps for colleges, hospitals, government buildings, and public transportations.

Fig. 4. The interface of mobile app in previous version, (a) A floor selection interface with floor plans listed in a facility; (b) A room selection interface where user can move up and down to select rooms as starting or ending positions of the trip; (c) The game play interface.

In the post-test survey, we ask more specific questions about the experience of using our mobile app, including the interface design, the app features that they like or dislike, and any new features they suggest. Here are some of the feedback: (1) They preferred the portrait mode on the mobile device and a conventional app interface with accessible feature. Figure 4 shows the interface design of the previous version that we showed to the users, which is a in landscape mode, with some special design of map and room selection; (2) Some suggested a summary of the route before the game starts; some preferred more details – such as information of surrounding landmarks (rooms, exits, elevators, restrooms, water fountains, etc.); (3) Most of the users liked the idea of learning map from game play and want to see it further developed.

We then modified the app design and implementation based on their feedbacks. We changed the display mode to portrait, and change the interface to a conventional interface with Talkback features, and added a summary before the training starts. In addition, we also added a configuration and setting mode (Figure 3.c) which allowed users to select their preferred setting, please refer to the section C for more detailed descriptions (User Interface of the App).

Conclusion

In this paper, we designed and implemented a mobile app for VIP to learn indoor map layout by planning trips. Trip planning will help them venture out into unfamiliar indoor environments easily. The app allows VIP users to practice trip planning as many times as need to feel familiar with the facility layout – building up a cognitive map. Such a learning process may be tedious, hence we apply the gamification concept in the app design to make the map learning easy and engaging. In the future, we will improve the user interface and enhance the game play experience to make the learning easier and more engaging. Our ultimate goal is to allow VIP users to easily plan and independent take trips, ultimately improving their quality of life.

Works Cited

Ahmetovic D., Gleason C., Ruan C., Takagi H., Asakawa C. NavCog*: A Navigational Cognitive Assistant for the Blind. International Conference on Human Computer Interaction with Mobile Devices (MobileHCI)* 2016.

Ariadne GPS, http://www.ariadnegps.eu/ (last visited Nov 30, 2016)

BlindSquare, http://blindsquare.com/ (last visited Nov 30, 2016)

Brock A., Interactive Maps for Visually Impaired People: Design, Usability and Spatial Cognition, *PhD thesis*, 2014, 1-361

Brock, A., Oriola, B., Truillet, P., Jouffrais, C., & Picard, D. (2013). Map design for visually impaired people: past, present, and future research. *MEI*, 36, 117-129.

ClickAndGo Wayfinding, http://www.clickandgomaps.com/ (last visited Nov 30, 2016)

Dias B. NavPal: Technology Solutions for Enhancing Urban Navigation for Blind Travelers, *CMU technical report*, 1-20.

Downs, R. M., & Stea, D. (1973). Cognitive maps and spatial behavior: Process and products. In R. M. Downs & D. Stea (Eds.), *Image and Environment* (pp. 8–26). Aldine Publishing Company.

Ganz A., Schafer J., Tao Y. PERCEPT Based Interactive Wayfinding for Visually Impaired Users in Subways, *Journal on Technology and Persons with Disabilities*, v3. 33-44, 2015

Hart, P. E.; Nilsson, N. J.; Raphael, B. (1968). A Formal Basis for the Heuristic Determination of Minimum Cost Paths. *IEEE Transactions on Systems Science and Cybernetics SSC4 4* (2): 100–107. doi:10.1109/TSSC.1968.300136.

Hu, F., Zhu, Z., and Zhang, J. "Mobile panoramic vision for assisting the blind via indexing and localization." *In Computer Vision-ECCV 2014 Workshops* (2014): 600-614. Print.

Ivanchev, Mihail, Francis Zinke, and Ulrike Lucke. "Pre-journey Visualization of Travel Routes for the Blind on Refreshable Interactive Tactile Displays." *Computers Helping People with Special Needs. Springer International Publishing*, (2014): 81-88. Print.

Kaklanis, N., Votis, K., & Tzovaras, D. (2013). Open Touch/Sound Maps: A system to convey street data through haptic and auditory feedback. *Computers & Geosciences*, 57, 59–67.

Klepeis N., Nelson W., Ott W., Robinson J., Tsang A., Switzer P., Behar J., Hern S. and Engelmann H.. The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants, *Journal of Exposure Analysis and Environmental Epidemiology* (2001) 11, 231–252.

Kumar Raja, M. The development and validation of a new smartphone based non-visual spatial interface for learning indoor layouts, *Master Thesis*, 2011

Manduchi, R. "Mobile vision as assistive technology for the blind: An experimental study." *The 13th Int. Conf. on Computers Helping People of Special Needs* (ICCHP 2012) (2012): 9-16. Print.

Meneghetti, C., Borella, E., Grasso, I., De Beni, R. Learning a route using a map and/or description in young and older adults. *Journal of Cognitive Psychology* 24(2), 165–178 (2012)

Montello, D. R. (2001). Spatial Cognition. In N. J. Smelser & P. B. Baltes (Eds.), *International Encyclopedia of the Social and Behavioral Sciences* (pp. 14771–14775). Oxford, UK: Pergamon Press.

Paisios, N. "Mobile Accessibility Tools for the Visually Impaired". *PhD thesis*, New York University, 2012. Print.

Poppinga, B., Magnusson, C and Pielot, M. TouchOver map: audio-tactile exploration of interactive maps. *MobileHCI '11 Proceedings of the 13th International Conference on Human Computer Interaction with Mobile Devices and Services*, 545-550

Sánchez J, and Claudio O. "Mobile audio assistance in bus transportation for the blind." *International Journal on Disability and Human Development* 10.4 (2011): 365-371.

Sánchez J, and Mauricio S. "Metro navigation for the blind." *Computers & Education* 55.3 (2010): 970-981. Lighthouse International, [Online].

Seeing Eye GPS, https://www.senderogroup.com/ (last visited Nov 30, 2016)

Tang, H., Tsering N., Feng H., Zhu Z. Automatic Pre-Journey Indoor Map Generation Using AutoCAD Floor Plan, *Journal on Technology & Persons with Disabilities*, v4. 176-191, Nov. 2016

Werbach K. For the Win: How Game Thinking Can Revolutionize Your Business, *Wharton Digital Press*. ISBN-10: 1613630239, 2012

Zeng, L., & Weber, G. (2010). Audio-Haptic Browser for a Geographical Information System. In K. Miesenberger, J. Klaus, W. Zagler, & A. Karshmer (Eds.), *ICCHP* 2010. LNCS, vol. 6180 (Vol. 6180/2010, pp. 466–473). Heidelberg: Springer.

Zeng, L.; Weber, G. (2011): Accessible Maps for the Visually Impaired, *Proc. ADDW 2011*, CEUR Vol. -792, S.54-60

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Virtual Mapping Party: Co-Creation of Maps for Visually Impaired People

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Abstract

In this paper, we present a new approach for collecting accessible information for visually impaired people. In the past, accessible maps for people with disabilities have been created by holding events called "mapping parties." During these mapping parties, participants are gathered at target sites to collect information and create maps while physically walking around the site. Due to the labor-intensive nature of this approach, mapping parties alone are not a practical means of creating enough maps to fulfill demand. To increase the efficiency of creating maps, we propose the "virtual mapping party," which enables the participants to contribute to the mapping party from anywhere and at any time. This method uses virtually reconstructed target sites instead of requiring participants to physically visit the sites. Omnidirectional movies and multichannel sound are recorded at the target site and are then used in the virtual reconstruction. Virtual mapping parties have advantages regarding costs, and inclusiveness by allowing visually impaired people to contribute to the mapping activity.

Keywords

Virtual mapping party, assisting technology for visually impaired people, omnidirectional images, head-mounted display

Introduction

Virtual Mapping Party

We have been developing technologies for assisting visually impaired people to walk to their destination by themselves. Previously, we developed a walking navigation system for the visually impaired by combining various localization methods, including pedestrian dead reckoning (PDR) and global navigation satellite system (GNSS) (Okuno et al.). Within the contents of the navigation, the system provides both POI (Point of Interest) and POR (Point of Reference) information. POI is defined as the name of a landmark in a map. POR is defined as a specific point location, the existence of which is easily recognized for confirming routes, such as steps, stairs, sloops, doors, sound/noise, and scent/odor.

In this paper, we present a new approach for collecting POR/POI information for visually impaired people. In the past, accessible maps for people with disabilities have been created by holding events called "mapping parties." During a mapping party, participants are gathered at target sites where they collect information and create maps while physically walking around the site. OpenStreetMap (OSM) is a project for making maps available to everyone around the world. Mapping parties have been held to create maps for OSM.

Due to the labor-intensive nature of this approach, mapping parties alone are not a practical means of creating enough maps to fulfill demand. To increase the efficiency of creating maps, we propose the "virtual mapping party," which enables the participants to contribute to the mapping party from anywhere at any time. This method uses virtually reconstructed target sites instead of requiring participants to physically visit the sites, as shown in Fig. 1. Therefore, at least one contributor must go to the actual site to record the site environment. Other contributors, through the internet, can experience the target sites in the virtual environment and search for

POR/POIs. We design the virtual mapping party as an inclusive activity by ensuring that visually impaired people can also contribute to the mapping. In order to allow them to contribute, we adopt an interactive tool called "AR (augmented reality) tactile maps" (Ichikari et al.) to confirm dynamic contents on the map using non-visual senses. AR tactile maps enable visually impaired people to not only confirm the contents collected during the virtual mapping party but also to request and verify the contents.

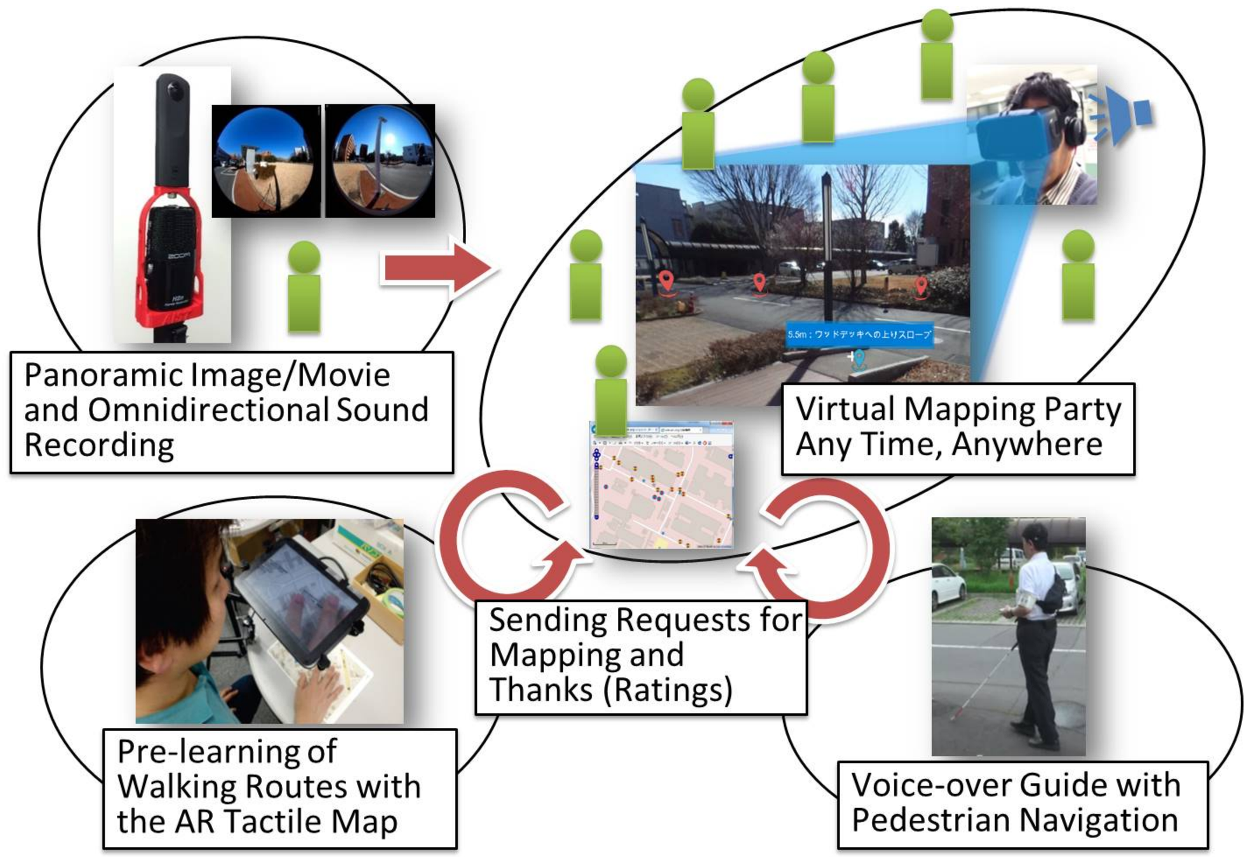

Fig. 1. Overview of Virtual Mapping Party.

In this paper, we introduce the system design of the visual mapping party as an inclusive activity for creating maps for visually impaired people. We implemented a prototype of the system and held a virtual mapping party workshop in order to obtain feedback about the system.

Related Works

There are existing activities designed to improve mobility assistance with the help of volunteer contributors. Miura et al. promoted an activity that collected accessible information with the help of volunteers by implementing smartphone applications (Miura et al.). Voigt et al. held mapping parties by utilizing ICT tools in many cities around Europe (Voigt et al). In one of them, they utilized Mapillary, which is a crowd-sourced service for sharing geo-tagged photos. They used Mapillary for collecting accessible information without going to actual sites. They called this a "Lab-based" approach. The Lab-based approach and our virtual mapping party are quite similar. However, distinctive characteristics of the virtual mapping party are as follows:

- The virtual mapping party focuses on collecting accessible information for visually impaired people.
- The virtual mapping party provides immersive virtual experiences of walking through environments by using pre-recorded omnidirectional movies and 3D sound.
- The virtual mapping party has compatibility for linking up with many applications, such as navigation systems and AR tactile maps (Ichikari et al.).
- The virtual mapping party aims to be an inclusive activity by allowing visually impaired people to join the activity with AR tactile maps.

In addition to the above comparison, we categorized the characteristics of various mapping activities and the differences between the activities, as shown in Table 1. In the next section, the system components used to create the virtual mapping party will be introduced.

Discussions

System Components

Capturing the Walking Environment

We adopt Ricoh's Theta S for capturing omnidirectional movies and Zoom's H2N for recording 4-channel sound. The Theta S and the H2N are vertically attached with a 3D printed mount for recording movies and sounds at the same location with alignment of frontal faces as shown in Fig. 2.

Fig. 2. Device for Capturing Walking Environments.

Table 1. Comparison of Various Mapping Activities.

Type of activities	Location	Time	Remarks
Conventional mapping party	On-site	Sync.	Face to face communication Deep understanding of real conditions Mandatory skill for organizing events Up to weather
Mapping party utilizing smartphones app.	On-site	Any time (Async.)	Mapping while commuting Easy to contribute Deep understanding of real conditions Position of contents depending on localization methods
Mapping party utilizing crowdsourcing image sharing service	Anywhere (Off-site)	Any time (Async.)	Crowdsourcing Remote mapping Easy to contribute anytime and anywhere Depend on shared data Limited understanding of real conditions
Virtual mapping party	Anywhere (Off-site)	Any time (Async.)	Crowdsourcing Remote mapping Easy to contribute anytime and anywhere Easy to measure contents' position Easy to verify registered contents Mandatory pre-recording

The length of captured data at each location should be more than a certain length since we would like to capture time-sequential data such as movies and sound. Therefore, movies and 3D sounds are captured by iteratively stopping and recording for about 30 sec. at 10 to 50 meter intervals. The Theta S can record 360-degree spherical movies at full HD resolution (1920x1080 pixels). We record both omnidirectional movies and 3D sound in synchronization.

Reconstructing the Walking Environments into a VR (virtual reality) Experience

To enable the contributors to join the mapping party without visiting the actual sites, the sites are reconstructed in virtual reality space. We use the Unity 3D game engine for the reconstruction. The recorded omnidirectional movie can be displayed in the VR space using texture mapping on spheres. To walk through the VR space, users can change the location by switching to different omnidirectional movies and 3D sounds. Unity 3D can generate naturally cropped images to fit an appropriate viewing angle for humans, depending on the viewing direction. Because of this, as shown in Fig. 3, the system can offer a 360-degree view of the site at each position.

Fig. 3. Reconstructed walking environment through omnidirectional movies.

One of the most important operations for reconstructing the walking environments is registering correct positions and orientations for each piece of recorded data, since the positional accuracy of the registered POR/POI depends on the positional and rotational accuracy of the arrangement of the omnidirectional images. The Theta S has functionality that provides auto horizon correction for the recorded omnidirectional images using gyroscopes. We can also measure the height of the Theta S camera position. Additionally, an initial estimate of the position can be obtained by a smartphone's GPS if the Theta is controlled by a smartphone remote controlling application. The parameters we need to calibrate are longitude, latitude, and yawing angle for each recorded data point. These positions and angles can be semi-automatically corrected at the same time if correct longitude and latitude information of the same objects in the omnidirectional images are known.

The four recorded channels of 3D sounds can be recreated by arranging four virtual sound sources around the user's location. We adopt Oculus Audio SDK for 3D sound.

As devices for experiencing the VR scene, we adopt various types of HMDs (head-mounted displays), such as Samsung's Gear VR, Oculus Rift DK2, and Google Cardboard-type instant HMDs. Through the HMDs, the contributors of the mapping activities can visually experience the reconstructed walking environment with a wide-range field of view, creating a sense of immersion. In addition, HMDs have head tracking sensors, which enable the users to look around the panoramic view by naturally changing their viewing direction. The Gear VR and the instant HMDs can utilize the user's smartphone to create the VR experience. For an option that does not require HMDs, we build the VR scene on the WebGL platform to reproduce the VR experience using only a web-browser. In this option, users can use a computer keyboard for text input. We also adopt headphones for hearing 3D sound and a Bluetooth game pad for inputting triggers into the system.

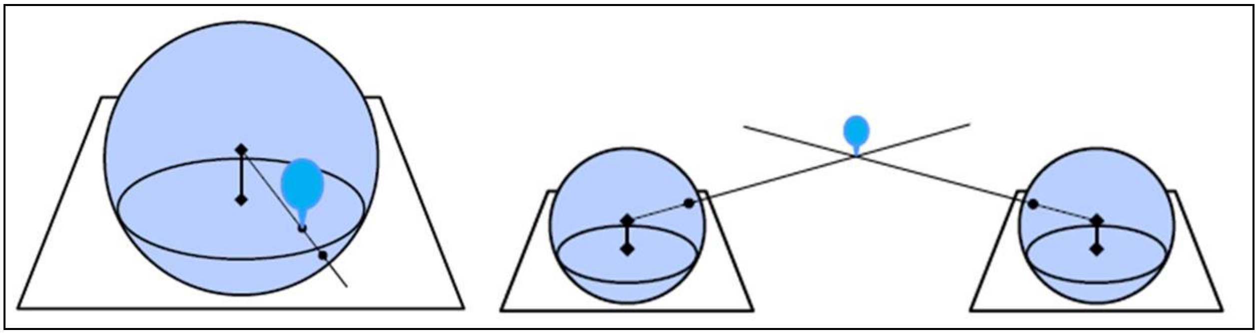

Fig. 4. Pointing Methods for POR/POI

(Left: For pointing to a nearby POR/POI, Right: For pointing to a far POR/POI)

Searching for and Collecting POR/POIs in the VR Space.

If the users find POR/POIs while experiencing the VR space, they can register them into the POR/POI database. The POR/POIs are shared with other contributors and superimposed onto their view as annotations in the VR environment. As a result, the activity of searching for POR/POIs can be split up while avoiding overlaps. It is impossible to know the distance between the viewpoint and the annotations, so the distance is displayed with the annotations.

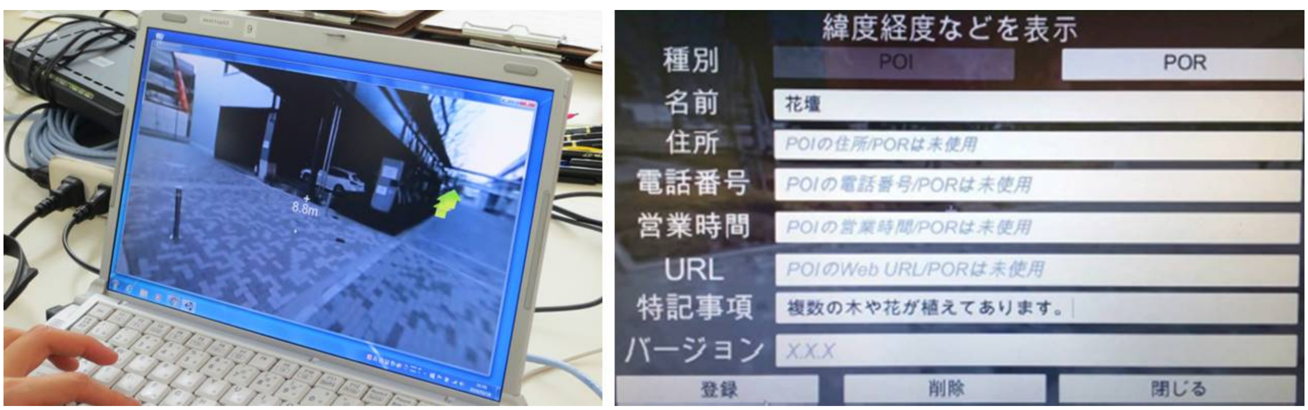

Fig. 5. Interface for Registering POR/POI for Web-GL Users.

The process for registering POR and POI into the database can be separated into pointing at the POR/POI location and registering attribute information. Fig. 4 shows the conceptual illustration of the methodologies for pointing at POR/POIs. First, the pointing vector in 3D is defined by finding the indicated pixel in the omnidirectional images. Then the indicated location in the world coordinates can be calculated by finding the intersection between the vector and a ground plane, if the intersection exists. If POR/POIs are far from the viewpoint, positions can be calculated by finding intersections between the multiple pointing vectors from different locations. Attribute information is inputted by normal text input. For Web-GL version users, text can be entered into GUI text forms by computer keyboard, as shown in Fig. 5. For HMD users, we implemented voice memo functionality since they cannot use keyboards while wearing a HMD. The voice memo can be heard afterward to make an accurate copy. A screenshot of the application for making an accurate copy is shown in Fig. 6.

Fig. 6. Interface for Registering POR/POI for Instant HMD Users.

We constructed a database server for sharing POR/POI information, request logs, and other auxiliary information for the virtual mapping party, such as links to the captured data in the file repository. As a database management system, we adopted PostgreSQL.

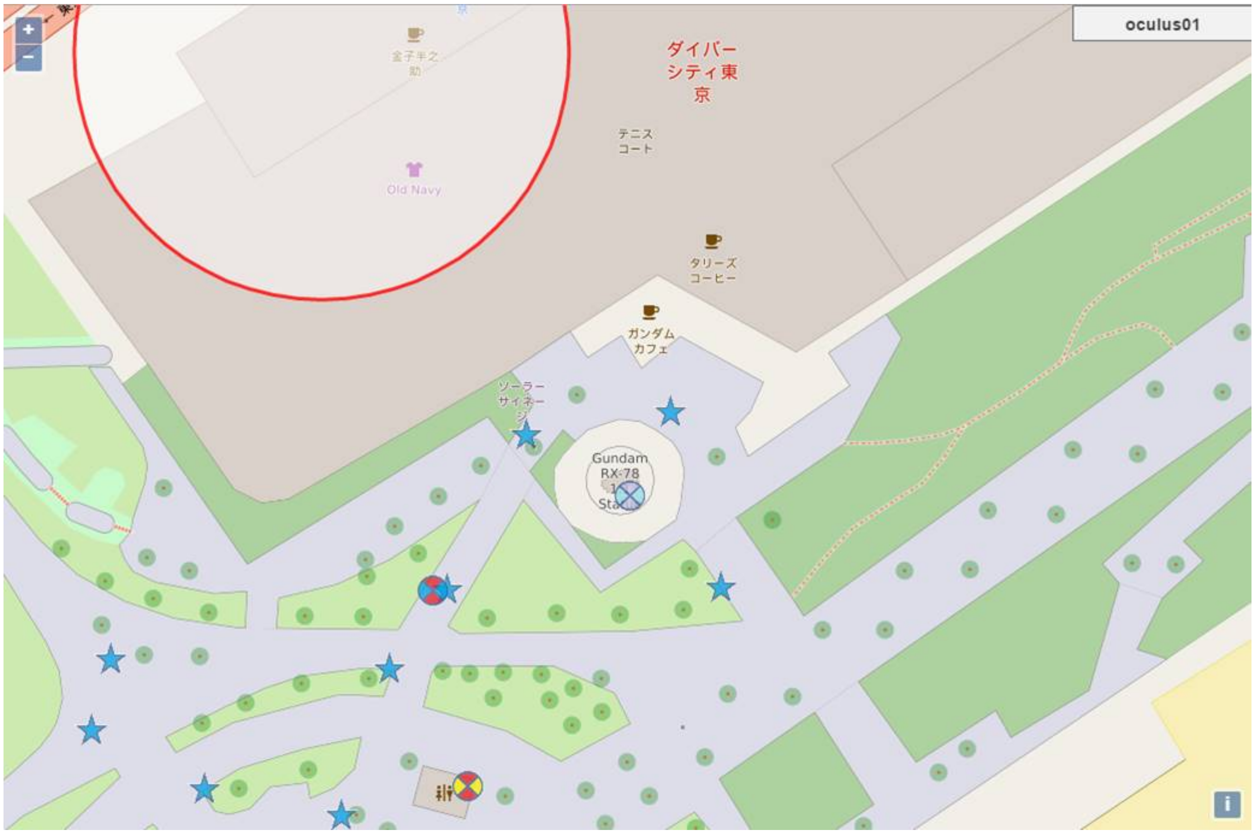

Fig. 7. Confirming POR/POIs with Maps.

Confirming and Checking POR/POIs on the Map Coordinates.

The registered POR/POIs can also be visualized with maps as shown in Figure 7. We implemented a web-based map application with OpenLayers for confirming POR/POIs on the maps. Confirming the position of the registered POR/POI at the map coordinates is a very important process because most of the applications of the collected data are based on the mapping coordinates, such as printing a map (including AR tactile maps) and navigation. The users can input and also edit POR/POI information with this application. This map application can be utilized for visualizing enlarged or enhanced representations of maps for low-vision users. The contents on the map are dynamically updated by reflecting the current data in the database.

Integration with AR Tactile Maps.

To enable visually impaired people to join the virtual mapping party, the system has the ability to utilize AR tactile maps. To integrate AR tactile maps with the virtual mapping party, the AR tactile map is connected to the same database as the virtual mapping party to share POR/POI data. AR tactile maps have functionality for detecting a position where the user touches the map, as well as gesture commands by utilizing RGB-D camera input. Gesture commands can be assigned to specific functions in the applications.

In the application of the virtual mapping party, we assigned gesture commands as follows. The tapping gesture is assigned to the act of confirming the POR/POIs through sound augmentation onto the tactile map and voice over. The detailed contents of POR/POIs can be read out when the user taps. The flat-hand gesture is assigned to the act of searching the existence of the contents around the location where the user touches the map. When the user touches the tactile map, they can find locations of POR/POIs around the touched area by sound feedback. The double tapping gesture can be used to transmit requests asking other contributors to add POR/POI around the specific area.

Workshop on Virtual Mapping Party

We held a workshop for the virtual mapping party in Tokyo, Japan, in March 2016. As the devices for the VR experience, we used HMDs including Oculus Rift DK2, Samsung's Gear VR, and the Google Cardboard-type HMDs. We also asked participants to try the AR tactile map for confirming and requesting POR/POIs. We held six one-hour-long workshops one weekend. The number of total participants was 44, and they collected 454 POR/POIs. The detailed statistics of the registered POR/POIs is shown in Table 2. Because of the limitation of the time for mapping and lack for instructions, we find many registered POR/POIs without attribute information. As shown in the Table 2, 97 percent of POR/POIs registered by Web-GL version users have attribute information. By contrast, only 27 percent of POR/POIs registered by Instant HMD users have attribute information. This table reveals the effectiveness of Web-GL version for inputting attribute information and necessity of the refinement of user interface to register attribute information for HMD users. At the end of the workshop, we asked the participants to answer a questionnaire, which consisted of open-ended questions related to several aspects of the virtual mapping party. Feedback from the participants is summarized in Table 3.

Table 2. Statistics of POR/POIs Registered at the Workshops.

	(a) Number of Total Registered POR/POIs	**(b) Number of Registered POR/POIs with Attribute Information**	**(b)/(a)**
PC(Web-GL)	203	197	0.97
Instant HMD	251	68	0.271
Total	454	265	0.584

Table 3. Feedback from the Participants who Attended the workshop on the virtual mapping party.

Categories of Feedback	Positive Feedback	Negative Feedback/Suggestions
About VR experience with omnidirectional images/movies and 3D sound	• I like the function for 3D sounds. • 3D sounds seem to be very useful, since visually impaired people can confirm amount of traffic on roads. • I could more realistically experience the VR scene by omnidirectional movies than still omnidirectional images.	• Estimating direction of sound sources was difficult. • The quality of the images/movies was not perfect.
About devices for VR experience	• I like instant HMD, since we can experience VR with what I have. • I like VR experience with Oculus VR HMD since I can realistically experience by movies. • I like Samsung's Gear VR HMD, because the image quality looked good and it was comfortable for wearing.	• It took a while to get used to HMD, and I got tired when I wore HMD. • Mapping with PC is better in terms of degree of fatigue. • An instant HMD was not so comfortable for wearing. • Wearing HMD on glass was difficult.
About user interfaces	• I like the function for pointing in first person's view not map view.	• PC is the easiest platform for inputting POR/POI.
About AR Tactile map	• I like the function for sending request by visually impaired people.	• The accuracy of gesture recognition for AR tactile map needs to be improved.
About POR/POIs	• There are so many POR/POIs in the display. I think it becomes much clearer if the displayed contents are limited to nearby contents.	• I found empty POR/POIs without detailed information. I think filtering of the registered contents are required.

Categories of Feedback	Positive Feedback	Negative Feedback/Suggestions
Other suggestions	• It was the most beneficial application of VR I have ever experienced.	• I wondered if the system could support communication between participants. • I would like to regularly contribute virtual mapping parties from my home.

Conclusions

In this paper, we proposed the virtual mapping party, which enables the collection of POR/POIs in VR space for co-creating maps for visually impaired people. We introduced the components of the virtual mapping party and feedback from the first workshops. In the workshops, we only asked the participants to answer open-ended questions about certain aspects of the virtual mapping party. Overall feedback was very positive, especially about the immersive VR experience and the inclusive aspects of this activity with AR tactile maps.

For future work, we will keep improving the components of the virtual mapping party by reflecting the feedback and the statistics obtained at the workshops. We will also plan to conduct objective evaluations in future workshops. Currently, the virtual mapping party is open at a limited level at the workshops, because many components are under development. To make the virtual mapping party ready for release, the aspects of preparing data, such as the arrangement of omnidirectional images, should be refined or automated. We plan to implement user-friendly tools for the contributors who can capture walking environments and upload data to the server. Our final goal is the social implementation of the virtual mapping party activity. Therefore, we would like to release the whole software package for potential organizers to start conducting the virtual mapping party activity without our help.

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Works Cited

Ichikari, R., Yanagimachi, T., and Kurata, T.: Augmented Reality Tactile Map with Hand Gesture Recognition, Proceeding of International Conference on Computers Helping People with Special Needs (2), pp. 123-130, 2016.

Miura, T., Yabu, K., Noro,T., Segawa, T., Kataoka, K., Nishimuta, A., Sanmonji, M., Hiyama, A., Hirose, M., and Ifukube, T.: Sharing Real-World Accessibility Conditions Using a Smartphone Application by a Volunteer Group, Proceeding of International Conference on Computers Helping People with Special Needs (2), 265-272, 2016.

Okuno, K., Kurata, T., Seki ,Y., Kourogi, M., and Ishikawa, J.: Smartphone-based Talking Navigation System for Walking Training, 30th Annual International Technology and Persons with Disabilities Conference (CSUN), IND-026, 2015.

Voigt, C., Dobner, S., Ferri, M., Hahmann, S., and Gareis, K.: Community Engagement Strategies for Crowdsourcing Accessibility Information - Paper, Wheelmap-Tags and Mapillary-Walks, Proceeding of International Conference on Computers Helping People with Special Needs (2), 257-264, 2016.

Description Strategies to Make an Interactive Science Simulation Accessible

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Abstract

Interactive simulations are increasingly important in science education, yet most are inaccessible to blind learners. In developing an accessible prototype of a PhET interactive science simulation, we encountered significant challenges in providing screen reader access, including the need to: 1) describe unpredictable event sequences, 2) cue productive interactions, and 3) to simultaneously convey multiple changes. To address these challenges, we extended existing practices for verbal description of visual interactive content, and we created new strategies for developing rich description for accessible interactive science simulations.

Keywords

Blind/Low Vision, Research & Development, Web, Interactives; Science Simulation; Natural Language Description; Non-visual Access

Introduction

Science simulations range in complexity from simple to highly complex. A broad range of description strategies are needed to effectively increase non-visual access to all interactive simulations. Recent guidelines (Keane and Laverent) for the description of interactive scientific graphics are particularly relevant for simple interactives, but more complex interactives, like simulations, present significant challenges. In this work, we share strategies for designing descriptions for a complex interactive simulation. We developed our strategies through an iterative design process, including extensive user interaction analysis and feedback, for a PhET interactive science simulation (Smith, et al.).

The PhET Interactive Simulations project at the University of Colorado Boulder creates science and mathematics simulations (or “sims”) for teaching and learning from elementary school to college. The PhET project reaches students around the world with over 150 interactive sims. Each sim is visually rich, highly interactive, and supports exploratory learning. In 2014 the PhET project began an initiative to increase the accessibility of PhET sims. This work focuses on the development of descriptions intended for screen reader access for the sim *Balloons and Static Electricity*.

The *Balloons and Static Electricity* sim (Fig.1) addresses topics related to charge and static electricity for students of age 10 to adult. The sim includes a Balloon, a Sweater, and a Wall, and allows students to explore the transfer of charges between these three objects, and the resulting effect of a negative or neutral net charge on the Balloon.

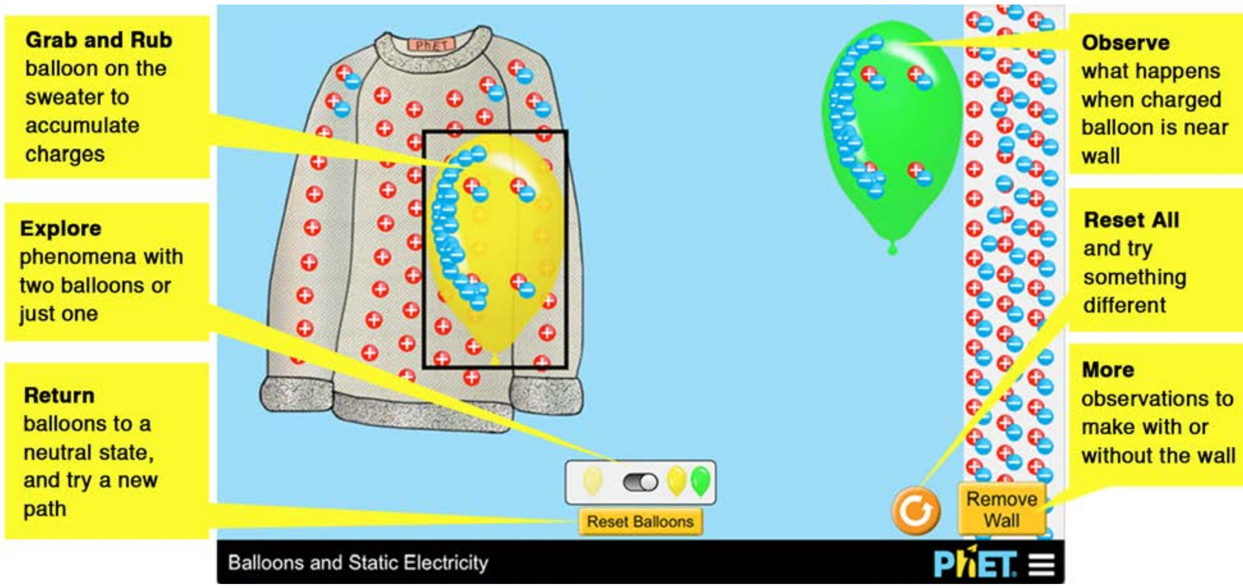

Fig. 1. In the *Balloons and Static Electricity* Sim, Students Can Try Several Possible Explorations (yellow callouts) with the Interactive Objects to Learn About Static Electricity.

Prior Work

Prior work in the development of *verbalized natural language descriptions* (or simply ‘descriptions’) is addressing significant access challenges in scientific images (DIAGRAM Center), graphs (Moskovitch and Walker), molecular chemical diagrams (Sorge, et al.), and math games (Gerino, et al.). The Keane and Laverent report provides guidance on creating effective descriptions for visually impaired students using interactive scientific graphics. Interactive scientific graphics are defined as “images that will change their appearance in response to actions taken by an external agent” (p.9). These resources provide useful guidance on aspects of developing effective descriptions (e.g., guidelines regarding brevity, context, and timeliness). In our work with a complex interactive sim we discovered new challenges in providing description during interaction, requiring development of additional strategies.

Method

Design Approach

Prior to this project, the *Balloons and Static Electricity* sim was inaccessible to screen reader software. Our goals in developing descriptions, was to support access through technology (computers and software) commonly available in classrooms and to incorporate descriptions into the same sim used by students without disabilities – resulting in a single, more inclusive, sim.

Our accessible design approach embraces the principles of the Web Content Accessibility Guidelines, and leverages the semantics of HTML5 and WAI-ARIA. It rests on three pillars:

1. **Infrastructure:** A robust webpage-like structure, our parallel Document Object Model (PDOM), that provides a hierarchical representation of the sim's objects, and that supports communication between sim, browser, and screen reader software.
2. **Multiple access points:** Keyboard navigation and operation that provide users familiar ways to navigate and interact with the sim, including screen reader commands.
3. **Descriptions:** Text-based descriptions read out by screen reader software that provide cues for interaction, dynamic state information, and real-time feedback as students explore and engage with the sim.

About the Participants & Procedures

As part of an iterative design process, we recruited 14 screen reader users for interviews - 12 on early prototypes (see also Smith, et al.), and 2 on more recent prototypes for a total of 14 interviews. The participants spanned a broad age range (19 years to 61 years). Participants demonstrated differing levels of expertise with their preferred screen reader. All participants had at least some post-secondary education.

Early prototypes were keyboard accessible, and contained descriptions for all static representations – names and descriptions of objects that do not change (blue sections in Fig.2), and two dynamic descriptions representing the changing amount of charge on the Balloon and the Sweater. The remaining dynamic representations were provided through live description by the interviewer, in what is sometimes called a Wizard of Oz procedure. This method allowed us to learn how participants explored an interactive sim, to test the wording of our static and dynamic descriptions, and to identify gaps in our description plan. Between interviews, we revised the design of the descriptions and the keyboard interactions. The last two interviews have been conducted on more complete prototypes without any live description provided.

Discussion

In this work, we summarize three description challenges found in our interviews, and the strategies we developed during our iterative design process to address these challenges. A side-by-side demonstration of the latest visual prototype and its description hierarchy can be found online at bit.ly/phetdemos-balloons-and-static-electricity.

Challenge 1: How to support multiple pathways of interaction and exploration?

PhET sims are designed to provide open-ended, exploratory experiences. In *Balloons and Static Electricity*, students may explore what happens when the Balloon is released near the Sweater or near the Wall. Students may explore what happens when the Balloon has a small or large amount of negative charges and is released. Students may explore both learning pathways, and more, in any order.

Additionally, students using a screen reader can utilize multiple ways to interact with an online resource. They may use any (or all) of the following approaches: the *arrow (or cursor) keys* to listen to descriptions line by line, screen reader *shortcut keys* to listen for structural features (e.g., headings), or the *Tab key* to navigate through interactive objects (e.g., buttons). Descriptions designed for *Balloons and Static Electricity* needed to support screen reader users in exploring multiple learning pathways in the sim while using diverse interaction approaches.

Our strategy to support multiple pathways of interaction and exploration is to provide a rich hierarchical system of modular descriptions. The hierarchical structure provides navigational support, uniquely identifies the objects in the sim with unchanging (or static) descriptions, and reflects any state changes to these objects with updated (or dynamic) descriptions. It also provides a summarized up-to-date description of the entire sim (the Scene Summary). All descriptions are modular, and make sense in context when heard in any order.

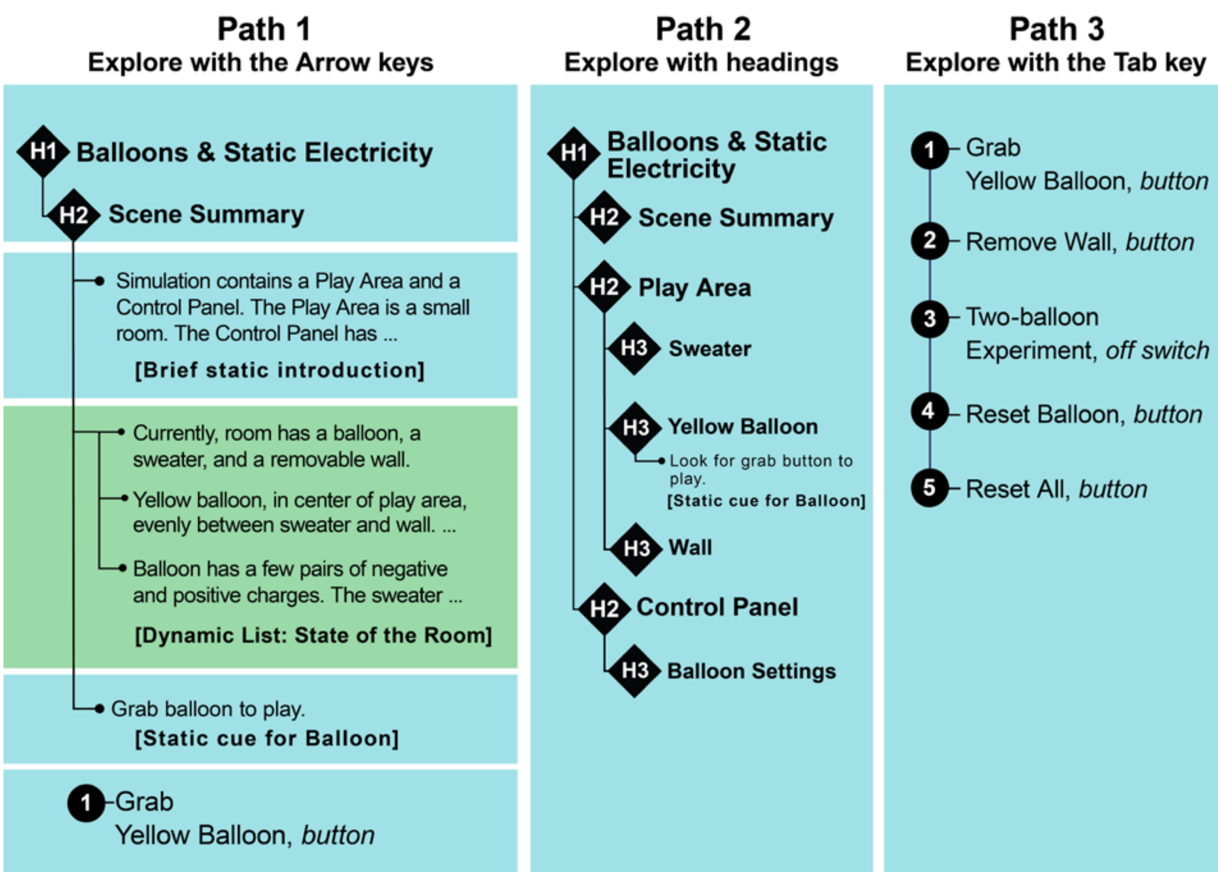

Fig. 2. Three Possible Interactive Learning Pathways Through the Sim's Hierarchical Description Structure: Arrow keys (left), headings (center), and Tab key (right).

The result is a rich set of descriptions that can be navigated by screen reader users in multiple ways (Fig.2), and remain understandable regardless of the learning pathway explored. A student choosing to navigate the sim line-by-line with the arrows keys (Fig.2, Path 1) will first encounter the Scene Summary (a big-picture view of the sim) and a cue for interaction. The student may choose to immediately interact by following the interaction cue, or continue exploring with the arrow keys to assess all possible interactions before choosing their learning path. A student choosing to navigate the sim by using shortcut keys to browse headings (Fig.2, Path 2) will find seven meaningful headings including those for the “Scene Summary” and “Play Area” sections. Exploring any section more deeply will provide the opportunity to interact with objects in the sim. A student choosing to navigate the interactive objects in the sim using the Tab key (Fig.2, Path 3) will find action-oriented static descriptions, like the “Grab Yellow Balloon” button or “Remove Wall” button, each understandable independent of other descriptions.

Challenge 2: How to support productive exploration without over-directing?

The design of the descriptions need to support students not only in exploring the sim, but also in choosing productive explorations for learning. With the *Balloons and Static Electricity* sim, learning from the sim requires interaction with the Balloon. The Balloon’s large size, its bright color, and its central location between the Sweater and Wall provide implicit visual cues. These cues indicate to sighted students that interacting with the Balloon and exploring relationships between the Balloon, Sweater, and Wall will be productive (Podolefsky, et al.), and students typically begin interacting with the Balloon within seconds of sim use. In our early accessible prototypes, screen reader users did not initially interact with the Balloon, choosing less informative interactions first. In these initial designs, neither the cues for interaction nor the Balloon descriptions effectively communicated the significance of the Balloon.

Our strategy to support productive exploration is to cue productive interactions through both navigation order and description. We designed the hierarchical navigation order to align with the visual scaffolding of the sim. Unchanging (or static) descriptions identify objects within the sim, indicate their hierarchical relationships to each other, and simultaneously provide a pedagogically relevant navigation order for the interactive items in the sim. For example, the Sweater, the Balloon, and the Wall are found within the hierarchy in the “Play Area” section (Fig.2, column 2). Though structurally at the same level of importance, when listening in order (first to last), the Balloon description comes after the description of the Sweater and before the description of the Wall. This order situates the Balloon semantically between the Sweater and the Wall, just as it is situated between these two objects in the visual layout, and cues the user that there are likely relationships to explore between these objects.

To highlight the significance of the Balloon, we embedded three playful interaction cues to suggest that grabbing the Balloon might be a productive way to begin exploration. The sim’s Scene Summary ends with a non-specific cue, “Grab balloon to play,” (Fig.2, column 1). A second cue, “Look for grab button to play” (Fig.2, column 2), is found at the end of the Balloon’s description, and provides specific structural information about the “Grab” interaction (i.e., it is a button). The final cue, the button’s label, is simple and action-oriented, “Grab Yellow Balloon”.

The static descriptions and navigation ordering provide information to the student about the objects and the relationships between them, while the interaction cues provide hints at what might be a productive opportunity for exploration. The navigation ordering neither prohibits nor enforces any specific interaction pathway, and nothing in the descriptions indicate to students specifically what explorations to engage with. Each description only provides cues to the student to support exploration.

To illustrate, here is an example user scenario. A student arrives at the sim, and the screen reader automatically begins reading the Scene Summary from the top of the description hierarchy, which ends with “Grab balloon to play.” The screen reader continues, reading through the Play Area, Sweater and Balloon descriptions. In the Balloon’s description, they hear the cue, “Look for Grab button to play”. The student presses the *Tab key* and hears, “Grab Yellow Balloon, button”. They press the Spacebar to begin an interactive exploration with the Balloon.

Challenge 3: How to support awareness of multiple simultaneous changes?

As students explore and interact with the sim, they make changes to objects and these changes can affect other objects. A single interaction often results in multiple simultaneous changes that students need to know about. For example, pressing the Reset All button (Table 1) results in state changes to at least two objects, the Balloon and the Sweater. A more complex example is the interaction of dragging the Balloon and rubbing it on the Sweater (Fig.3). This interaction results in multiple changes to the Balloon (position and net charge), and to the Sweater (location of remaining pairs of charges and net charge). Descriptions repeat as rubbing continues.

Table 1. Improved Description for the Reset All Button

Early prototypes released state changes for all objects upon pressing the Reset All button	**Redesigned description releases an alert to summarize what happened**
• Yellow balloon in center of Play Area. • Has no more negative charges than positive charges. • Sweater has no more positive charges than negative charges.	• Sim screen restarted. • Everything reset.

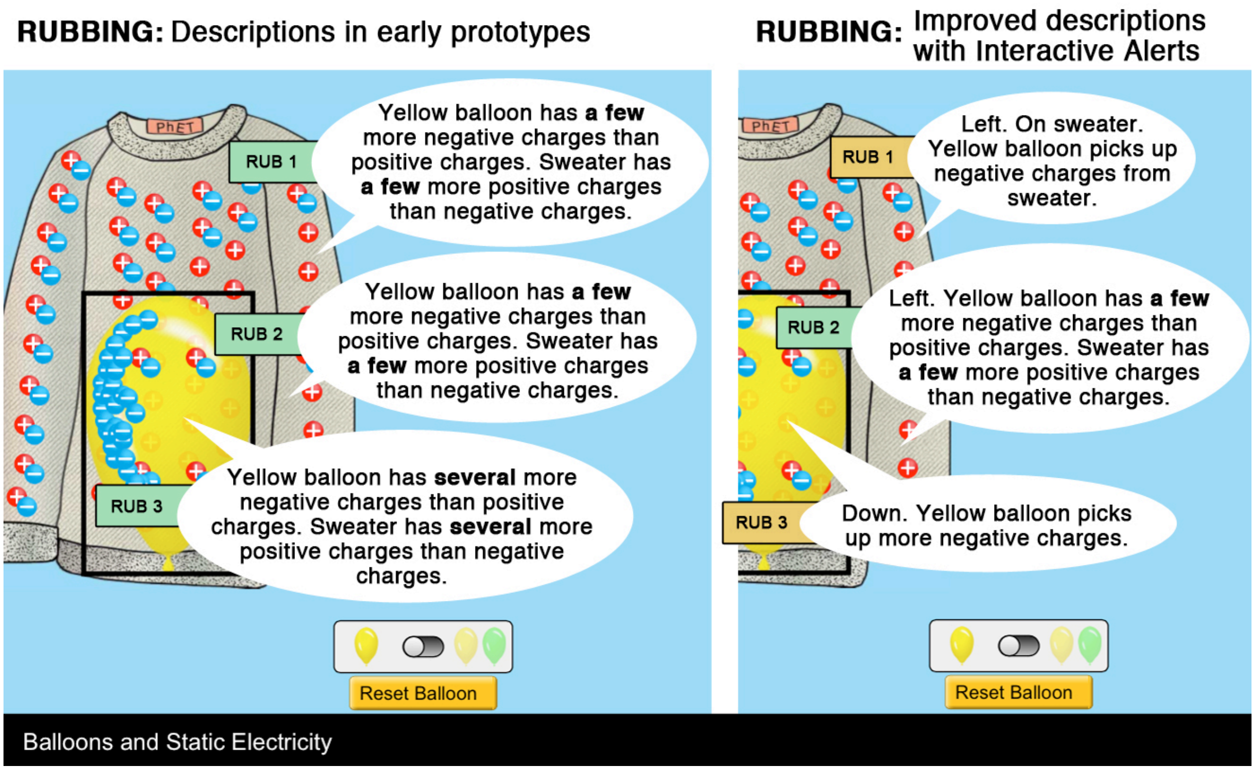

Fig. 3. Repetitive Dynamic Descriptions for the Balloon and Sweater (RUB 1, 2, and 3 on left), Layered with Interactive Alerts (RUB 1 and 3 on right) to Reduce Verbosity and Repetition.

In early prototypes, state changes were communicated through updated Dynamic Descriptions (Fig.5, column 2) for each sim object. Describing the state changes, alone, however; resulted in lengthy and repetitive descriptions when changes occurred simultaneously (Table 1, column 1 and Fig.3 speech bubbles on the left), and silence when no changes occurred. Users, in response, often ignored the verbose and repetitive descriptions, had to deduce on their own that the change in charges was due to a charge transfer, and were left unaware of the state of the sim when rubbing interactions resulted in no charges being transferred.

Our strategy for providing descriptions of multiple simultaneous changes is to design highly-contextualized description alerts (Interactive Alerts), to replace and/or strategically support state changes (Dynamic Descriptions). Dynamic Descriptions (Fig.4, column 2) reflect the state changes in the description hierarchy, can be accessed at any time for review, and are read aloud during interaction. Interactive Alerts (Fig.4, column 3), in comparison, are succinct descriptions of what is happening in the sim, are only announced in context at the instant they are relevant as the event occurs, and remain hidden from review in the sim's hierarchy.

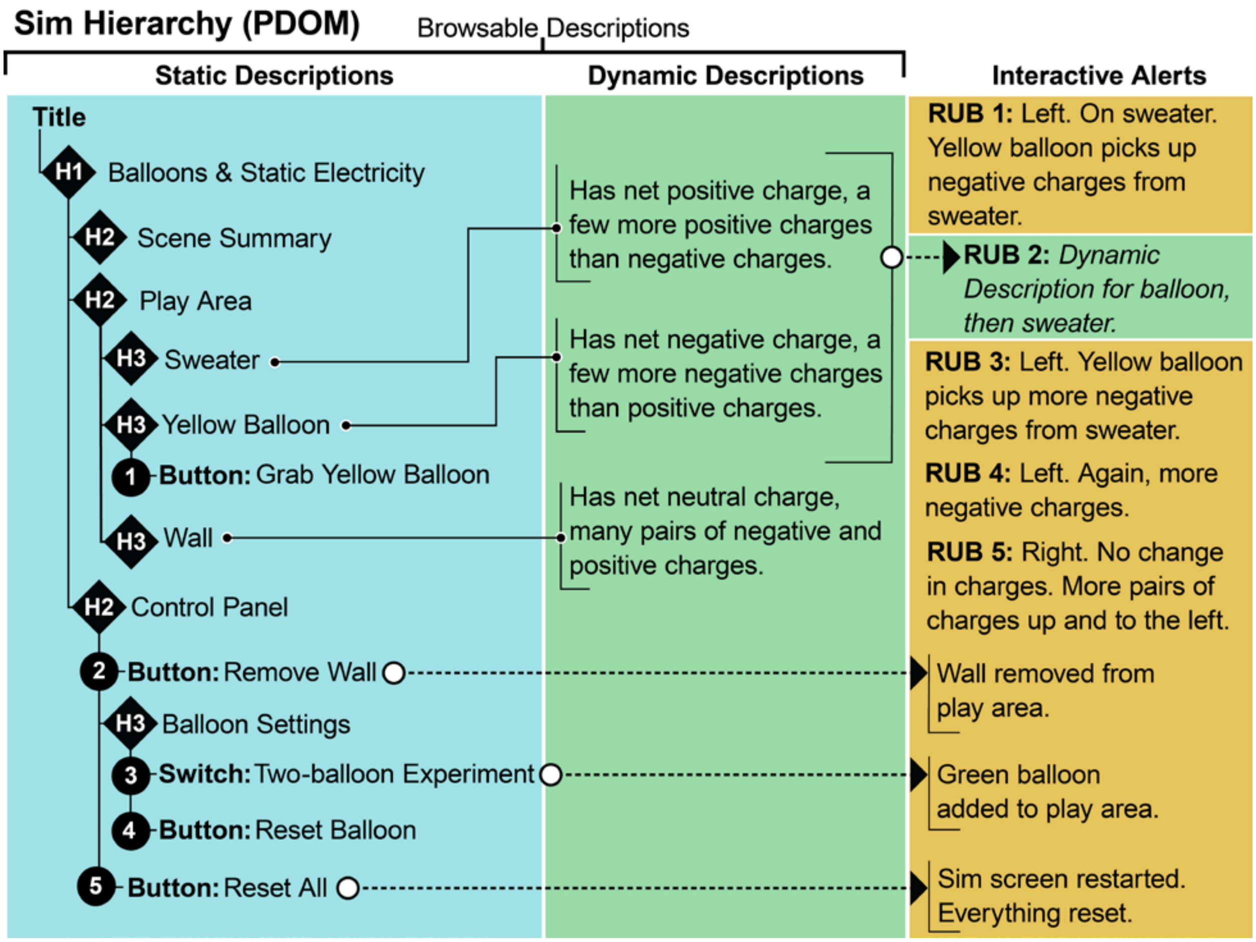

Fig. 4. Description Strategy Includes Three Types of Descriptions Embedded Within a Parallel DOM. Static Descriptions (column 1) form a Browsable Outline, Dynamic Descriptions (column 2) describe reviewable state changes, and Interactive Alerts (column 3) support interaction.

For interactions, like the Reset All example in Table 1, a summarized Interactive Alert, "Sim screen restarted. Everything reset", is read out instead of the two lengthier Dynamic Descriptions. For the more complex rubbing interaction (Fig.3), succinct real-time Interactive Alerts that describe what is happening support the lengthier and repetitive Dynamic Descriptions about the amount of charges on the sim's objects. The experience overall, in both scenarios, becomes more engaging while still effectively conveying the complexity of changes that the student's interaction caused.

Conclusion

Throughout our work we sought to maintain brevity, ensure timeliness of description delivery, and create descriptions that always make sense in context, consistent with previous work on descriptions for interactive scientific graphics (Keane and Laverent). To do this within a complex interactive simulation required that we utilize new strategies for the design and delivery of the descriptions. These strategies included providing a robust hierarchical structure to support multiple pathways of exploration and interaction, providing cues to support pedagogical use of the sim, and layering of three different types of description to support the conveyance of complexity. User testing with our sim prototypes indicate that these strategies can be used to effectively address the challenges we have highlighted for complex interactive simulations. The set of strategies presented may also be a useful companion to existing guidelines for describing other types of interactive graphics.

Acknowledgements

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Works Cited

DIAGRAM Center. "Image Description Guidelines." diagramcenter.org/table-of-contents-2.html Accessed 9 Feb 2016.

Gerino, Andrea, Nicolò Alabastro, Cristian Bernareggi, Dragan Ahmetovic, and Sergio Mascetti. "MathMelodies: Inclusive Design of a Didactic Game to Practice Mathematics." *Proceedings of the 14th International Conference ICCHP*. July 9-11, 2014. Paris, France. Springer International Publishing. 2014.

Keane, Kyle, and Christina Laverent. *Interactive Scientific Graphics Recommended Practices for Verbal Description*. diagramcenter.org/accessible-dynamic-scientific-graphics.html. Accessed 26 Oct. 2015.

Moskovitch, Yarden, and Bruce N. Walker. "Evaluating Text Descriptions of Mathematical Graphs." *Proceedings of the 12th International ACM SIGACCESS Conference on Computers and Accessibility*. Oct. 25-27, 2010. Orlando, Florida. ACM. 2010.

PhET Interactive Simulations. "Balloons and Static Electricity." phet.colorado.edu/en/accessibility/prototypes. Accessed 30 Nov. 2016.

Podolefsky, Noah S., Emily B. Moore, and Katherine K. Perkins. "Implicit Scaffolding in Interactive Simulations: Design Strategies to Support Multiple Educational Goals." *arXiv,* preprint arXiv:1306.6544v3.

Smith, Taliesin L., Clayton Lewis, and Emily B. Moore. "A Balloon, a Sweater, and a Wall: Developing Design Strategies for Accessible User Experiences with a Science Simulation." *Universal Access in Human-Computer Interaction. Users and Context Diversity*. Edited by Margherita Antona and Constantine Stephanidis. Vol. 9739. 147–58.

HCI International. July 17-22, 2016. Toronto, Canada. Springer International Publishing, 2016.

Sorge, Volker, Mark Lee, and Sandy Wilkinson. "End-to-End Solution for Accessible Chemical Diagrams." *Proceedings of the 12th Web for All Conference*. May 18-20, 2015. Florence, Italy. ACM Press, 2015.

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THE JOURNAL ON TECHNOLOGY AND PERSONS WITH DISABILITIES

EAGLE: An Accessible Platform for Delivery of Learning Materials

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Abstract

Employment opportunities for persons with disabilities are very much hampered by inaccessible software. This is particularly true when those who are employed must engage in Continuous Personal Development (CPD) but the online training platforms they must use are inaccessible. This paper describes the platform developed by the members of the Enhanced Government Learning (EAGLE) project team to produce a training platform for workers in rural municipalities. It outlines efforts made to ensure the platform, and associated content, are accessible and usable by as wide a range of people as possible.

Keywords

Accessibility, EAGLE, Open Educational Resources, Technology-enhanced Learning, WCAG

Introduction

When the topic of online learning is considered, the context of learners outside formalised educational settings such as those provided by universities is often completely ignored. However, continuing professional development (CPD) can, and often does, require the use of online resources. Failure to participate in CPD-related activities, can frequently be a barrier to promotion, or indeed prevent it entirely. It is therefore of grave importance that any system which provides access to online training materials, or community-supported knowledge exchange, be accessible to as wide a range of users as possible. Failure to do so can, and does, result in the exclusion of many employees and unnecessary barriers to career-advancement being created.

This paper presents a discussion of the EnhAnced Government LEarning (EAGLE) project, which has been funded under the seventh Framework Programme of the European Union to provide an accessible platform for the provision of Open Educational Resources (OERs), and to foster communities of knowledge-sharing. In the sections which follow, the philosophy, concepts and technologies underpinning the platform will be discussed. The paper further presents and discusses the main components of the platform, and also details strategies which aim to ensure that both the software components and sample content are universally usable.

Background

Open Educational Resources (OER) are materials which are freely available online for use by everyone irrespective of whether the person seeking to access them is a student, self-learner or indeed an educator. Such materials are useful not only in the context of formal education (for example primary, second or third level courses) but also in the context of professional development and/or other training scenarios. Use of OER also provides an interesting avenue for disseminating accessible learning materials. Recent research by members of the universal design for learning (UDL) community acknowledge that "Access to OER is growing, but, not for all. Not only do the online educational materials need to be freely available and with permission to use, OER need to be designed so individuals with disabilities can use them for their teaching and learning." To achieve these goals necessitates a variety of technological and organisational components to work together. Some of these are: i) A platform capable of producing accessible OER; ii) Resources which guide personnel in the production of accessible OER; iii) Organisational policies which ensure compliance with criteria guaranteeing accessible OER.

Technology-enhanced learning (TEL) represents thus a sensible option for the provision of online training materials to public employees who need to keep up with such changing environments, but do have limited access to training courses. EAGLE's main objective is to equip employees in local governments with a holistic training solution based on Open Educational Resources (OER) and Open Source tools, supporting learning of critical transferrable skills such as ICT literacy and professional management of change situations.

It is one of the key project goals that all artefacts are accessible. For example, the platform currently under development is being thoroughly tested to ensure compliance with all relevant standards (e.g. Web Content Accessibility Guidelines (WCAG), Authoring Tool Accessibility Guidelines (ATAG) and Accessible Rich Internet Applications (WAI-ARIA). All project partners are committed to ensuring that not only this platform is accessible, but that the OER produced are also universally usable by as wide a demographic as possible.

Overview of the EAGLE Platform

The EAGLE platform has been built using the principles of user-centred design (UCD). To that end, stakeholders in four countries (Ireland, Luxembourg, Germany and Montenegro) have been involved and consulted at all stages in the development process. The first involvement with users took place early in the lifecycle of the platform, when workshops were held with representatives of local government organisations (municipalities) in the four countries previously mentioned. The outcome of these workshops was a detailed analysis of barriers to the adoption of a learning platform such as EAGLE in a Public Administration setting. Amongst the barriers to emerge from these exercises were: i) A lack of relevant ICT knowledge; ii) A lack of awareness of the advantages of online training/learning; iii) A lack of trust in any learning platform and associated content; iv) An unwillingness to share/impart knowledge lest it be seen as reducing the employee's usefulness.

Following on from this, a workshop specifically focussed on defining accessibility requirements for a platform such as EAGLE was held. Here, invited experts from diverse sectors of the accessibility landscape gathered and contributed to the discussion. The topics on the agenda were: i) How to ensure the platform itself was accessible; ii) How to ensure that all content produced on the platform was accessible.

The most tangible output from this workshop was the production of a persona which depicted Seamus, a vision-impaired worker in a rural office of an Irish municipality. This persona captured the personality, ambition, and most importantly technological capabilities and needs of this fictitious gentleman. This persona complemented others produced within the project which described other employees in Public Administrations in various countries, and in various contexts. These personas were then given to developers, and along with a scenario detailing how the EAGLE platform could/would be used, assisted in the generation of early-stage mock-ups, and the subsequent development of the portal.

What is important to note here is that accessibility was considered right from the beginning of the project, and not retro-fitted as a well-meaning afterthought. The importance of this approach cannot be overstated. Had considerations of accessibility not been included at the very earliest design phase, it is unlikely that the solution would have been as accessible as it is.

High-level System Architecture

The EAGLE Platform is built on Liferay (liferay.com) which is a free and open source portal platform distributed under LGPL. The EAGLE Knowledge Backend System (Figure 1) incorporating the EAGLE Ontology for Local Governments (EAGLE Knowledge Base). The EAGLE Knowledge Base represents the backbone of the EAGLE Platform. It manages the metadata of the information collected in the EAGLE Platform. Knowledge management plays a central role in the EAGLE Learning Platform providing a storage backend for the management of metadata related to OER's, the learners as OER users, and their learning competences and skills.

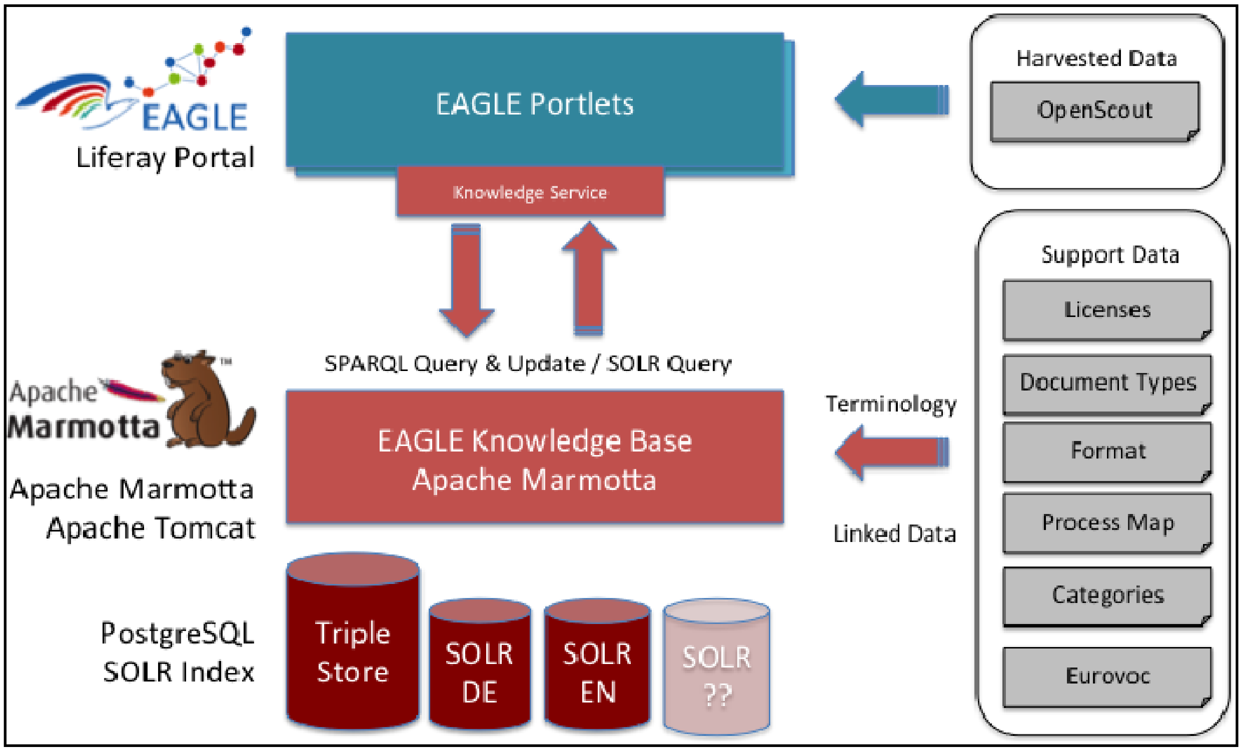

Fig. 1. High-level Architecture of EAGLE Knowledge Backend.

In EAGLE, knowledge management is based on Apache Marmotta, which is an implementation of the LDP standard. In addition, the design and development of the architecture uses the concepts of OSGi (Wikipedia, 2016) and model-driven engineering. For each data provider, a single harvester module is implemented that extends the abstract super harvester. The mechanism of data management illustrated in Figure 2 shows the overall workflow of the harvester controller.

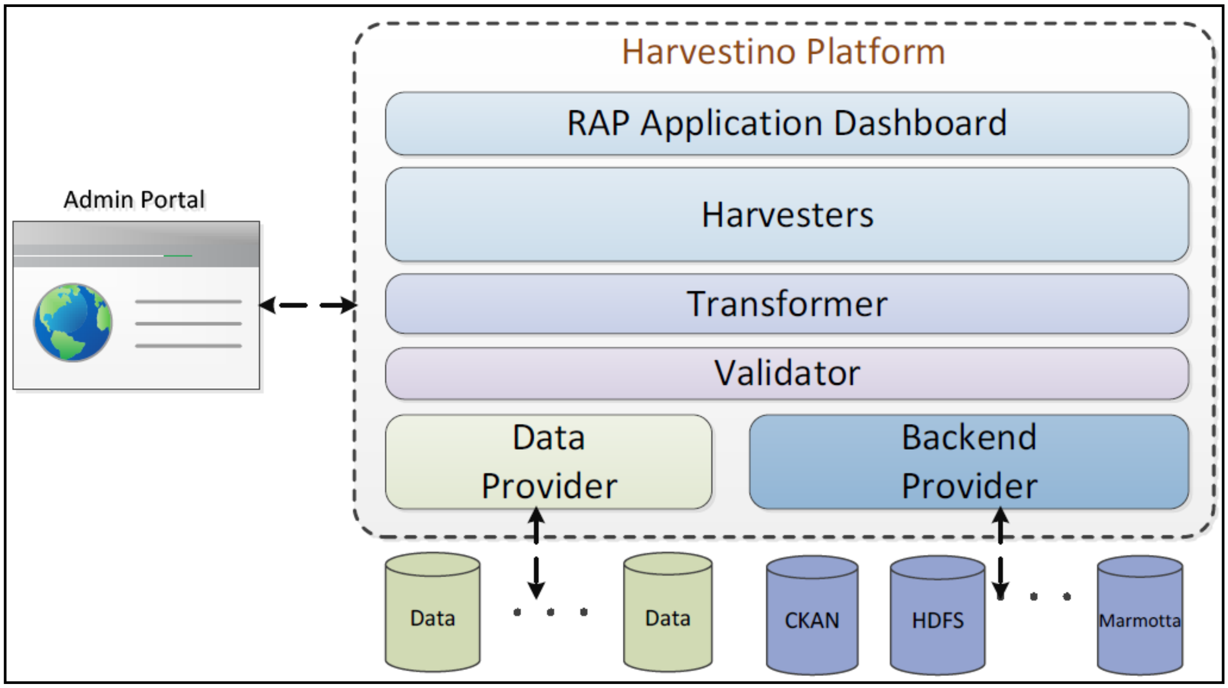

Fig. 2. Overall Stack of Harvestino

As depicted in Figure 2, the harvesting mechanism comprises of five simple steps: i) First, the data is extracted from the data source with the help of data providers; ii) The extracted data is immediately validated for syntactic and semantic errors which, having been obtained from the validation process are logged and reported back to the data provider; iii) Upon successful validation, the input data is transformed to a target meta-model that is the OER model in the case of EAGLE; iv) The transformed datasets are validated once again to check the transformation errors and v) Finally pushed to the backend through the help of a backend provider, for instance Marmotta knowledge service.

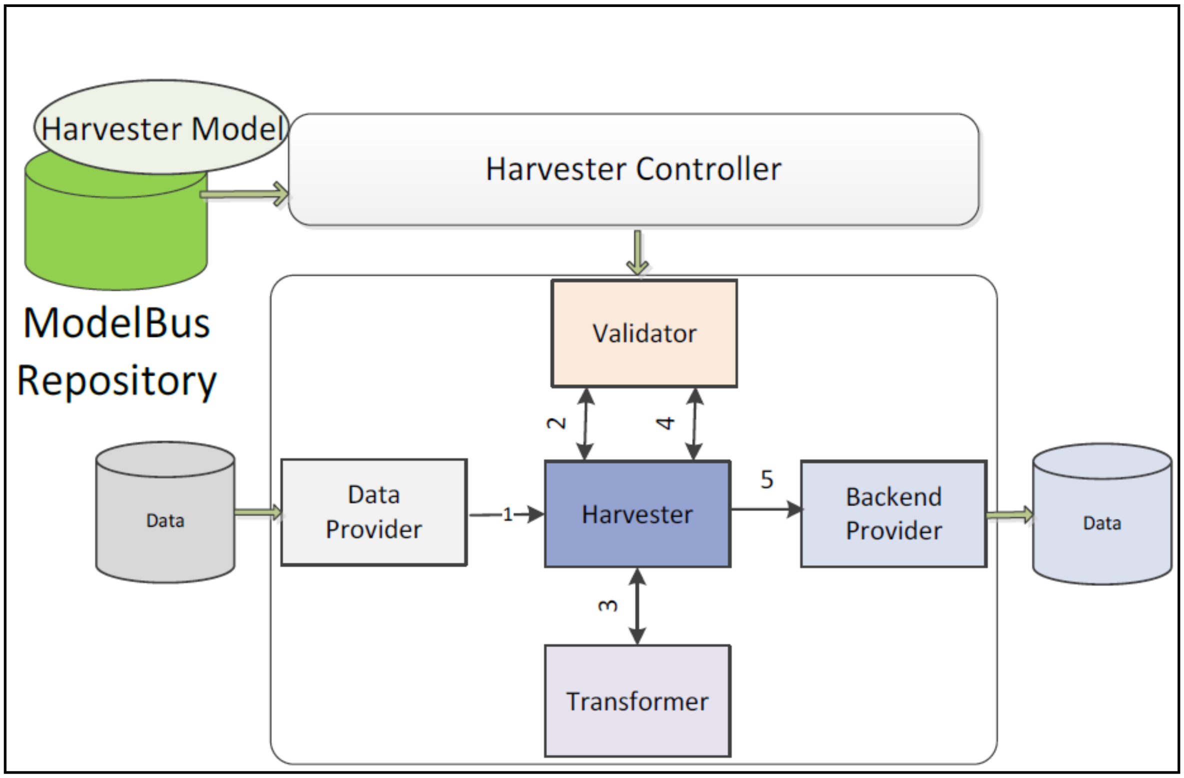

Fig. 3. Modular Workflow of Harvestor Controller.

All the developed modules are based on OSGi extension mechanism and are operated by the Harvester Controller Module (HCM) (depicted in Figure 3). HCM controls the configuration, scheduling as well as the operation of Harvesters. Individual Harvesters are instantiated by the HCM through the Eclipse Extension Point mechanism (Vogella, 2014). This incorporates the *Dependency Inversion Principle* (Vogel, 2012-May and Wikipedia, 2016), through the abstract Harvester class. To attain the cohesive as well as scalable nature, all the modules are designed based on SOLID Design principles (R.C.M.U. BOB, 2009). Harvestino also provides inbuilt Authentication and Authorization to safeguard the security and integrity of the harvesters. As Harvestino uses Model- Driven Engineering concepts, all modules inherently work on models instead of raw data. The HCM controls the operation of modules based on the configurations (individual Harvester Models) stored in the ModelBus repository. ModelBus (Aldazabal, A., Baily, T., Nanclares, F., Sadovykh, A., Hein, C., Esser, M., and Ritter, T., 2008) serves as a model integration framework that provides the internal storage of harvester related configurations. As Harvestino is built with OSGi, it provides features for hot deployment of modules through the OSGi console. Apart from the OSGi console, Harvestino also realizes a Remote Application Platform (Eclipse.com, 2016) user interface to provide a thin client with a rich widget set to administer the harvesters.

EAGLE Main Features

EAGLE consists of three main components (depicted in Figure 4): i) Search and find, ii) Create and keep track and iii) Engage and share. The Create and keep component enables the users to produce a learning resource: i) Step-1 User Registration and login; ii) Step-2 MyEAGLE Studio; iii) Step-3 Authoring of content. The authoring component is further sub-divided into four components (metadata, resources, categorize and the publishing of the OER. It is considered essential that these various components are entirely accessible.

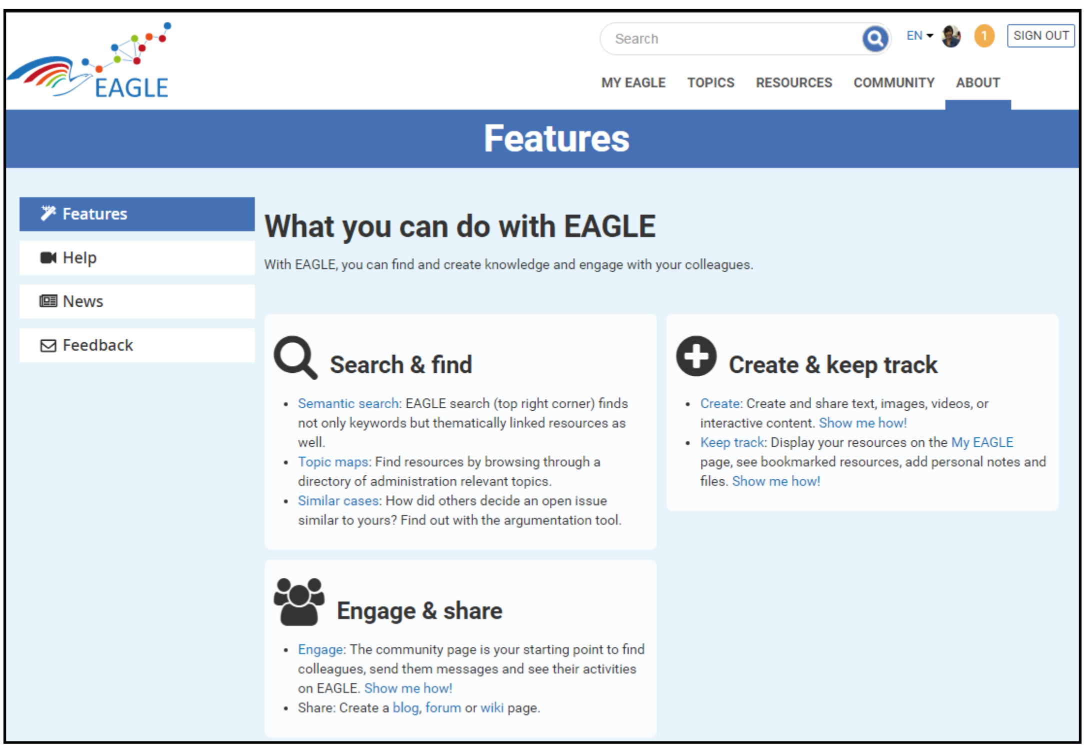

Fig. 4. EAGLE Features.

Therefore, the underlying user interface (UI) frameworks which have been used to build them have all been chosen based on their adherence to WCAG2.0 and ARIA 1.0. As previously mentioned, the EAGLE platform relies on the use of external components to perform various tasks. In order to make tool selections which catered for the needs of diverse users, the criteria developed by the Ageweb project (Ageweb.ch) have been adopted. These criteria do not deviate in any way from the guidelines contained in WCAG2.0; however they expand upon them and focus on usability as well as the more technical aspects of accessibility.

Evaluation

Over the development lifecycle, care has been taken to perform automated as well as manual accessibility checks on the various components and workflows within the platform. Each template has been checked against WCAG2.0 and WAI-ARIA. Evaluation has been undertaken by a Screenreader user to ensure that (in so far as is possible) the platform can be effectively be used with this form of Assistive Technology. Both JAWS and NVDA have been used with the system, in conjunction with Firefox and Internet Explorer. Whilst a thorough analysis has been carried out by an expert Screenreader user in order to ascertain the technical shortcomings in the platform, it has not as yet been possible to carry out an in-depth user-evaluation with other users of this form of assistive technology. The main reason for this is that the development process is only just completed.

The manner in which the expert evaluation was conducted was based around completion of five key tasks. These tasks were: 1) To find information on the platform on a certain topic; 2) Engage in discussions on the forum; 3) To create a blog entry and also to comment on a blog entry of another user of the platform; 4) To interact with various resources on the platform and rate them, bookmark them, and perform various other related tasks; 5) Establish ties with other colleagues, and create networks for knowledge sharing and peer support.

The results of the expert review were, on the whole, positive. Indeed, most tasks could be completed without difficulty. The one exception to this was that, although resources and other results could be found, interacting with them (i.e., viewing the specific piece of content) required expert knowledge of both NVDA and JAWS. Thus, whilst in theory the portion of the system concerning the task was accessible; its usability was less than satisfactory. As accessibility has been included at all stages of the project, the fix is relatively simple; requiring only that keyboard navigation be added to one key component.

This paper in no way seeks to suggest that the expert evaluation carried out here is a replacement for a comprehensive user evaluation with users of Screenreaders, or indeed other Assistive Technologies. Rather, the members of the project team see this as merely the precursor to carrying out these tests. It is essential that, once the basic accessibility, and more importantly usability of the system is assured, the input of real-world stakeholders is elicited and any issues addressed.

Conclusion

Ensuring that employees have access to online training resources is essential for most organisations today. It is equally important that those with disabilities are not left behind due to inaccessible systems or content. This paper has sought to describe the EAGLE platform; a holistic learning solution which aims to provide a vehicle for learning and knowledge-sharing for employees in local authorities.

In order to ensure the long-term viability of the platform, it is essential that resources are made available to those using it which assists them in making their content accessible. Doing so ensures that not only the system itself is usable by people with disabilities, but the learning materials stored on the platform are also usable, and thereby guarantee that those who can benefit most from digital content can avail of it easily and effectively.

Works Cited

"About Universal Design for Universe." Centre for Universal Design. http://enact.sonoma.edu/content.php?pid=218878&sid=2606294

"About OSGi " Wikipedia 2016. http://en.wikipedia.org/wiki/OSGi

Vogella.com, "Eclipse Extension Mechanism". December 2014. Available http://www.vogella.com/tutorials/- EclipseExtensionPoint/article.html

Vogel, L. "Using dependency injection in java - introduction – tutorial (2012, May)". Available http://- www.vogella.com/tutorials/DependencyInjection/article.html

"About Dependency Injection." Dependency Injection 2016, Available https://en.wikipedia.org/wiki/- Dependency_injection

R. C. M. U. BOB. "Design principles and design patterns" Last verified 2009-01-14. Available http://www.objectmentor.com/resources/articles/Principles_and_Patterns.pdf

Aldazabal, A., Baily, T., Nanclares, F., Sadovykh, A., Hein, C., Esser, M., and Ritter, T. "Automated Model Driven Development Processes", ser. ISBN: 978-3-8167-7645-1, in Proceedings of the ECMDA workshop on Model Driven Tool and P. Integration, Eds. Fraunhofer IRB Verlag, Stuttgart, 2008.

"About Eclipse". Remote application platform, 2016. Available http://www.eclipse.org/rap/

"About liferay" Available: https://www.liferay.com/

"About AgeWeb" AgeWeb Project. Available: http://ageweb.ch/

"About marmotta" http://marmotta.apache.org

"About w3.org" https://www.w3.org/TR/ldp

THE JOURNAL ON TECHNOLOGY AND PERSONS WITH DISABILITIES

Impact of the MODELER AAC Strategy for Secondary Students with Complex Communication Needs

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Abstract

This single-case non-concurrent multiple baseline design intervention study targeted four young adults in public high school with complex communication needs who lacked augmentative and alternative communication using the Model, Encourage, Respond (MODELER) partner instructional strategy. The intervention included coaching paraprofessionals to model AAC as they spoke using various AAC apps running on an Apple iPad, provide time delay, and respond to student communication attempts modeling AAC. In response to training and coaching, the paraprofessionals all made large instructional gains. Three out of the four young adults with complex communication needs demonstrated large increases in communication turns in response to intervention. This study demonstrated that paraprofessionals who had previously received little AAC intervention training could be coached by a special educator to provide impactful interventions in just a few sessions. These findings must be interpreted as preliminary due to the level of the experimental design.

Keywords

Augmentative and alternative communication, iPad, AAC modeling, paraprofessionals, partner communication training

Introduction

In today's technologic world, life offers many communication opportunities for students who do not use speech to communicate. These individuals are described as those with *complex communication needs* (CCN). Through the power of *augmentative and alternative communication* (AAC) in the form of emerging technologies such as mobile devices combined with apps, sensors, and input devices, individuals with CCN can select pictures, words, and sentences that can be spoken out loud by high quality speech synthesis, also known as text-to-speech (Beukelman & Mirenda). Fortunately, there is evidence that intervention packages that include these AAC systems combined with various instructional supports are now introduced during early childhood (Romski, Sevcik, Barton-Hulsey, & Whitmore; Sennott, Light, & McNaughton). However, there remain many students at the secondary level have still not been introduced to these AAC interventions. In many cases, these students have used unconventional means of communication throughout their adolescence that have been reinforced and effective to some extent. The purpose of this project was to study serving a group of these secondary level students who attend a public high school through providing AAC systems made up of an iPad with an AAC app combined with communication partner training to the *instructional assistants* (IAs), paraprofessionals, that work most closely with the students using the new Model, Encourage, Respond (MODELER) AAC intervention strategy instructional package.

MODELER was developed based on the systematic review of AAC modeling interventions conducted by Sennott, Light, and McNaughton, which reported on 10 single-case design studies and one randomized clinical trial that had AAC modeling, also known as aided language stimulation, as the primary intervention component. AAC modeling was defined as the communication partner using the AAC system as their own voice, modeling both speech and use of the system in a naturalistic interaction. The systematic review indicated strong positive communication outcomes across pragmatic, semantic, syntactic, and morphologic domains. Based on analysis of the independent variable packages in these studies, three key components stood out as practically and theoretically important, including AAC modeling, providing a time delay procedure, and a responsiveness approach to an individual's communication attempts, with these three forming the basis for the model, encourage, and respond steps in the strategy. The purpose of the MODELER strategy instructional package is to help students who are acquiring expressive language using AAC by coaching their communication partners to interactively model AAC as they speak, during conversations (Sennott & Mason).

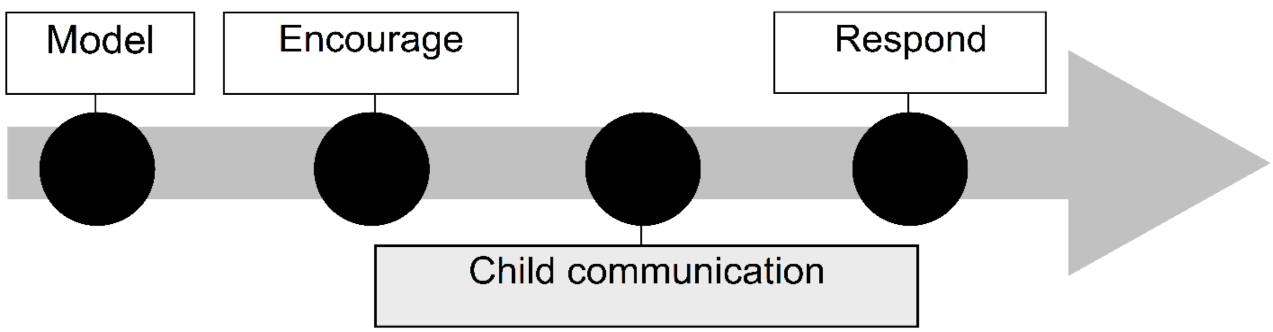

Fig. 1. MODELER AAC intervention strategy.

Research Question and Study Design

This study examines the effects of the MODELER strategy instructional package on Instructional Assistant's use of language modeling, using an iPad based AAC device, and student communication turns, in the secondary setting, during shared storybook reading based on the approach used by Sennott & Mason. The following research questions will be addressed:

1. What is the impact of the MODELER strategy instruction, using a partner-instruction approach, on AAC modeling by Instructional Assistants?

2. What is the impact of IA use of MODELER on the student's total communication turns?

This research question will be addressed by comparing participant performance before and after the intervention is introduced, using a single-case non-concurrent multiple baseline across participant design that would otherwise meet Institute for Educational Sciences (IES) design standards with reservations (Kratochwill et al). The multiple baseline design worked across the IES recommended number of replications (n=4) and had a minimum of three data points per phase of intervention. Because of time constraints on this action research project that involved collaboration between an in-service Master's of Science student and a faculty researcher, a non-concurrent approach (Hanser & Erickson) was chosen, which because of the chronic nature of the challenges these young adults faced controls partially for the maturation threat to internal validity.

Setting and Participants

This study took place in a suburban high school in the Pacific Northwest. Approximately 1,811 students attend this high school. The adolescent participants in the study participate in an individualized program, in which they are included for part of their day and removed from the general education classroom for a major portion of their school day. The student and Instructional Assistant (IA) participants were considered based on specific inclusion criteria. Four student participants were selected for inclusion in this study, based on the following criteria, (1) Students age 14-19, (2) access to a robust AAC speech-generating system for six months or less, (3) need for AAC speech-generating system had been discussed and agreed upon by the IEP team within one year (4) significantly limited to no use of intelligible speech (<50 words) and, (5) work with an adult Instructional Assistant (IA) on a daily basis. The inclusion criteria for the adult IAs that worked with the students included the following criteria, (1) works with the student regularly (at least 25% of the day) and (2) has worked with the student for at least one month prior to the beginning of this study.

Table 1a. Student (Tanner) Participant and Instructional Assistant Characteristics.

Student Name, Gender, Age	Tanner, Male, 14 years
Disability	Chiari I Malformation, Cerebral Palsy
Communication	Limited intelligible speech (<50 words), inconsistent access to GoTalk iPad communication system containing only core vocabulary and preferred items. Spits or yells to communicate frustration or displeasure. **Recently taught by staff to slap the table top to indicate agreement. No history of AAC use or intervention.
iPad based AAC System used in this study	Proloquo2Go
IA, Age, Experience in Schools	Sydney, 49, 8 years total experience including volunteer positions at the elementary level and Instructional Assistant positions at the secondary level.

Table 1b. Student (Samantha) Participant and Instructional Assistant Characteristics.

Student Name, Gender, Age	Samantha, Female, 14 Years
Disability	Myotonic Dystrophy
Communication	Limited intelligible speech (<50 words), initiation of LAMP program trial within three months of study commencement. History of access to Vantage system, but little to no independent use outside of requests for preferred activities and items.
iPad based AAC System used in this study	LAMP
IA, Age, Experience in Schools	Molly, 67, 13 years total experience, all of which in the Instructional Assistant position.

Table 1c. Student (Alex) Participant and Instructional Assistant Characteristics.

Student Name, Gender, Age	Alex, Male, 17 years
Disability	Intellectual Disability
Communication	Limited intelligible speech (<50 words), minimal communicative expression used across setting and communication partners. Reported history of access to low-tech PODD book. Independent use not reported.
iPad based AAC System used in this study	Tobii Dynavox Compass
IA, Age, Experience in Schools	Leslie, 44, 11 years total experience, with 7 years experience as an Instructional Assistant at the elementary level and 4 years at the secondary level.

Table 1d. Student (Claire) Participant and Instructional Assistant Characteristics.

Student Name, Gender, Age	Claire, Female, 15 years
Disability	Intellectual Disability, Cerebral Palsy
Communication	Limited intelligible speech (<50 words), access to mid-tech GoTalk 20+ device lacking robust language. Uses gestures, vocalizations, modified sign language to communicate wants and needs. Exhibits aggressive behavior (hitting, kicking, grabbing, biting) when frustrated or anxious.
iPad based AAC System used in this study	Proloquo2Go
IA, Age, Experience in Schools	Vanessa, 52, 9 years total experience, with 7 years worked as a licensed elementary school teacher

Independent Variables and Treatment fidelity

This study's independent measures included (a) introduction of an iPad based AAC system, (b) use of a low- or high-tech book of high interest based on preference assessment and (c) Instructional Assistant training in the MODELER for Read and Talk strategy plus in-session coaching. The specific AAC system was decided based on the system currently in place and programs previously discussed and agreed upon by the IEP team.

Table 2. MODELER for Read and Talk Implementation Elements (adapted from Sennott & Mason)

Strategy Step	**Description**
Model	IA models one or more AAC symbols during the communication turn, using the iPad-based AAC system as they are speaking.
Encourage	IA provides a time delay or wait time until child takes a communication turn or 5-15 seconds.
Respond	IA responds to the student communication turn verbally, or with an AAC recast by repeating some portion of the student's utterance and models one or more AAC symbols during a communication turn using the iPad based AAC system
Read	IA reads a page or page spread in the book and uses MODELER
Talk	IA makes a comment or asks a question using MODELER

Dependent Variables

The study’s dependent measures included (a) IA communication turns using MODELER for Read and Talk and (b) student communication turns in any modality. For the purposes of this study, IA communication turns were scored as including an AAC model defined as IA activation of at least one AAC iPad icon, combined with verbal communication. The definition of student communication turns was adopted from Sennott and Mason. Student communication turns were defined as the student engaging in communication through one or more of the following modalities, (a) gesture, (b) speech or vocalization, (c) method of communication that may be unconventional but had been taught as acceptable prior to the commencement of this study. All communication turns needed to be intentional and did not include accidental activation of the iPad icons. Approximately 20% of sessions were scored for reliability by a second trained graduate student scorer and maintained at or above the 80% level for inter-rater reliability. See table 3.

Intervention Procedures

Baseline

During baseline, the student participant and identified adult IA engaged in shared storybook reading, using either an iPad based online book involving a highly preferred topic, or a low-tech paper book previously selected by the student. All participants were asked to proceed with the task as they would on the normal occasion. If an AAC device was commonly used with the student, the device would be included in the baseline session. All participants participated in at least three baseline sessions prior to initiation of intervention phase.

Intervention, Training, and Coaching

The intervention phase began with a 30 to 45-minute session in which the interventionist trained and coached the student participant and adult IA, using MODELER for Read and Talk. A visual, conceptual model was presented at this initial training (figure 1). The training and introduction was conducted in one session, while coaching continued for at least three subsequent sessions. Following the training session, the IA resumed shared storybook reading while being coached by the interventionist and practicing MODELER for Read and Talk. The MODELER for Read and Talk instructional training was presented in a practical fashion, with all components modeled with the student, by the interventionist. Each of the MODELER steps were explained by the interventionist and then modeled with the student. For example, the interventionist would verbally ask the student participant or IA “How are you feeling today?,” both verbally and by modeling AAC (Model). The interventionist then discussed the importance of wait time and provided at least 5 seconds before initiating another communication turn (encourage). The interventionist then responded with, "I feel excited today" verbally and with modeled AAC (respond). As was done in the Sennott & Mason initial MODELER study, it was emphasized that the MODELER steps can be used flexibly, either independently or in sequence. The IA's were also coached that the expectation was not for every spoken word to be modeled, but for at least one or two keywords to be spoken and paired with AAC. They were also coached that this instructional package was intended to be as natural in delivery as possible. Language was to be modeled as a conversational turn, not just an instructional prompt. For example, if a student gestures that they want a ball, the correct instructional response would be, "Oh! You want the ball?" while modeling "you want ball" on the AAC device, instead of prompting something such as "say, 'I want ball." It was coached that the intent of MODELER is for the verbal communication partner to also use the AAC device as their own voice. Prior to the commencement of the intervention session, the student participant was given the option of three to five iPad-based books involving preferred topics, previously identified through preference assessment. All intervention sessions lasted at least 10 minutes. Student engagement and required processing time varied by participant.

Discussion

IA Performance

The results for study question one that targets the performance of the IAs in learning to provide an increased number of AAC models in response to the MODELER training and coaching are reported. IA's consistently demonstrated an immediate level change from a zero mean baseline and a high percentage of non-overlapping data (PND), all with an upward trend to the number of AAC models during intervention.

Table 3. Student Communication Turn Descriptions (adopted from Sennott & Mason, 2015).

Turn Type	**Description**
Total communication turns	Communication turns are defined as use of the AAC system, vocalization or speech, or a gesture (i.e pointing, motioning). A turn is considered finished by the communication partner taking a turn or a pause of more than 5 seconds and a change of communication focus. Communication turns can include more than one modality (i.e a turn with a gesture and AAC system activation). Only communication turns related to the shared storybook reading were coded (i.e. not turns such as pointing to an object in the room or requesting a preferred activity or item).
AAC	Student uses the AAC system by activating a vocabulary item. Navigational items were not coded as an iPad AAC turn.
Gesture	Student uses a gesture (i.e. pointing at a picture in the book)
Speech	Student makes a communicative vocalization or speaks words.

Sydney. From baseline to intervention, Sydney made a large overall level increase in use of the MODELER for Read and Talk strategy with a steady upward trend in AAC models during intervention. At baseline, Sydney was performing a very low number of AAC models, with a mean of 0 steps per session. During intervention, Sydney's use of AAC modeling increased to a mean of 8.26 with 100% non-overlapping data.

Molly. Molly also demonstrated a large level increase in use of AAC models from baseline to intervention. At baseline, Molly was also performing a very low number of MODELER steps, with a mean of 0 AAC models per session. During intervention, Molly's use of AAC Modeling increased to a mean of 6.17 with 100% non-overlapping data.

Leslie. Leslie demonstrated a large level increase in AAC models with an upward trend to the data. At baseline, Leslie was performing a a mean of 0 AAC models steps per session. During intervention, Leslie's use increased to a mean of 7.21 with 100% non-overlapping data.

Vanessa. Vanessa made a level increase in AAC models across two out of three intervention sessions, when compared to baseline. She was unable to adequately participate in intervention session two due to escalation in student challenging behavior. At baseline, Vanessa was performing a mean of 0 AAC models. During intervention, Vanessa's use increased to a mean of 7.19 with 67% non-overlapping data.

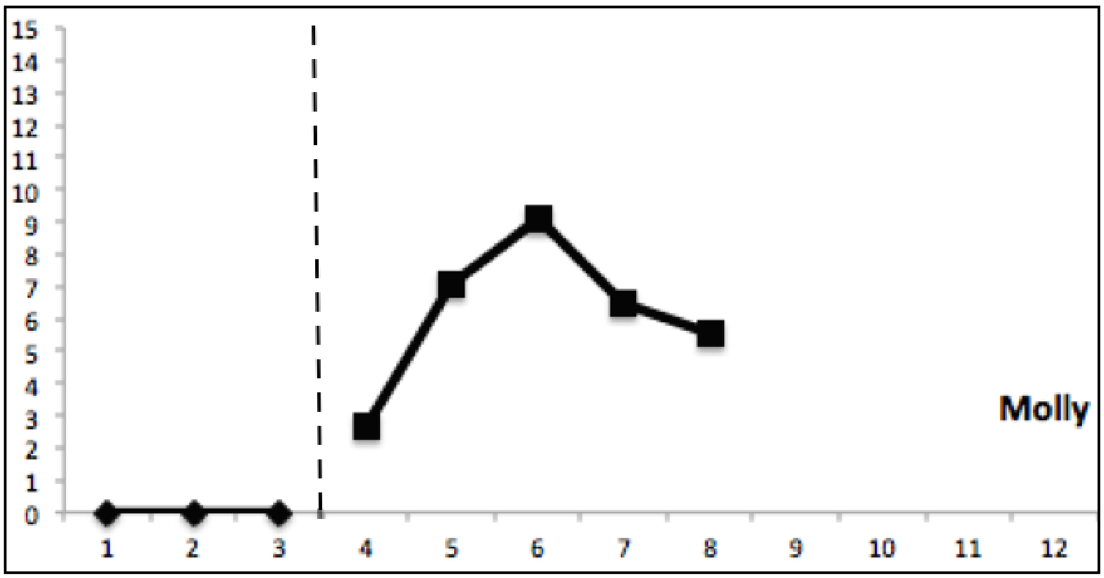

Fig. 2a. (Molly) Number of Communication Turns with AAC Models Provided by IAs per 10 Minutes. **X axis**: Sessions **Y axis:** Number of IA MODELER Turns per 10 Minutes.

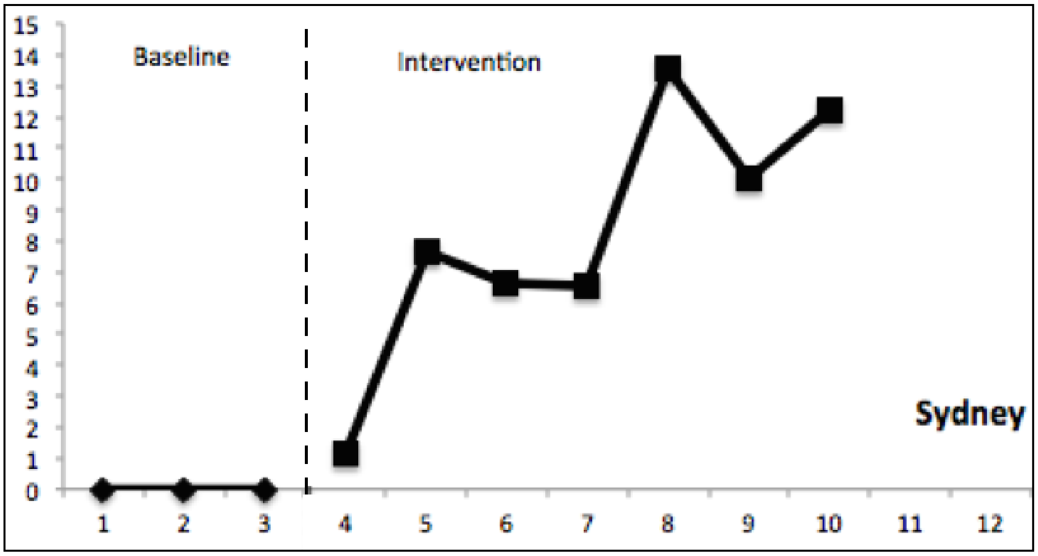

Fig. 2b. (Sydney) Number of Communication Turns with AAC Models Provided by IAs per 10 Minutes. **X axis**: Sessions **Y axis:** Number of IA MODELER Turns per 10 Minutes.

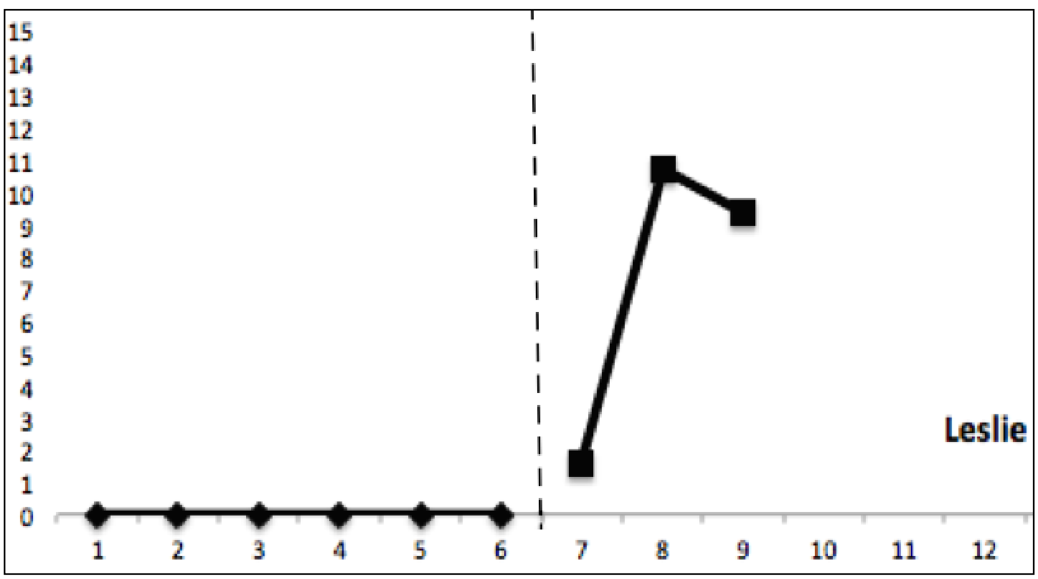

Fig. 2c. (Leslie) Number of Communication Turns with AAC Models Provided by IAs per 10 Minutes. **X axis**: Sessions **Y axis:** Number of IA MODELER Turns per 10 Minutes.

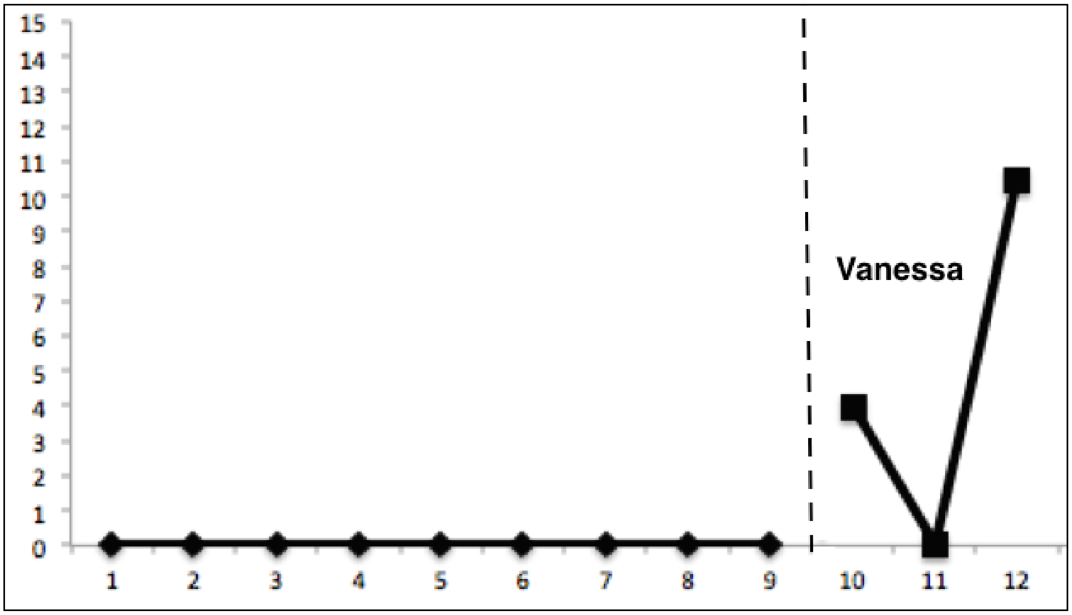

Fig. 2d. (Vanessa) Number of Communication Turns with AAC Models Provided by IAs per 10 Minutes. **X axis**: Sessions **Y axis:** Number of IA MODELER Turns per 10 Minutes.

Student Communication Performance

Student communication performance is reported in Figure 3, demonstrating immediate and large level changes in communication turns from baseline for three of four participants.

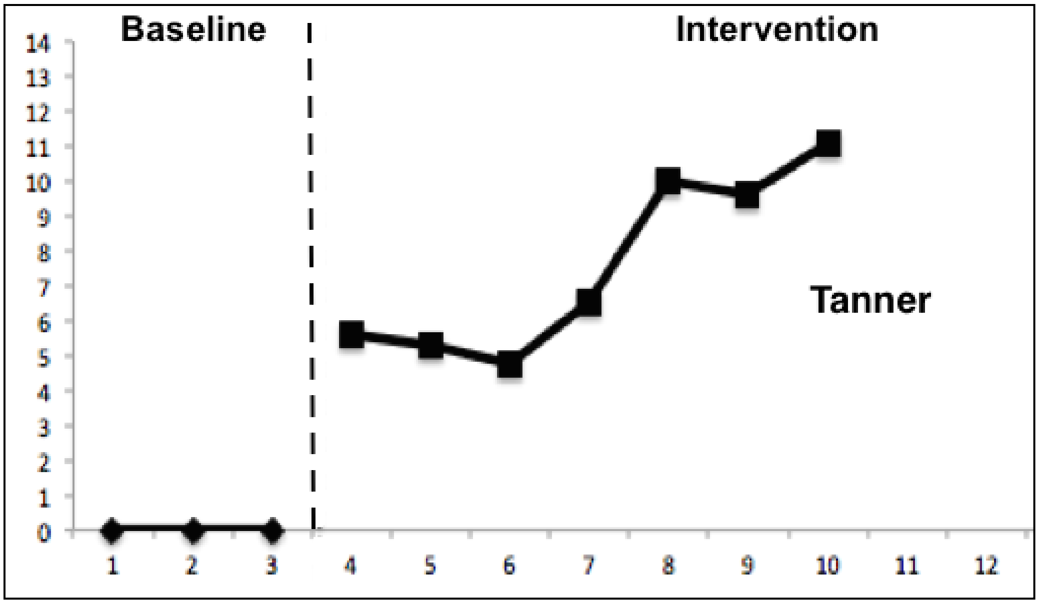

Fig. 3a. (Tanner) Frequency of communication turns per 10 minutes.

X Axis: Session Y Axis: Number of Communication Turns per 10 Minutes.

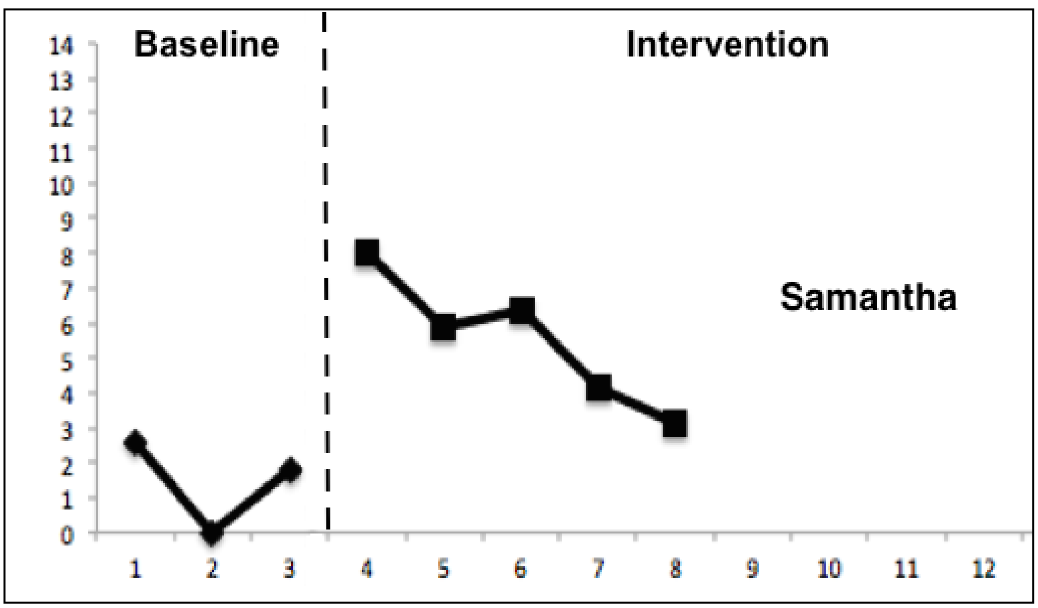

Fig. 3b. (Samantha) Frequency of communication turns per 10 minutes.

X Axis: Session Y Axis: Number of Communication Turns per 10 Minutes.

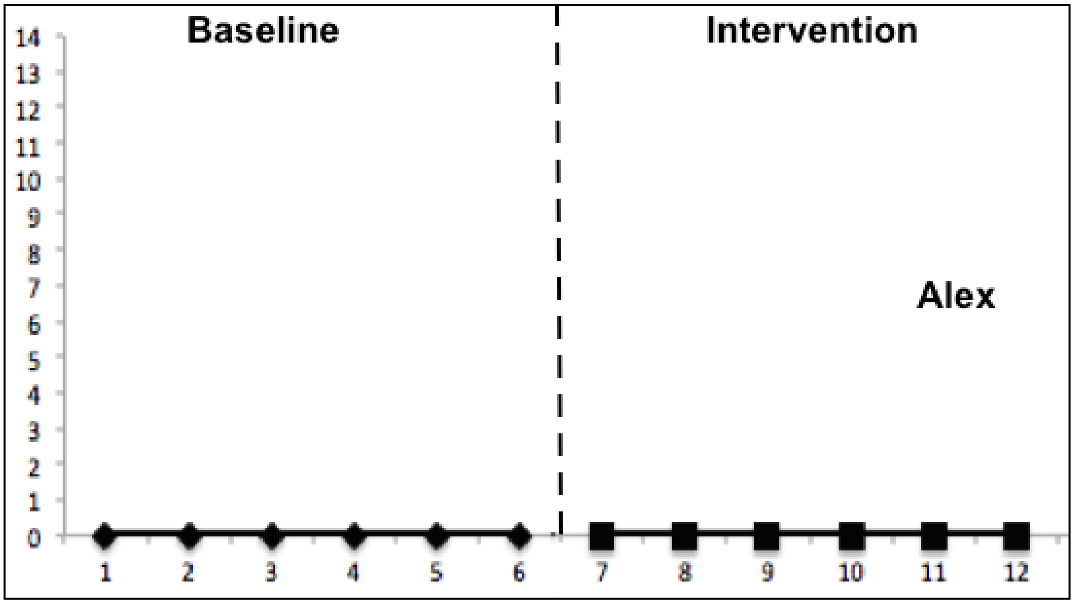

Fig. 3c. (Alex) Frequency of communication turns per 10 minutes.

X Axis: Session Y Axis: Number of Communication Turns per 10 Minutes.

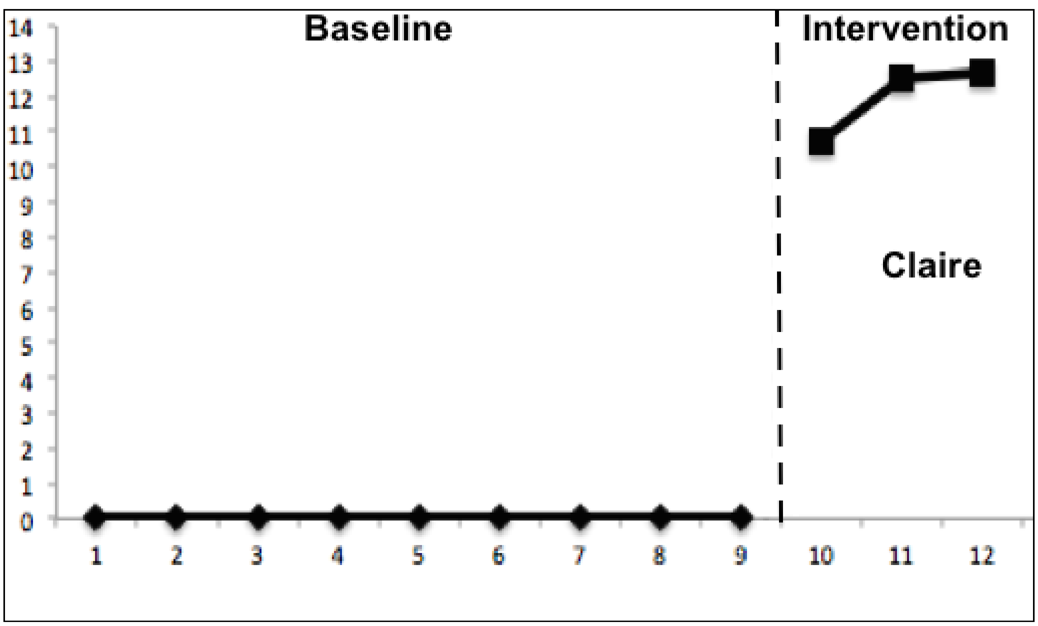

Fig. 3d. (Claire) Frequency of communication turns per 10 minutes.

X Axis: Session Y Axis: Number of Communication Turns per 10 Minutes.

Tanner. Tanner increased in level for the total number of communication turns taken from baseline to intervention. This included use of both gestural and AAC modalities. At baseline, Tanner was taking a very low number of communication turns with a mean of 0 turns per 10-minute session. During intervention, Tanner's number of communication turns increased to a mean of 7.54 per 10-minute session with 100% non-overlapping data.

Samantha. Samantha also increased in level for the total number of communication turns taken from baseline to intervention. At baseline, Samantha was taking a low number of communication turns with a mean of 1.47. Despite the presence of a speech-generating AAC device, these turns were all gestural in nature. During intervention, Samantha's level of communication turns per 10-minute session increased to a mean of 5.49 with 100% non-overlapping data.

Alex. Alex did not increase in level for the total number of communication turns from baseline to intervention, regardless of modality. At baseline, Alex was taking a very low number of communication turns with a mean of 0. During intervention, Alex's level of communication turns per 10-minute session maintained with a mean of 0 with 0% non-overlapping data.

Claire. Claire increased significantly in level for the total number of communication turns taken from baseline to intervention. This included the use of gestural and AAC modalities. At baseline, Claire was taking a very low number of communication turns with a mean of 0. During intervention, Claire's level of communication turns taken per ten-minute session increased with a mean of 11.97 with 100% non-overlapping data.

Conclusions

This study demonstrated that paraprofessionals who had previously received little AAC intervention training could be coached by a special educator to provide impactful interventions in just a few sessions. The positive outcomes also demonstrate promise that young adults who are still beginning communicators can respond to naturalistic AAC interventions that create an AAC immersion like environment where people are talking to them using the same communication modality that they use. The implications for practice from this study can be summed up by one of the participating para-professionals statements just after an intervention session, “I’ve never seen him communicate more in his life!” It can be concluded that while much assistive technology was present in the environment of the students, it was only when their communication partners were provided with training and coaching that the technology became impactful in their lives. The message for parents, teachers, and administrators alike is to not give up on older beginning communicators with CCN, but instead be sure that the language acquisition environment is rich, filled with engaging input and interaction. This study points to teacher and paraprofessional communication partner training and empowerment as important steps towards that aim, matching the findings of the recent meta-analysis on partner communication training (Kent-Walsh, et al.).

Yet, caution must be taken when interpreting these positive findings in light of the study’s non-concurrent multiple baseline design. Future research that fully adheres to the Institute of Educational Sciences single case design standards is warranted. Future research is also needed that investigates naturalistic AAC interventions across multiple communication partners, contexts, and over longer periods of time.

Works Cited

Beukelman, David., and Mirenda, Pat. "Augmentative and Alternative Communication: Supporting Children and Adults with Complex Communication Needs (4th ed.)." Brookes Publishing, 2013.

Hanser, Gretchen A., and Karen A. Erickson. "Integrated Word Identification and Communication Instruction for Students With Complex Communication Needs." *Focus on Autism and Other Developmental Disabilities*, vol. 22, no. 4, 2007, pp. 268 –278.

Kent-Walsh, Jennifer, et al. "Effects of Communication Partner Instruction on the Communication of Individuals Using AAC: A Meta-analysis." *Augmentative and Alternative Communication*. vol. 31, no. 4, 2015, pp. 271-284.

Kratochwill, T. R., et al. "Single-case Design Technical Documentation." 2010, Retrieved from: http://ies.ed.gov/ncee/wwc/Docs/ReferenceResources/wwc_scd.pdf

Romski, MaryAnn et al. "Early Intervention and AAC: What a Difference 30 Years Makes." *Augmentative and Alternative Communication*, vol. 31, no. 3, 2015, pp. 181–202.

Sennott, Samuel C., and Mason, Linda H.. "AAC Modeling With the iPad During Shared Storybook Reading Pilot Study." *Communication Disorders Quarterly*, vol. 37, no. 4, 2016, pp. 242–254.

Sennott, Samuel C., Janice C. Light, and David McNaughton. "AAC Modeling Intervention Research Review." *Research and Practice for Persons with Severe Disabilities*, vol. 41, no. 2, 2016, pp. 101–115.

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MODELER AAC Coaching Intervention with an iPad During Shared Reading and Play in Early Childhood as Multiple Means of Action and Expression

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Abstract

The purpose of this study was to examine the impact of teacher coaching and augmentative and alternative communication (AAC) modeling using an Apple iPad, during the implementation of Model, Encourage, Respond (MODELER) for Read and Talk and Play and Talk for children with complex communication needs (CCN). The study assessed the results of AAC teacher modeling, using a single-case multiple baseline design. The AAC intervention took place in an inclusive early childhood setting, and included three child participants, and three teacher and student teacher participants. Results indicate significant gains in AAC modeling by teachers.

Keywords

Augmentative and alternative communication, assistive technology, AAC modeling, iPad

Introduction

Inclusion in the expressive communication experiences of early childhood is important. For many children who are able to speak and communicate competently, participation in early childhood classroom environments is easily accessed. However, for children with complex communication needs (CCN), who cannot fully use speech, communication with peers, and engagement with classroom activities remains challenging (Beukelman & Mirenda; Romski, Sevcik, Barton-Hulsey, & Whitmore). Throughout the past few decades, early childhood programs in the United States have steadily moved towards inclusive models of education (Odom, Buysee, & Soukakou). Yet, unfortunately many of these children continue to have difficulty engaging with peers and activities within the classroom environment due to a lack of communication skills.

Universal Design for Learning in Early Childhood

Universal Design for Learning (UDL) has emerged as a promising organizational framework for helping educational teams include children with CCN (Stockall, Dennis, & Miller). The framework advocates learning environments be made accessible through providing: (a) *multiple means of representation*, (b) *multiple means of action and expression*; and (c) *multiple means of engagement*. While all three elements of UDL are important, multiple means of action and expression emerges as a key area of need for children with CCN.

AAC as Multiple Means of Action and Expression.

For children with CCN, who may not be able to communicate fully using speech, *Augmentative and Alternative Communication* (AAC) affords the ability to use multiple modalities to communicate such as speech, gestures, sign language, writing, and symbol-based paper or computer systems (Beukelman & Mirenda). The Apple iPad has emerged as an extremely popular AAC tool in the field through combining it with speech synthesis apps (Mirenda). Chai, Vail, and Ayers noted that when used appropriately, technology can assist students with disabilities in participating in the same activities as their typically developing peers. AAC can help provide a solid foundation in which children can develop their spoken language comprehension, as well as create a platform for expressive communication growth during a child's preschool and early elementary years (Romski and Sevcik; Romski, et al.). Despite the popularity of the iPad and other mobile technologies in both American culture and in AAC, we frequently encounter early childhood education providers who lack knowledge and skill in AAC intervention.

Communication Partner Coaching to Close Skill Gaps

Communication partner coaching holds the potential to create a mechanism of change through impacting the intervention performance of the communication partners that interact with young children with CCN (Kent-Walsh, Murza, Malani, and Binger; Sennott, Light, & McNaughton). AAC modeling is a fundamental component of AAC intervention in early childhood that has demonstrated positive results across communication turn taking, vocabulary building, multi-turn communication utterance, and morphology skills (Mirenda; Sennott, Light, & McNaughton). "The increase in AAC modeling combined with speech turns provides language input to children who require AAC to communicate, which better matches the way they communicate expressively" (Sennott & Mason, p. 11). This in turn positively impacts the child's expressive communication in the form of increased communication turns.

Discussion

Study Research Questions and Design

In order to further explore the impact that teacher coaching has on AAC intervention for children with CCN in early childhood, this research study examined the following questions:

1. What is the impact of utilizing the MODELER for Read and Talk and MODELER for Play and Talk strategy instructional packages on the frequency of teacher AAC modeling while using an AAC iPad-based system with children in preschool? (see figure 1)
2. What is the feasibility of pre-service early interventionists implementing the MODELER intervention piloting a technology supported coaching system during AAC intervention?

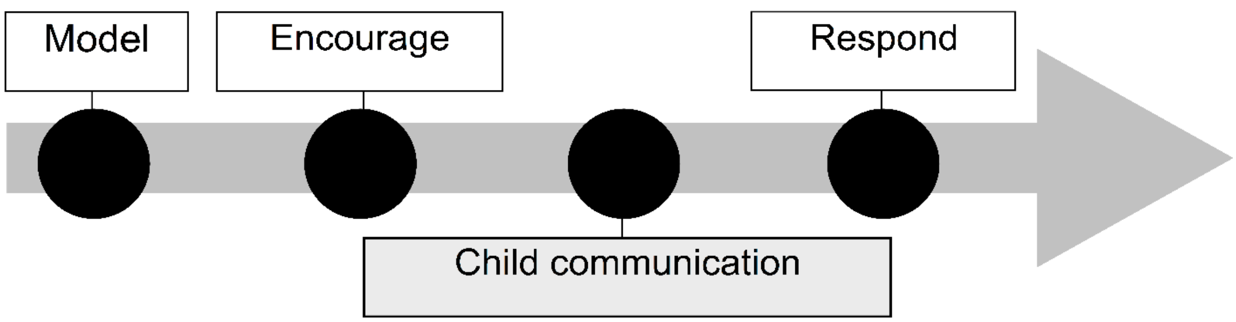

Fig. 1. MODELER AAC intervention strategy.

This study used a single case design (SCD). Specifically, this study used a combination design that included a single case multiple baseline, multiple probe design combined with an alternating treatment design (Kratochwill et al.). The alternating treatment consisted of interventions focused on reading and play. Within a 10-minute session, five minutes were devoted to a reading session and five were devoted to a play session. Randomization of session order was applied in the form of a coin flip. Additionally, a blocking strategy was used so that if there were two sessions in a row that began with the same activity, the alternate activity was to be first during the following session. The study's dependent measure was the teacher's AAC modeling communication utilizing an AAC device based upon the strategies outlined in the MODELER for Read and Talk strategy instructional package (Sennott & Mason). An AAC model in this study is defined as the teacher using one or more AAC symbols as they speak an utterance during a communication turn using the iPad-based AAC system.

Setting and Participants

The study was conducted in a Reggio Emilia inclusive early childhood education center located in an urban area in the USA. The inclusion criteria child participants included: (a) children aged 3 through 5 years; (b) had severe speech impairment as evidenced by no intelligible speech production or a repertoire of fewer than 50 intelligible spoken words. The inclusion criteria for the communication partners included: (a) works with the child regularly (typically at least 3 times per week) and (b) had worked with the child for longer than 4 weeks. Intervention coaches were three pre-service early intervention Master's students.

Jessie and Ali.

Jessie, the teacher of Ali, has a Master's Degree and twenty years of teaching experience working with children of varying ages and level of ability. Jessie has worked in many inclusive educational environments, and had experience with children with disabilities. Previous to the study, Jessie worked with one student who used AAC, but had not received any formal education of the use of AAC. Ali, a five-year, two month-old female child, was diagnosed with a genetic condition called Hypomelanosis of Ito, developmental delay, and seizure activity. In addition, Ali also has visual and hearing impairments for which she wears glasses and a hearing aide in her left ear. Though Ali vocalizes, sings, and talks frequently, little of what she says in intelligible. Previous to the study, Ali was introduced to AAC when she was three years old; however, her mother reports that the intervention was not successful.

Ellen and Nolan.

Ellen, the teacher of Nola, had a Master's Degree and six years of experience teaching young children. She had other experience working with children with disabilities, but prior to this study did not have any experience utilizing an AAC device. Nolan, is a 3-year-old male with a medical diagnosis of autism spectrum disorder. Nolan was officially diagnosed with autism within the six months prior to the start of the study. During the implementation of the study, he received applied behavioral analysis (ABA) therapy five days a week and was served by a speech-language pathologist one time a week in his early childhood classroom.

Chris and Wyatt.

Chris was an undergraduate student teacher who has been working with children for two and a half years. Chris has been at his current position as a student teacher for two years. Chris has been working with Wyatt in the classroom for six months, and has never used AT or AAC interventions. Wyatt is a 3 year an 11-month old male with a medical diagnosis of cerebral palsy. Wyatt uses a walker for independent mobility, and has vision impairments that require the use of glasses. Wyatt has worked with AAC devices with his specialists, however his family reported that Wyatt has had little interest in using the various devices.

Methods

Table 1. MODELER for Read and Talk + Play and Talk Implementation Elements (adapted from Sennott & Mason).

Strategy Step	**Description**
Model	Teacher models one or more AAC symbols during the communication turn, using the iPad-based AAC system as they are speaking.
Encourage	Teacher provides a time delay or wait time until child takes a communication turn or 5-15 seconds.
Respond	Teacher responds to the student communication turn verbally, or with an AAC recast by repeating some portion of the student's utterance and models one or more AAC symbols during a communication turn using the iPad based AAC system
Read	Teacher reads a page or page spread in the book and uses MODELER
Play	Teacher engages in a play behavior and uses MODELER
Talk	Teacher makes a comment or asks a question using MODELER

Baseline

At the beginning of the reading portion of the session, the child was instructed to choose one of four books provided. Similarly, at the beginning of the play activity, the child was instructed to choose one of four play sets containing play materials adapted from the books utilized in the study. The teacher was given the direction to read or play with the student as they normally would for five minutes for each activity using the materials provided. Each of the sessions lasted approximately 10 minutes in duration and were coded for analysis. The investigator video recorded the session.

Intervention

After four (Ellen) or five (Jessie and Chris) stable baseline points for each teacher were obtained, training of MODELER began (see Table 1). The intervention phase is based on providing a six-part strategy instructional model that emphasizes coaching as the most important element. The MODELER for Read and Talk and MODELER for Play and Talk strategy instructional training (Sennott; Sennott and Mason) included the following steps: (1) develop background knowledge, (2) discuss MODELER for Read and Talk, (3) model MODELER for Read and Talk, (4) memorize MODELER for Read and Talk, (5) support MODELER for Read and Talk, and (6) independent performance of MODELER for Read and Talk. First, an initial training was conducted, that covered steps one to five. The materials used for this included an iPad running a training software and a speech-generating device with book specific activity boards, and a children's story book. For all participants, the initial training lasted 90 minutes.

The first phase of intervention sessions focused on the pre-service early interventionist providing a model of an intervention session. Added to the table were two iPads were equipped with Proloquo2Go communication software that included a core vocabulary, plus topic based fringe words. At the beginning of each model session, the teacher used an iPhone to complete a Google Forms based online check-in form rating his or her level of initial preparedness to implement the MODELER instructional approach (see Figure 2). Though the investigator led the model sessions, the teachers were able to participate in these sessions depending upon their level of comfort. At the end of the session, the teacher again used an iPhone to fill out the online check-out form rating their performance during the model session (see Figure 3). During the second phase of intervention, the teacher led each session utilizing the MODELER for Read and Talk and Play and Talk intervention. The investigator (coach) provided supportive and informative feedback during the session (Sennott & Mason). Specific feedback included comments such as "nice model," and in some cases, a redirecting comment such as "great work, remember to encourage before that model." In addition, the coach worked to fade the feedback provided.

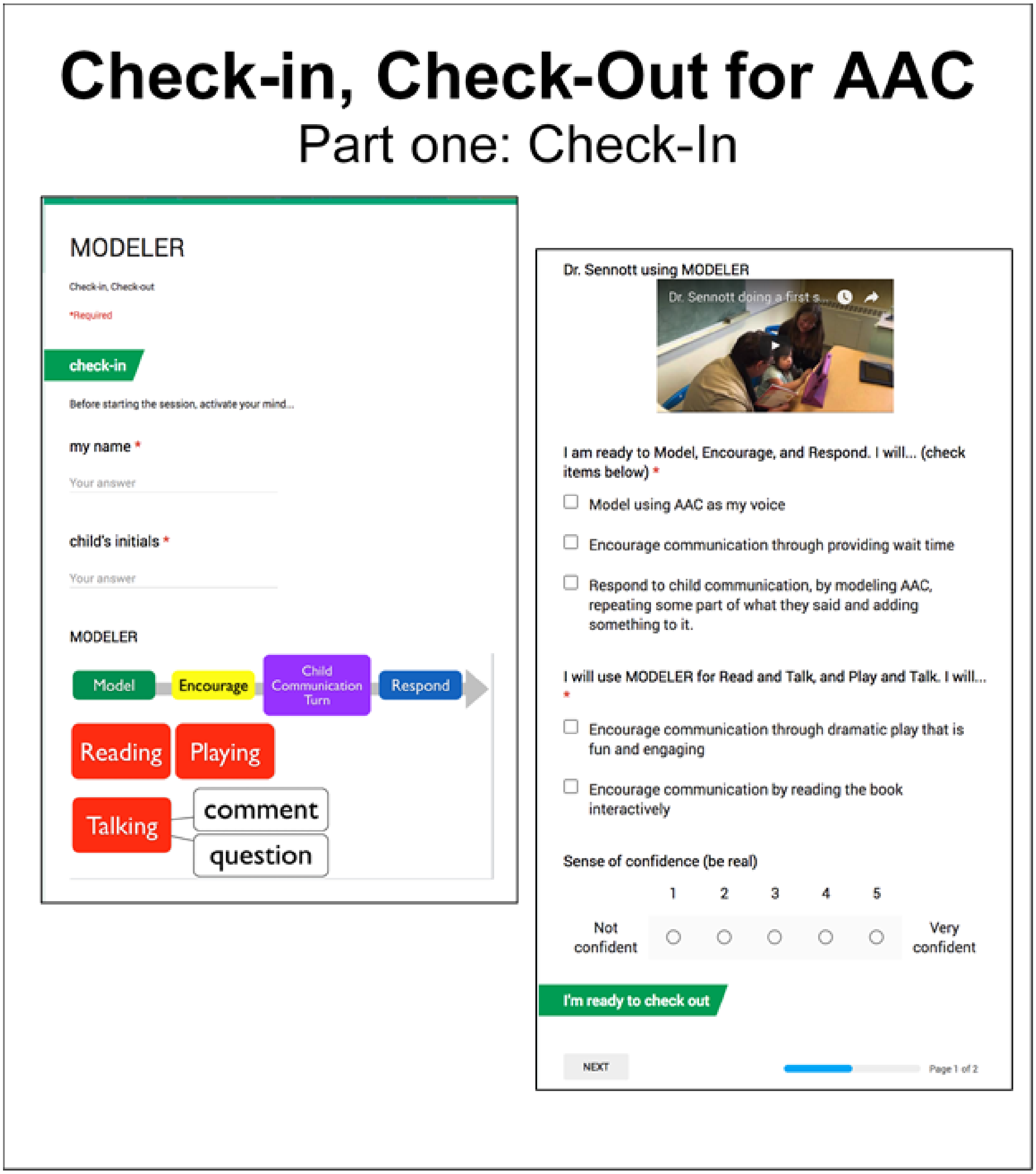

Fig. 2. Check-in for before the intervention session, powered by Google Forms.

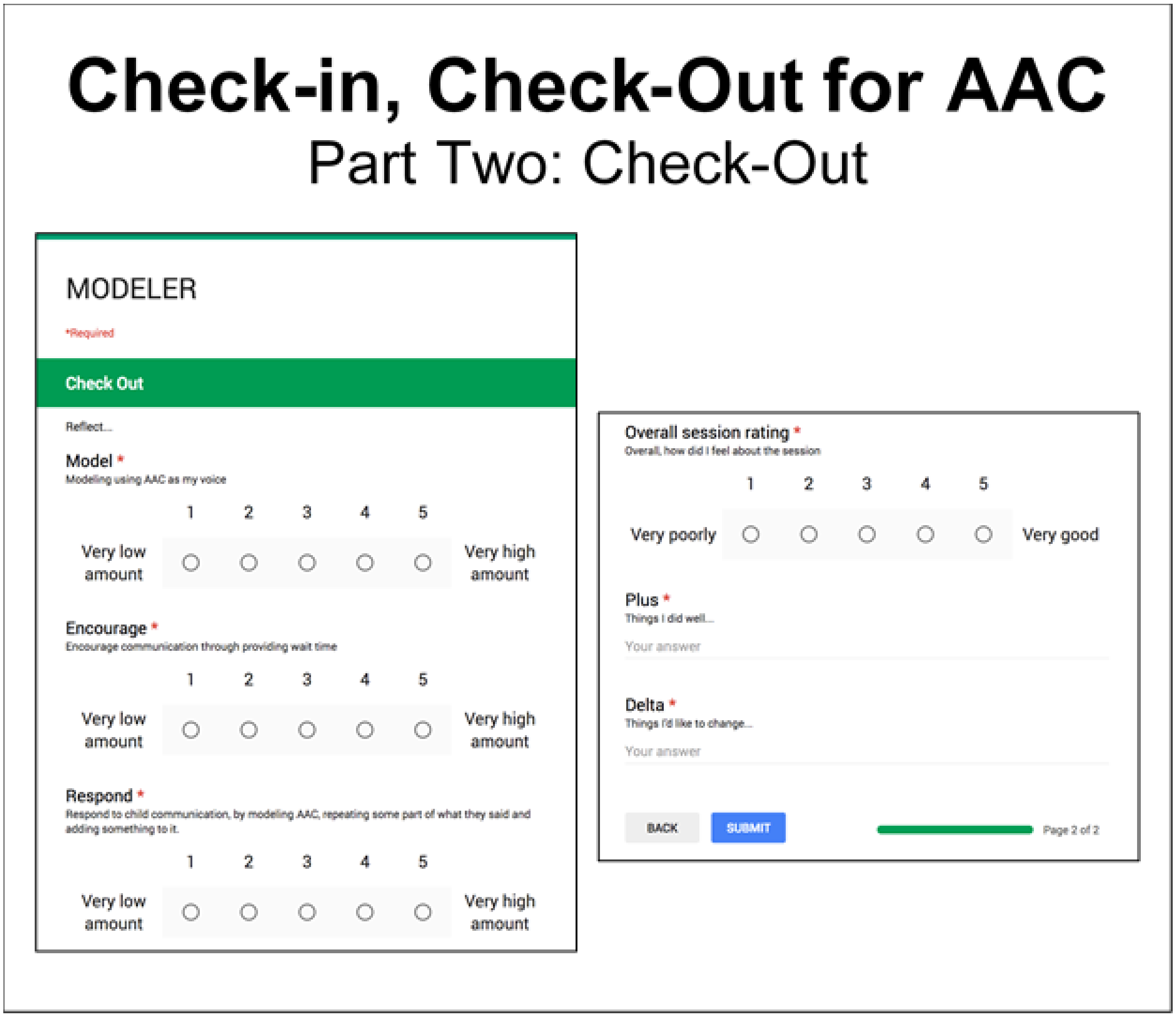

Fig. 3. Check-out for after the intervention session, powered by Google Forms

Post-Intervention

After the completion of the model and coached sessions, each teacher and student entered into the post-intervention phase. The post intervention phase consisted of independent performance of the MODELER for Read and Talk and Play and Talk strategies in the context of both reading and play. This completed the sixth step in the strategy instructional model. At this point, the teacher reached independence and investigator did not interfere with the session through giving constructive feedback. Three post-intervention data points were acquired for each of the three student participants.

Scoring and Data Analysis

To code for the study measures, each shared reading and play session were videotaped with the camera positioned so that the student and teacher and use of the AAC communication system could be seen. Coding of the data was conducted using the StudioCode software. Each pre-service early interventionist investigator independently watched and coded the videos for their focus child. At least 20% of the videos were scored by a second rater, maintaining at least 80% inter-rater reliability. Data was scaled per minute using the following criteria: 0 = No instances of AAC modeling, 1 = Few instances of AAC modeling (< 1 per minute), 2 = Some instances of AAC modeling (< 3 per minute), 3 = Many instances of AAC modeling. (> 3 per minute).

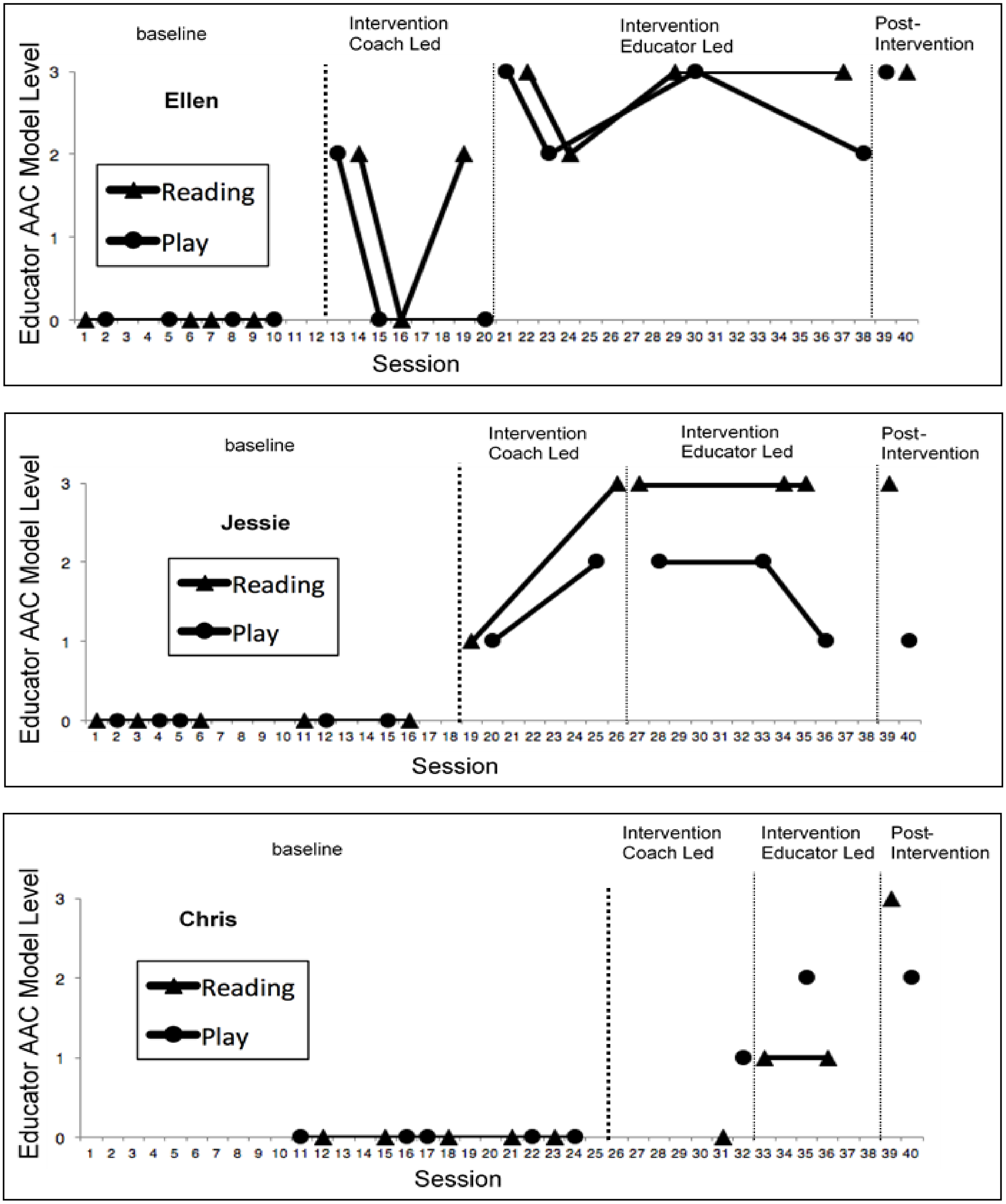

Fig. 4. The level of educator AAC models. *Note:* 0 = No AAC models, 1 = Few AAC Models (< 1 per minute), 2 = Some AAC Models (< 3 per minute), 3 = Many AAC Models (> 3 per minute)

Results

The graph in Figure 4 displays the AAC modeling performance results from all three participants, during both reading and play. During baseline, all three participants were not modeling AAC. For all three teachers, the data shows a predicted increase during the coach led intervention phase, with an even greater level gain during the educator led intervention phase when they are leading the session. All three teachers maintain the gains during the fully independent post-intervention phase, displaying a large number of AAC models.

Ellen demonstrated increased performance in AAC modeling through each phase of intervention and post-intervention. As observed across phases, at baseline Ellen did not initiate communication with Nolan to the extent at which she did in the intervention phase. After the MODELER coaching, Ellen began scaffolding communication attempts and encouraged communication. Anecdotally, Nolan increased his attempts as communication and engagement.

Chris, the student teacher, demonstrated growth in his ability to implement AAC modeling during shared storybook reading and play. During baseline, communication turns and engagement were limited between Chris and Wyatt. The AAC device served as a way for Chris to interact with Wyatt, which created a shared communication experience. Wyatt made gains in his communication turns during intervention and post-intervention.

Jessie made meaningful gains in her ability to model using the AAC device. During the first intervention session, Jessie engaged in only a few instances of modeling; however, by the end of the intervention period Jessie demonstrated large numbers of AAC models on the device per session. Allie also made meaningful communication gains. During baseline, Allie made multiple attempts at communicating verbally; however, the majority of her verbal communication was unintelligible. After the introduction of the communication device, Allie took multiple turns activating the device to communicate her thoughts, ideas, and feelings.

Conclusions

Through the duration of this study, each teacher demonstrated a marked increase in his or her ability to implement AAC modeling during shared storybook reading and play. In addition, the investigators utilized this intervention as a dynamic assessment of each of the student's AAC needs. The incorporation of the Check-in, Check-Out for AAC procedure allowed both activation and reminder of the intervention and an efficient data collection method that appears to be clinically feasible. This dynamic assessment allowed us to gain insight into what additional supports or alternations to AAC supports are necessary in order for the student to effectively access his or her AAC device and communicate that to the children's support teams.

Though positive results for increased teacher AAC intervention performance were achieved, the results must be considered in light of various limitations. First, it should be noted that the researchers were Master's candidates in the field of early intervention/early childhood special education with a short time frame to plan, organize, and carry out the study. This limited the quantitative measurement to teacher performance. Future research should quantify the impact on child performance.

It is crucial that young children using AAC to communicate and interact, have access to appropriate educational supports that help create a rich language learning environment. Results demonstrated teachers creating a more immersive communication environment where children with CCN were given a means of expressive communication, and receive communicative input in an augmentative format that matches the way they communicate.

Works Cited

Beukelman, David., and Mirenda, Pat. "Augmentative and alternative communication: supporting children and adults with complex communication needs (4th ed.)." Brookes Publishing, 2013.

Chai, Zhen, Vail, Cynthia O., and Ayres, Kevin M.. "Using an iPad application to promote early literacy development in young children with disabilities." *Journal of Special Education* vol. 48, no. 4, 2015, pp. 268-278.

Kent-Walsh, Jennifer, et al. "Effects of communication partner instruction on the communication of individuals using AAC: A meta-analysis." *Augmentative and Alternative Communication*. vol. 31, no. 4, 2015, pp. 271-284.

Kratochwill, T. R., et al. "Single-case design technical documentation." 2010, Retrieved from: http://ies.ed.gov/ncee/wwc/Docs/ReferenceResources/wwc_scd.pdf

Mirenda, Pat. "Values, Practice, Science, and AAC." *Research and Practice for Persons with Severe Disabilities*, 2016.

Odom, Samuel L., Virginia Buysse, and Elena Soukakou. "Inclusion for young children with disabilities a quarter century of research perspectives." *Journal of Early Intervention*. vol. 33, no. 4. 2011. pp. 344-356.

Romski, MaryAnn, and Rose A. Sevcik. "Augmentative communication and early intervention: Myths and realities." *Infants & Young Children*. vol. 18, no. 3. 2005. pp. 174-185.

Romski, MaryAnn et al. "Early intervention and AAC: What a difference 30 years makes." *Augmentative and Alternative Communication*, vol. 31, no. 3, 2015, pp. 181–202.

Sennott, S., & Niemeijer, D. *Proloquo2Go* (Computer software). Assistiveware, 2008.

Sennott, Samuel C. Empowering children with complex communication needs to use iPad based AAC during shared storybook reading. Diss. The Pennsylvania State University, 2013.

Sennott, Samuel C., and Mason, Linda H. "AAC modeling with the iPad during shared storybook reading pilot study." *Communication Disorders Quarterly*, vol. 37, no. 4, 2016, pp. 242–254.

Sennott, Samuel C., Light, Janice C., and McNaughton, David. "AAC modeling intervention research review." *Research and Practice for Persons with Severe Disabilities*, vol. 41, no. 2, 2016, pp. 101–115.

Stockall, Nancy S., Lindsay Dennis, and Melinda Miller. "Right from the start: Universal design for preschool." *Teaching Exceptional Children* 45.1 (2012): 10.

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Tactile Detection by Blind People of Embossed Lines and Squares with Selected Dot Elevation

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Abstract

Dot elevation and dot density are two main variables that dominate the recognition and conceptualization of tactile embossed graphics by blind individuals. Nevertheless, few studies have investigated tactile sensitivity to the elevation (third dimension) of tactile graphics. In a pilot experiment we conducted recently using 8 dot elevations of embossed lines and squares, in 20 or 10 dpi, produced by a Tiger VP200 braille embosser, we observed that participants can detect only two highs with accuracy above 50%. We present here the results of an experimental study with 30 congenitally blind participants to investigate the detection accuracy of embossed tactile lines and squares in four selected dot elevations among the eight possible dot heights that can be produced by the VP200 embosser. A total of 1,920 responses were recorded. The detection accuracy and response time of the matching task were examined for each type of test stimuli. The results of correct and misclassified stimuli are presented in confusion matrixes for the raised-dot lines and squares stimuli. Moreover, the overall mean response time of the detection task is provided. We observed that in all cases, only the stimuli with the lower two heights H-1 and H-3 provide detection accuracy above 70%.

Keywords

Braille graphics, tactile graphics, embossed graphics, dot elevation, tactual readability

Introduction

Some of the current braille embossers permit a change in height of the dots when producing tactile graphics. The usage of embossed tactile graphics implies some benefits on their production process as well as on the end user usability. But often embossed graphics lack some of the characteristics of tactual readability. For example, embossed tactile graphics: (i) can be produced concurrently with the braille text, in the same paper sheet and using one machine, (ii) can be combined within a typical braille book, (iii) can mix easily braille text with the graphics during the production process, (iv) can be produced promptly in one step and (v) have a much lower cost compared to other common techniques like the stereo-copying technique or through the vacuum forming technique (thermoforming). On the other hand, embossed graphics often lack some of the characteristics of tactual readability, there is little variation in height, point symbols are difficult to discern, and the number of textures that can be produced is limited.

Dot density and dot elevation are two main variables that dominate the recognition and conceptualization of tactile embossed graphics by individuals with severe visual impairments (Krufka & Barner, 297-311). Guidelines and Standards for Tactile Graphics developed by the Braille Authority of North America (BANA/CBA) cover the design principles that must be followed in the production software of embossed graphics. Recently a number of software applications have been developed to automate the production process (Pather; Gardner, 417-420).

While research has shown that dot elevation influences detection and discrimination thresholds for tactile stimuli (Heler, 379-389) and that the physiological response of fingertip receptors varies with texture, little is known about the influence of these parameters on the detection of embossed stimuli with variable dot height and density. In a pilot experiment we conducted (Kouroupetroglou et al. 77-84) using eight dot elevations of embossed lines and squares produced by a Tiger VP200 braille embosser in 20 or 10 dpi we observed that participants can detect only two highs with accuracy above 50%. Based on the above, we present in the current work the results of an experimental study with 30 blind participants to investigate the detection accuracy of embossed tactile lines and squares in four only selected dot elevations among the eight possible dot heights that can be produced by the Tiger VP200 braille embosser.

Method

Thirty congenitally blind volunteers (11 male and 19 female) participated in the experiment. Their age ranged from 14 to 55 (mean= 30.87, SD=10.84). All of them learned to read and write braille from 5-18 years old and still remain active users of the braille code. None of the participants had any hearing impairment or other disability.

Two types of stimuli were used in the study: raised-dot lines (with a length of 7 cm) and raised-dot squares (2 X 2 cm). All stimuli were produced by a Tiger VP200 braille embosser in two densities (10 dpi and 20 dpi) on paper of 160 gr/m^2. The Tiger VP200 embosser can produce eight elevations of dots, from 0.25mm to 0.53mm (we represent each height as H-1 to H-8, starting from the lower elevation). We have selected heights H-1, H-3, H-5 and H-7 for both types of stimuli of the experiment. The target set includes the same four types of stimuli in multiples of 4 for each height (i.e. in total 16 target stimuli) in a random order.

Participants were briefed on the objectives of the study and verbal instructions were given. During the matching phase, participants were seated in front of a table. Tactile stimuli of one type and one density were given to them each time. They were asked to touch and feel one test stimulus of a specific height, randomly selected among the four elevations (H1, H3, H5 and H7) and then to detect, as fast and accurately as possible, the same 4 from the set of the 16 target stimuli placed on the table. The researcher recorded the matching stimuli and the time spent by the participants for the detection. The maximum number of answers was four and the maximum allowed detection time was 1 min. Thus, each identification trial ended after the participant announced that he has identified the 4 target stimuli (independently if the matching are correct or not) or after he/she has used up the maximum identification time. This procedure was repeated until all the four tactile stimuli of the same type were tested. The task was repeated two times for each type of test stimuli and for each dot density (in total four tasks).

Results

A total of 1,920 responses (30 participants X 16 matching stimuli X 2 types of test stimuli X 2 densities) were recorded. For each type of test stimuli we examined the detection accuracy and response time of the matching task.

The confusion matrixes for the raised-dot line and square stimuli in both 10 and 20 dpi are given in Tables 1-4 respectively, showing percentages of correctly matched (diagonal) and misclassified stimuli. The last column in Tables 1-4 provides the percentage of out-of-time (no response after the limit of 1 min for each trial) for the heights H-1, H-3, H-5 and H-7 for the cases of line and square stimuli respectively. Tables 5 and 6 give the overall mean response time (MRT) of the detection task for each height and type of test stimulus respectively, along with their standard deviation (SD) and range.

Table 1. Matrix of Matching Percentages (%) Between Test Stimuli (rows) and Target Stimuli (columns) for the Case of Raised-Dot Lines in 10 dpi

	H-1	H-3	H-5	H-7	Out-of-time
H-1	**95.0**	3.3			1.7
H-3		**91.7**	3.3	3.3	1.7
H-5		25.0	**46.7**	28.3	0.0
H-7		24.2	36.7	**38.3**	0.8

Table 2. Matrix of Matching Percentages (%) Between Test Stimuli (rows) and Target Stimuli (columns) for the Case of Raised-Dot Lines in 20 dpi

	H-1	H-3	H-5	H-7	Out-of-time
H-1	**93.3**	5.9			0.8
H-3		**85.0**	10.9	3.3	0.8
H-5		63.3	**21.7**	13.3	1.7
H-7		34.1	35.0	**29.2**	1.7

Table 3. Matrix of Matching Percentages (%) Between Test Stimuli (rows) and Target Stimuli (columns) for the Case of Raised-Dot Squares in 10 dpi

	H-1	H-3	H-5	H-7	Out-of-time
H-1	**96.7**	1.7	0.8		0.8
H-3		**81.7**	11.7	0.8	5.8
H-5		20.0	**40.8**	39.2	0.0
H-7	0.8	20.0	28.4	**50.0**	0.8

Table 4. Matrix of Matching Percentages (%) Between Test Stimuli (rows) and Target Stimuli (columns) for the Case of Raised-Dot Squares in 20 dpi

	H-1	H-3	H-5	H-7	Out-of-time
H-1	**94.1**	4.2			1.7
H-3		**70.8**	15.1	10.8	3.3
H-5		45.8	**27.5**	25.9	0.8
H-7		28.3	33.4	**38.3**	0.0

Table 5. Overall Mean Response Time (MRT) of the Detection Task with its Standard Deviation (SD) and Range for the Case of Raised-Dot Lines Stimuli in 10 dpi and 20 dpi

Height	10 dpi MRT sec	10 dpi SD sec	10dpi Range sec	20 dpi MRT sec	20 dpi SD sec	20dpi Range sec
H-1	24.5	12.2	10-59	17.4	7.3	8-39
H-3	32.2	10.8	15-58	31.1	11.6	12-49
H-5	31.2	13.7	9-59	27.6	9.4	9-53
H-7	33.5	13.0	11-59	31.6	11.1	12-54

Table 6. Overall Mean Response Time (MRT) of the Detection Task with its Standard Deviation (SD) and Range for the Case of Raised-Dot Squares Stimuli in 10 dpi and 20 dpi

Height	10 dpi MRT sec	10 dpi SD sec	10 dpi Range sec	20 dpi MRT sec	20 dpi SD sec	20 dpi Range sec
H-1	19.1	8.1	9-37	7.3	12.3	7-60
H-3	28.9	10.0	13-56	11.6	14.0	12-59
H-5	32.4	13.4	10-58	9.4	13.0	9-58
H-7	28.5	13.0	8-59	11.1	12.6	8-52

Discussion

From the results in Tables 1-4 we observed that, in all cases, only the stimuli with the lower two heights H-1 and H-3 provide detection accuracy above 70%. The highest detection accuracy was obtained with the H-1 elevation and it was above 93% in all instances. H-1 is confused only with H-3, except in 10 dpi raised squares where it is also confused with H-5. H-3, H-5 and H-7 are perplexed with at least another two elevations, but H-7 in 10 dpi raised squares with three. For the H-5 elevation, the detection accuracy for all cases was found in the range from 29.2% - 50%. The two lowest values were for H-5 in the case of 20 dpi raised-dot lines (21.7%) and 20 dpi raised-dot squares (27.5%). The maximum detection accuracy was found for the H-1 (96.7%) in raised-dot squares, followed by H-1 (95.0%) in raised-dot lines, both in 10 dpi. The minimum detection accuracy was found for the elevation of H-5 in the case of 20 dpi raised-dot lines (21.7%), followed by the case of 20 dpi raised-dot squares (27.5%). The order of the detection accuracy is H-1, H-3, H-7 and H-5 in every case, except the raised-dot lines in 10 dpi.

The overall out-of-time percentage was lower in raised-dot lines compared to raised-dot squares. Out-of-time percentage was less than 1.8% in all cases except in H-3 for the raised-dot squares in 10 dpi (5.8%) and in 20 dpi (3.3%). Results with not out out-of-time were obtained for the H-5 in 10 dpi raised-dot lines and squares and for the H-7 in 20 dpi raised-dot squares.

The overall mean response time (MRT) was lower in raised-dot squares compared to raised-dot lines for both 10 dpi and 20 dpi. The maximum MRT in 10 dpi was found for the H-7 (33.5 sec) in raised-dot lines, followed by H-5 (32.4 sec) in raised-dot squares. The minimum MRT in 20 dpi was found for the case of H-1 (7.3 sec) followed by H-5 (9.4 sec) both in raised-dot squares.

Conclusions

In our pilot study (Kouroupetroglou et al. 77-84) we observed that using eight dot elevations (H-1 to H-8) of embossed lines and squares produced by a Tiger VP200 braille embosser in 20 or 10 dpi, the participants who are blind can detect only two heights with an accuracy above 50%. Following that, we conducted in this work an experimental investigation with participants who are blind to address the identification of embossed tactile lines and squares in two densities (10 and 20 dpi) at four dot elevations (H-1, H-3, H-5 and H-7) selected among the eight of our pilot. We observed that in all cases, only the stimuli with the lower two heights H-1 and H-3 provide detection accuracy above 70%. In 20 dpi the detection accuracy was found as low as 21.7% for the raised-dot lines and 27.5% for the raised-dot squares, both in the case of H-5. Concerning the overall mean response time we found that it was lower in raised-dot squares compared to raised-dot lines for both 10 dpi and 20 dpi.

The results indicate that the selected elevations (H-1, H-3, H-5 and H-5) do not constitute an appropriate set of heights to be used in embossed tactile graphics in an effective way and thus further investigation is required. In order to extract practical implications, such as issues in education, as well as to help the designers to choose suitable design parameters for the tactile rendition of graphics or maps produced using embossed raised dots our planned activities include: a) the extension of the pilot study by including more participants who are blind and b) to study another selected set among the eight heights (e.g. H1, H2, H3 and H4)

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Works cited

BANA/CBA "Guidelines and Standards for Tactile Graphics." *The Braille Authority of North America*, 2010, http:// www.brailleauthority.org

Gardner, A. John. "Universally Accessible Figures." *Lecture Notes in Computer Science*, vol. 9758, 2016, pp. 417-420. doi 10.1007/978-3-319-41264-1_57.

Heller, A. Morton. "Picture and pattern perception in the sighted and the blind: the advantage of the late blind." *Perception*, vol. 18, no. 3, 1989, pp. 379-389. doi: 10.1068/p180379.

Kouroupetroglou, Georgios, Martos, Aineias, Papandreou, Nikolaos, Papadopoulos, Konstantinos, Argyropoulous, Vassilios, and Sideridis, D. Georgios. "Tactile Identification of Embossed Raised Lines and Raised Squares with Variable Dot Elevation by Persons Who Are Blind." *Lecture Notes in Computer Science*, vol. 9759, 2016, pp. 77-84. doi 10.1007/978-3-319-41267-2_11.

Krufka S.E., and Barner, K.E. "A user study on tactile graphic generation methods." *Behaviour and Information Technology*, vol. 25, no. 4, 2006, pp. 297-311.

Pather, B. Aquinas. "The innovative use of vector-based tactile graphics design software to automate the production of raised-line tactile graphics in accordance with BANA's newly adopted guidelines and standards for tactile graphics, 2010." *Journal of Blindness Innovation and Research*, vol. 4, no.1, 2014. doi http://dx.doi.org/10.5241/4-49.

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