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VR for ASD: Therapeutic Environments for Individuals on the Autism Spectrum

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Abstract

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder that affects individuals on a large spectrum; some of these individuals are considered high functioning while others while others experience significant impairments in that impact their ability to function in their daily lives. One such symptom is sensory overload due to hypersensitivity, which is often crippling for individuals across the autism spectrum. This study looked into the viability of using a virtual underground transit environment to help individuals grow accustomed to noises and lights and to help these individuals function even when they are hypersensitive to their surroundings. Seven adults, five diagnosed with high functioning autism and two diagnosed with more significant impairments, test the program. It was found that the heart rate of the individuals on the spectrum had decreased while experiencing the environment and they also face no virtual reality sickness. These findings suggest that virtual reality environments can be a therapeutic and effective training mechanism for improving cognition, adaptability, and functioning in autism.

Keywords

Autism Spectrum Disorder, Sensory Overloading, Social Interaction, Virtual Reality

Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder that is characterized by difficulties with social communication and interaction, verbal and nonverbal communication, and repetitive behaviors (Amir, et al, 1999). ASD affects individuals on a large spectrum (Lord, et al, 2000; Tsai, 1992; Rutter, 1978; Strickland, 1998; Bölte & Hallmayer, 2011); some people with high functioning ASD have little impact in their daily functioning while others experience significant impairments including little to no language skills and intellectual disability. Sensory overloading occurs when individuals diagnosed with ASD have difficulty processing everyday sensory information, which then in turn affects behavior by causing stress, anxiety, and even physical pain at times (The UK National Autistic Society, 2016; Hendricks & Wehman, 2009). The effects of hypersensitivity to sights, sounds, balance, and spatial awareness can be crippling when attempting to perform day-to-day activities. Studies in the past have quantified social cognition, and interpersonal functional skills over time, using an array of non-technological advanced methods, and have provided researchers with mixed results. The methods behind this sort of research have been predominantly broken down in the following categories: observational techniques (scenario based conversations) (Howlin & Yates, 1999), self-rated questionnaires (Hillier, et al, 2007), and the recording and quantification of social performance measures (Golan & Baron-Cohen, 2006). Though this portion of research on ASD has provided significant insights on the development of possible interventions, it is limited in that it fails to address concerns outside of group based social aptitude.

To address some concerns of testing individual independence, social interactions/behavior in a large group setting, and specifically independence in the group environment there has been a push to use virtual reality (VR) as a new generational intervention tool. VR has shown relative success in improving social competence and helping individuals develop coping mechanisms to diagnosed severe paranoia (Autism Speaker, 2014; Oxford University 2016; Freeman, et al, 2016). With recent developments in VR technologies, such as potable headsets, ASD research involving VR environments is dispersed. Early studies seem to be focusing on the utilization of VR by children/adolescents, diagnosed with ASD, as a way to develop social cognition skills from an early age. These early VR utilization studies focused on research ranging from teaching basic skills, such as street-crossing (Josman, et al 2008), to social interaction skills, such as emotion recognition and social convention (Cheng & Ye, 2010; Parsons, et al, 2004). These studies, using older VR technologies, demonstrated two different things at the time. First being that the overall hypothesis put forward, that VR environments can be used to practice social cognition, was supported by numerous studies. Secondly, it also opened up a whole new array of opportunities for research today by demonstrating that most individuals with ASD can grasp the concept of VR, use and enjoy it, and implement it as a method of practice and personal development.

However, these early studies presented their own limitations as VR technology became more sophisticated over time, in both interaction and data collection. Current VR technologies hold the key to developing efficient and realistic intervention tools for autistic individuals by providing an accommodating audio/visual platform to safely develop overall cognitive functionality. Very few published studies focus on VR training as intervention techniques for adults, and of those few all of them focus on improving upon social interactions. The *VR for ASD: Therapeutic Environments* (***VR-ASD:TE***) is a training ecosystem developed as an intervention tool for all individuals, diagnosed with ASD, with sensory hypersensitivity. The initial and primary goal of developing this platform was to provide autistic individuals an environment to slowly grow accustomed to an underground transit system, such as the New York City Subway. A secondary aim was to measure and record the changes in the user's heart rate while he or she was immersed in the environment.

Discussion

Why VR Could Be Useful

The strengths of a VR ecosystem greatly complement the need of interventions, which focus on an autistic individual's independence in crowd settings. The VR ecosystem, allows for the development of an intervention to help master interaction in specific scenarios, provides the following adaptive functionality:

1. A Visual and Auditory World: Oftentimes hypersensitivity/sensory overload is due to an increased influx of information from the eyes and ears to the brain. Current VR ecosystems account for primarily visual and auditory responses, which allow the user to focus on increasing comfort level.

2. Safer Learning Situation: The user is able to develop/practice coping mechanisms in the comfort of their own safe space, as a VR ecosystem is more forgiving and less hazardous, initially, than the real world.

3. Adjustable Input Stimuli: Since no two profiles of ASD are the same the threshold for input stimuli varies from person to person; a virtual environment can be modified to operate on a sliding scale based on user ability and comfort. This allows for an individualized treatment approach using dynamic environments to cater to the changing patterns of development.

4. Continuous Development: VR ecosystems being built today can be constantly updated to reflect the changes in society, which allows for a shorter duration between testing groups and ultimately a larger data set to analyze.

Participants

Seven participants, all above the age of 18, participated in the alpha testing of the VR environment; five of the eight participants were affiliated with a Goodwill Dayhabilitation Service in Long Island City (LIC), NY and the other two were affiliated with a Goodwill Dayhabilitation Service in Harlem, NY. Each participant volunteered and provided verbal consent to participate in the alpha testing. All participants were diagnosed as having ASD. The five individuals tested in Long Island City were considered "high-functioning"— the individuals were capable of some degree of communicatory and motor dexterity, but still possessed difficulties with verbal cues and day-to-day conversation. The individuals tested in Harlem, NY had more significant communication and social functioning deficits than the individuals tested in Long Island City — their verbal communication was more varied and infrequent. This claim was confirmed by each individual's supervisor at his or her respective Goodwill location. Table 1 summarizes some information of the seven participants.

Table 1. Alpha tester characteristics: some information of the seven participants

Tester	Age	ASD Condition	Location	Notes
A	20	More significant impairments	Goodwill Harlem	Problem with crowded trains; More impairment in social behaviors
B	21	More significant impairments	Goodwill Harlem	More impairment in social behaviors
C	> 18	High Functioning	Goodwill LIC	Problem with bright/flickering lights
D	> 18	High Functioning	Goodwill LIC	Doesn't like going into crowded places
E	> 18	High Functioning	Goodwill LIC	
F	> 18	High Functioning	Goodwill LIC	
G	> 18	High Functioning	Goodwill LIC	

Materials

The VR environment was developed using Unity3D a cross-platform game engine and editor available to the public. The study utilized Unity (Personal) 5.2.5 run on Microsoft Windows 10, 8Gb of ram, graphics cards of Nvidia 960M 2Gb, Intel I7 processor at 2.6GHz. The VR environment was rendered on an Oculus DK2; Oculus Development Kit 2 is a virtual reality headset that comes with a 60fps camera that is used for positional tracking. The heart rate was monitored using a Fitbit Charge HR.

A cross-OS standalone project was created in Unity followed by an integration of underground transit system assets and humanoid models to design the environment for this study. Using Unity's built-in standard shader, which allows for physical effects such as diffuse lighting energy based conservation, and high dynamic range, the environment was made to look as realistic as possible. The physical appearance of the humanoid models was diversified, and they were able to walk from one location to another on the subway platform. The user's character was moved by a standard QWERTY keyboard, which could be operated by the user or someone else.

Intervention Method

The VR-ASD:TE was developed to provide a realistic virtual environment for autistic individuals to adjust to as the amount of sensory information being passed to the user increased in increments over time. The alpha testing was done one user at a time. The user first put on the Fitbit device, which calibrated and started storing information on the individual's initial heart rate. After the Fitbit started collecting data, the VR environment was rendered onto the Oculus headset, while the headset is still connected to the laptop on which Unity is running.

A train arrival event/scenario (Figure 1) was constructed to serve three directives: (1) To make the environment seem more realistic with the typical examples of sensory overload instances; (2) To have the humanoid models move and reposition themselves as if they are about to board the train once it comes to a stop. (3) To be the first instance to check for in the Fitbit time log to see a potential change in heart rate. Figure 2 shows a VR screenshot of an empty train car. This is the initial stage in order to slowly ease the user into the VR environment setting. Figure 3 shows a train car with a dozen of “passengers”.

Fig. 1. VR screenshot of the train arrival event.

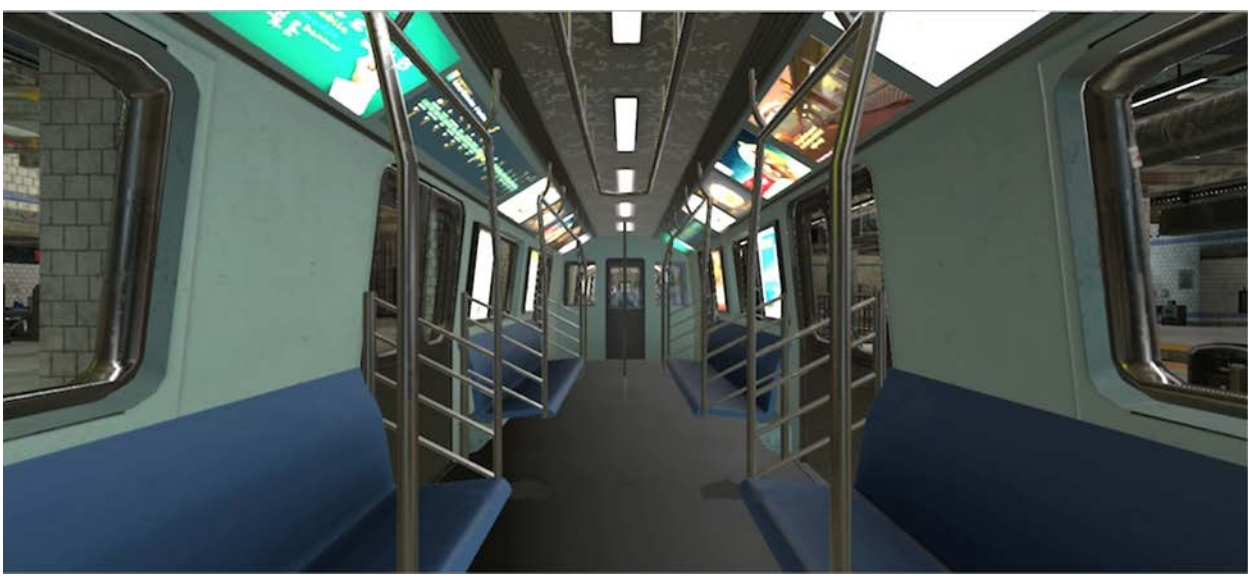

Fig. 2. VR screenshot of an empty train car. This is the initial stage in order to slowly ease the user into the VR environment setting.

Fig. 3. A train car with rendered passengers.

After the train arrival event a second person moves the user, using the keyboard, to board a car on the train. This is where the alpha test branches out; each user does this process a total of four times, with each time the number of people in the car, that the user enters, is increasing. The change in heart-rate was monitored each iteration to see at which level the user was the most uncomfortable and how long it took the user to readjust to the new surrounding.

Table 2 describes a generalized autism spectrum condition and then pinpoints on the events occurring in the environment that might make the user uncomfortable. A VR environment should be created in order to mimic a real-world location and situation that are commonly experienced by individuals who use public transit on a daily basis. At the moment, we only simulated the realistic scenes with platforms, train cars (still or in motion), and various densities of passengers on the car, but other events (such as audio and touch) shall be simulated in the future.

Table 2. Events in the VR-ASD:TE that potentially trigger autism spectrum conditions.

Autism Spectrum Conditions	Causes of condition triggering due to event in environment
Auditory Hypersensitivity/ Hyperhearing (e.g., frightened by sudden unpredictable sounds)	• Loud background noises (such as people chattering, something falling down, loudspeaker announcements and crying baby) • Screeching when a train comes to a halt
Visual Hypersensitivity/ Hypervision (Including: vision too acute and sharp; pulsating lights; colors overpowering and too bright)	• Incoming train headlights • Flickering bulb • Random events (such as colorful balloons)
Hypertactile (Fear of being touched, sometimes slightest touch can cause anxiety)	• Crowding by the train doors when the train arrives (The VR:ASD:TE being used doesn't cover haptic feedback, however some individuals get anxiety from just thinking about being touched
Vestibular Hypersensitivity (Including: difficulty changing direction; fearful when their feet leave the ground)	The user won't actually be walking into anything physically but with a realistic looking environment they feel the fear while: • Walking over the gap between the platform and the train • Maneuvering through the crowd to board a train

Measurements and Results

To assess the performance and the effectiveness of the VR-ASD:TE intervention, only two sets of data were gathered in our current test: (1) heart rate before, during, and after immersion into the environment at all 4 levels, and (2) user feedback on the environment. Heart-rate monitoring has been a measurement device which has been previously used to assess VR induced symptoms and to gauge anxiety levels of the user (Cobb, et al, 1999).

Subject A was the only participant who went through the entire alpha program, of four levels, with continuous measurements of heart rate on the Fitbit device. Subject B tried out the level four scenarios, which is the densely crowded train. Subjects C through G tested the environment and provided feedback and personal experiences. Figures 4 through 7 are the graphs of Subject A's heart-rate while going through each of the four intensities in the alpha program. Figure 8 is a graph of Subject B's heart rate while going through level four of the alpha program.

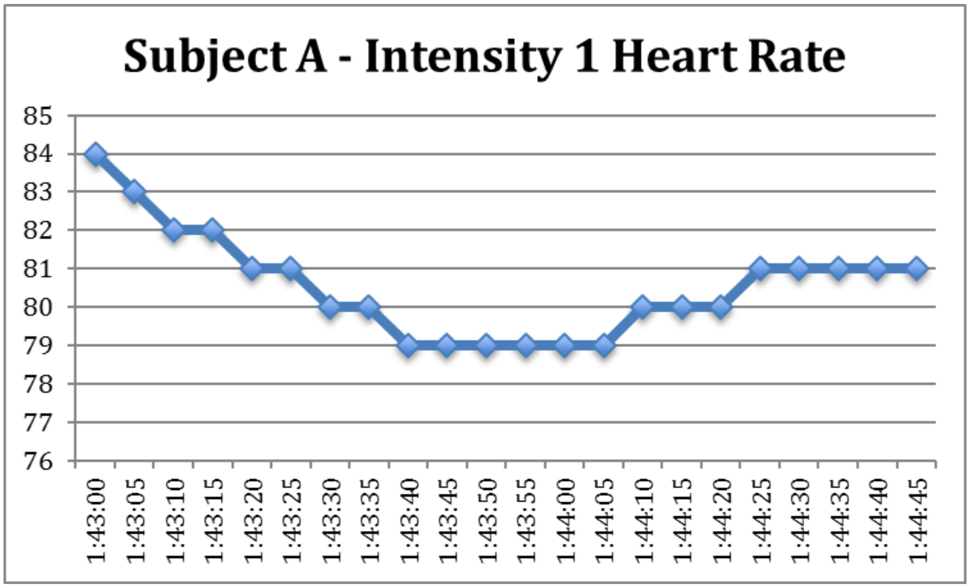

Fig. 4. Subject A - Intensity 1 - No people on train - 1:42 to 1:45. Response: No Problem

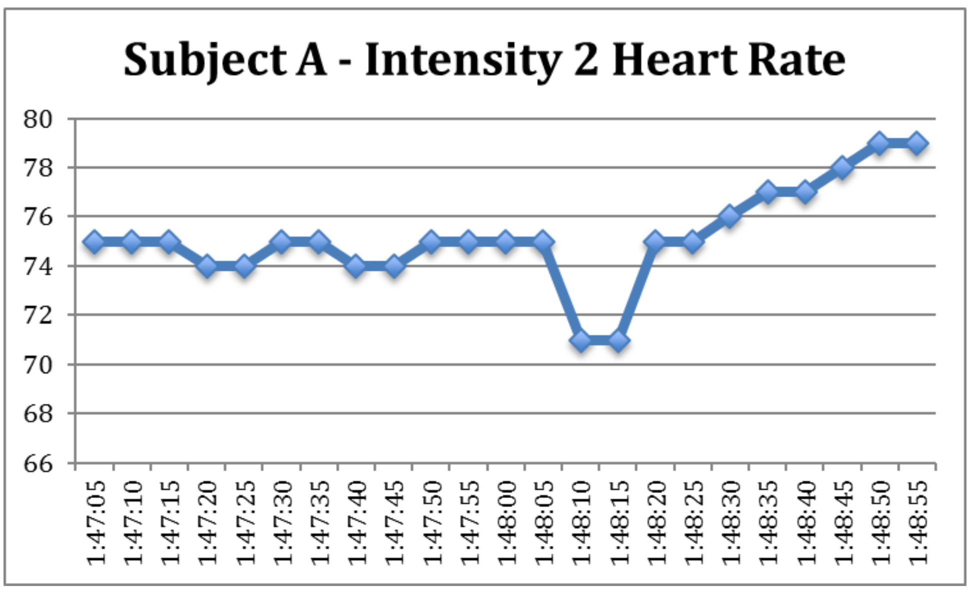

Fig. 5. Subject A - Intensity 2 - Handful of people on the train - 1:47-1:49.

Response: No Problem

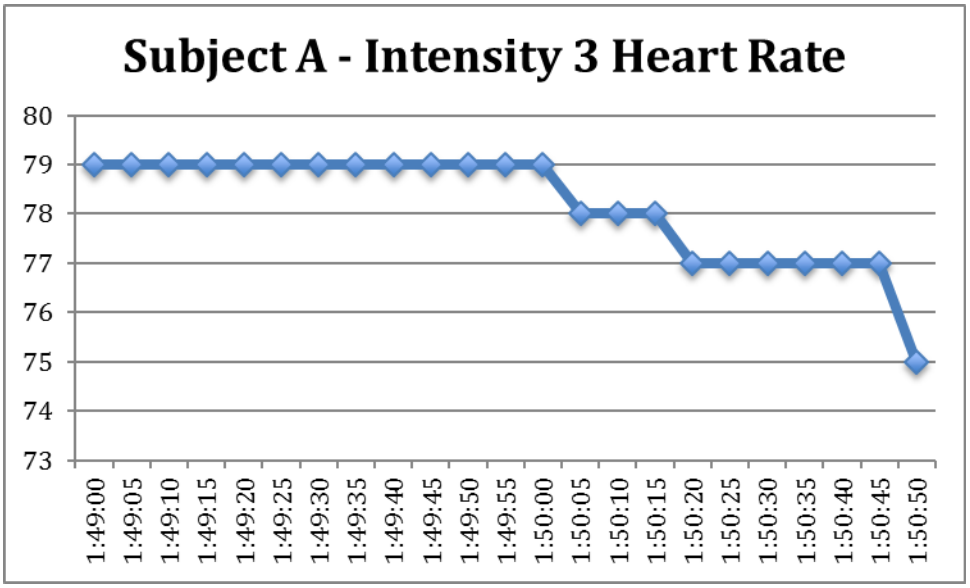

Fig. 6. Subject A - Intensity 3 - A dozen people on the train - 1:49 to 1:51.

Response: Manageable/OK

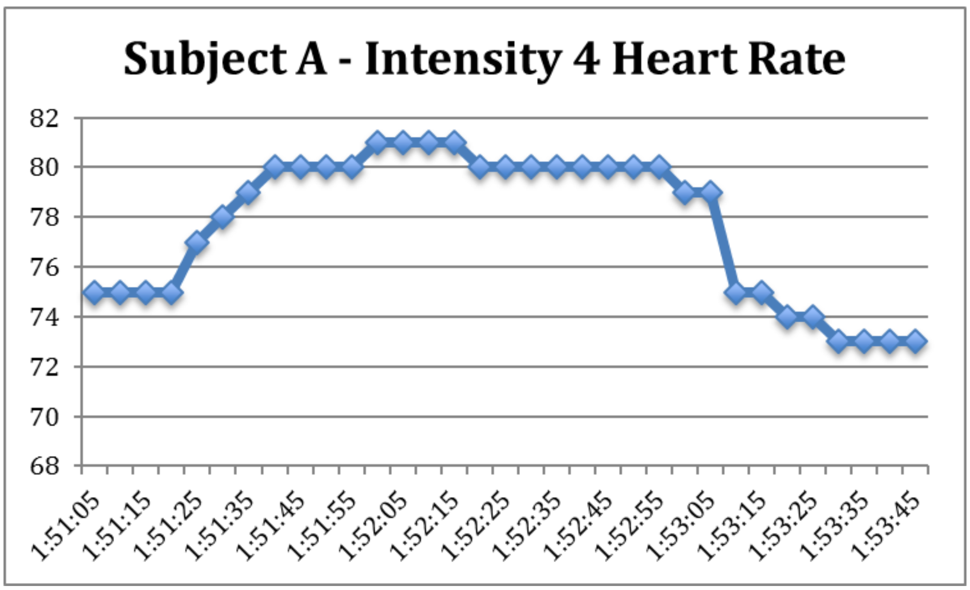

Fig. 7. Subject A - Intensity 4 - Very Crowded - 1:51 to 1:54.

Response: Little uncomfortable

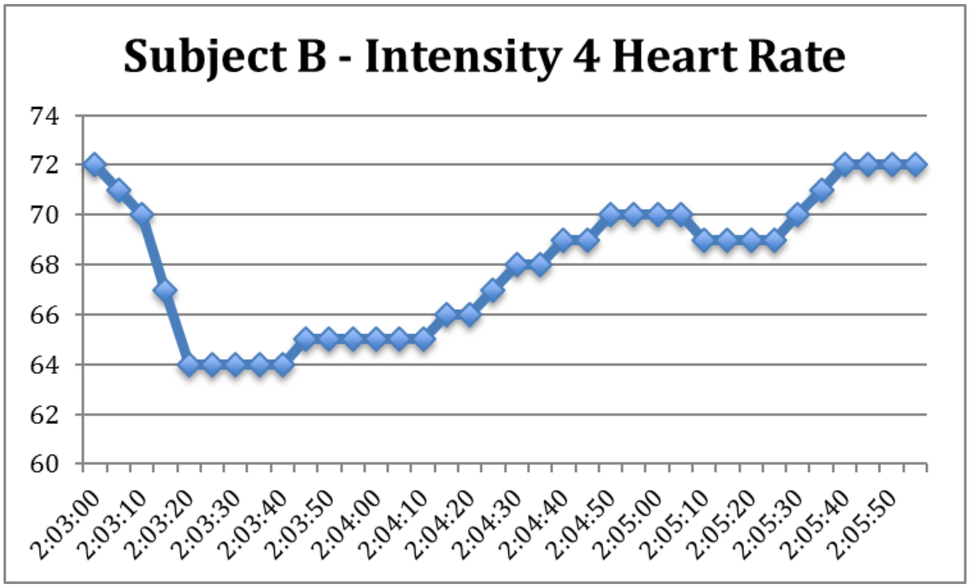

Fig. 8. Subject B - Intensity 4 - Very Crowded - 2:03 to 2:06.

Response: No problem

Adjusting to the VR environment did not take a long time for any of the participants; it is notable that none of the participants mentioned nausea or dizziness when using the VR headset, a complaint commonly cited by neurotypical individuals. ASD conditions mentioned by participants A, C, D mimicked their reactions to the different scenarios presented to them in the environment. They were all excited to be trying out the headset and were very enthusiastic about the process. The verbal feedback received from the participants at the end of the sessions was resoundingly positive, where they all mentioned that they would be willing to test the environment again more thoroughly.

Conclusion

This alpha test is among one of the first projects to take a dive into the use of VR to help people with Autism acclimate to unfavorable and somewhat triggering surroundings. The VR-ASD: TE was developed as a base case with tiered interventions specifically for hypersensitive individuals, which fully utilizes the benefits provided by VR platforms. By implementing an environment which takes most symptoms of hypersensitivity into consideration, the VR-ASD:TE helps individuals slowly grow used to scenarios which would have previously caused anxiety. Even just after a few minutes in the environment, the participants were at ease with their surroundings. These responses from the participants support the idea of implementing and further developing VR environments for the use of cognitive development and for the use of developing coping mechanisms.

Results of the current study found that an intervention to slowly immerse autistic individuals into uncomfortable scenarios may help them build a tolerance to their hypersensitivity symptoms. Going through the heart-rate graphs (Figures 4-7) of Subject A, there is a clear increase in heart-rate at the beginning of each graph which then slowly begins to depreciate as Subject A gets more and more accustomed to the scenario. The only scenario where Subject A's heart-rate remains high is at intensity level four in our alpha program (Figure 7), because Subject A has a problem with crowded trains to begin with. The decreasing heart-rate in the first three intensity levels may suggest a carryover where given enough 'training' sessions in the VR environment, Subject A can practice containing his or her anxiety in a surprising situation.

The results suggest that VR-ASD:TE can offer a therapeutic VR training platform for cognitive development for autistic individuals who also experience symptoms of hypersensitivity. Further control trials are required to validate the preliminary findings presented in this paper. In addition, a larger and more diverse sample size is needed to gauge the needs of individuals across the entire spectrum and further develop VR-ASD:TE to those needs.

This VR environment was also limited by the lack of a desktop machine available at the site of test to run an Oculus Rift headset. Further research and studies on the cognitive development of autistic individuals should incorporate well-documented procedures and more of a deep dive with a seamless transition between intensity levels. Further research into another form of measurement to gauge anxiety would greatly support the theory of an increased heart-rate implies unease.

Overall the current study and alpha test provides a basis for future testing of the intersection between VR and cognitive development in autistic individuals. The future implementations of headset VR to enhance cognitive development will allows autistic individuals to immerse themselves fully into a safe and controlled environment. VR-ASD:TE will be further developed into a truly visually realistic and immersive approach to helping build a higher tolerance to hypersensitivity and in result increase an individual's cognitive function.

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Panoramik: Finding and Locating Objects via Panoramic Camera Techniques

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Abstract

One of the areas that poses a challenge for individuals with significantly low sight and blindness is the dynamic nature of their work surroundings. Visually impaired individuals tend to prefer a very well organized and static environment because it allows them to know exactly where everything is at any given time. However, in a dynamic work environment, there are fellow co-workers, colleagues, and customers that may move or misplace key items and objects that visually impaired individuals may need in order to carry out their job. Because of these issues, we propose to build an affordable camera-based system to find and track key objects for visually impaired individuals. Our solution is to use a mobile panoramic imaging system that joins 360-degree surveillance with user-defined panoramic photos to create a self-aware environment. By tracking objects and item placement, the system will be able to assist visually impaired individuals locate objects using audio cues. For the software component, a phone application is developed that is Android friendly for users. The application consists of a classifier algorithm to locate objects and save the memory of these objects. The hardware component utilizes a 360 omnidirectional camera (or equivalent) and a smartphone.

Keywords

Blind and visually impaired; Object detection; Object localization; Panoramic vision

Introduction

There are 285 million visually impaired people in the world, and of them 39 million are considered totally blind; 37.7% of visually impaired people are actively employed in the workforce (WHO Facts, 2016), which means that there is a considerable barrier for visually impaired individuals to achieve and keep employment positions. One of the most prevalent challenges for working individuals with significantly low vision and blindness is the dynamic nature of their work surroundings (Beck, 2010). Visually impaired individuals tend to prefer a very well organized and static environment because it allows them to know exactly where everything is at any given time. This enables them to perform tasks quickly. However, in such dynamic work environments, there are fellow co-workers, colleagues, and/or customers that may move or misplace key items and objects that visually impaired individuals may need in order to carry out their job. When an object is misplaced, it makes their job harder to fulfill, reduces their productivity, increases their stress, and can make it much more difficult for visually impaired individuals to retain their jobs. Because of these issues, we propose to build an affordable and effective camera-based system to find and track key objects for visually impaired individuals. The system can be used in both a collaborative workplace, where a visually impaired user doesn't have the full control of the environment, or a private environment, where the user may be alone.

Problem Statements

There are not many applications in the market today targeted for the visually impaired or blind that perform spatial object detection and tracking. There are smartphone apps like iDentifi and TapTapSee that focus on specific image or scene detection from a still image from the smartphone (Coldewey, 2016; Taptapseeapp, 2016). These do not have any type of object tracking ability, nor do they have any sort of spatial component to the detections. One approach that comes close is the O'Map approach, where an Object Map is generated from a sweeping panoramic image taken by a smart phone to generate spatial object detection regions (Alam, at al, 2015). While this presented a strong and viable solution to spatial object detection, it lacks the object-tracking dimension of the problem, and is therefore limited to single-point-in-time detection and location for objects. A handful of challenges come up with creating such a system. The first challenge is to make sure the system has a 360-degree view range of the user's environment. Generally mobile applications have a limited view range - often less than 180 degrees. It is also necessary that users are able to focus on a specified area and not just a general view provided by the system. This is necessary because a lot of times objects get misplaced behind a range of view so without a user customized range, it will be difficult to locate objects in areas not covered by the 360 degree system.

Another challenge is to add use verbal cues in the application so users don't have to rely on vision to interact with the system. To top it all, our system had to be an affordable solution so users from all backgrounds could have access and benefit from our project.

In any application or software system, processing speed plays an important role. Users will not use something that takes a long time to deliver an end result so we had to create a system that was as fast as possible without sacrificing object detection accuracy.

Rationale

Affordability is a crucial component of this project as 90% of visually impaired people live in low-income settings (WHO Facts, 2016), which makes expensive solutions impractical, such as 3D scanning and RF (radio frequency) tagging. By creating an inexpensive system that finds missing objects, we will be able to increase the number of people who can afford and use the application.

Our solution, *Panoramik*, is to use a mobile panoramic imaging system that joins 360-degree surveillance with user-defined panoramic photos to create a self-aware environment, such as a room. Panoramik is created with hopes of making the visually impaired more independent and less stressed. To make sure visually impaired users do not have to rely on others to use our system, we have to build a simple, easy to use solution. By tracking objects and item placement, the system will be able to assist visually impaired individuals locate objects using audio cues. For the software component, a phone application is developed that is Android friendly for users. The application consists of a classifier algorithm to locate objects and save the memory of these objects. The hardware component utilizes a 360 omnidirectional camera (or equivalent, as of November 2017, a Ricoh Theta S 360 Camera we used cost about $200) and a smartphone (that users typically already own).

When a visually impaired person loses an object, they have to rely on others to find the misplaced object. This makes them dependent on another person. This system will help the visually impaired people become more independent. The application will also improve productivity of people. Searching for a missing object, especially for a visually impaired person takes time. By using the application, we can reduce the search time and increase the productivity. The system improves the organization ability of the visually impaired as well. When they know where each item is placed, they can track the items and reorganize them based on their preference. Finding an object increases stress in some people. In some cases if the missing item is valuable, it can increase the anxiety as well. The application will help reduce high stress and anxiety situation by helping the visually impaired find their misplaced object efficiently.

Discussion

Design

A high level overview of the client-server system is shown in Figure 1. The smartphone on the left represents the user-facing client. The 360 Camera client (Ricoh Theta S 360 Camera in Figure 1) is shown on the right. This client requires no interaction by users, as it will periodically take omnidirectional photos of the given indoor area at fixed intervals and send them to the Compute System. The 360 Camera client can either be activated manually by a supervisor or managing individual, or set automatically to activate once a day. After it is activated, the client is left to run continuously for the rest of the day. Having the 360 Camera Client start operating automatically allows for easy set up by the end-user (someone who is blind or has a visual impairment), which would give the user greater independence and autonomy. Since it is a 360-degree camera, there is less of a concern about aiming the camera correctly. The 360 camera client runs in the background, identifying objects, as well as monitoring the movements of these objects.

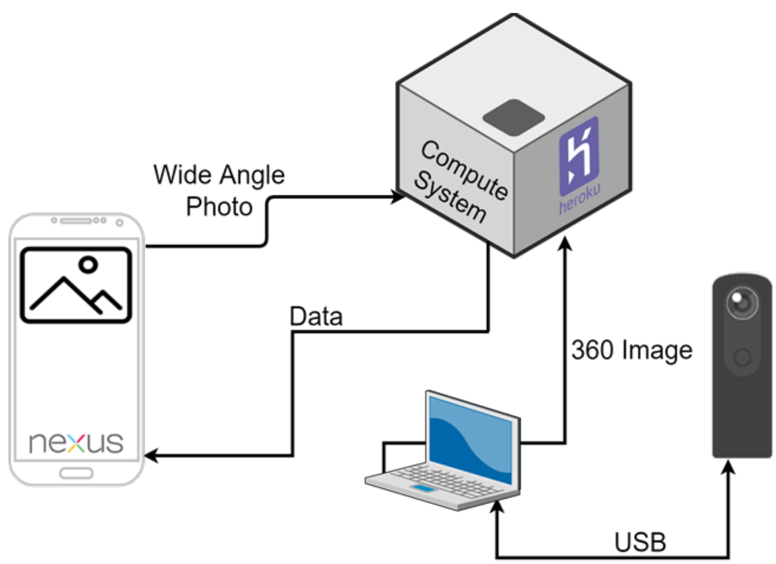

Fig. 1. A high-level overview of the Panoramik system.

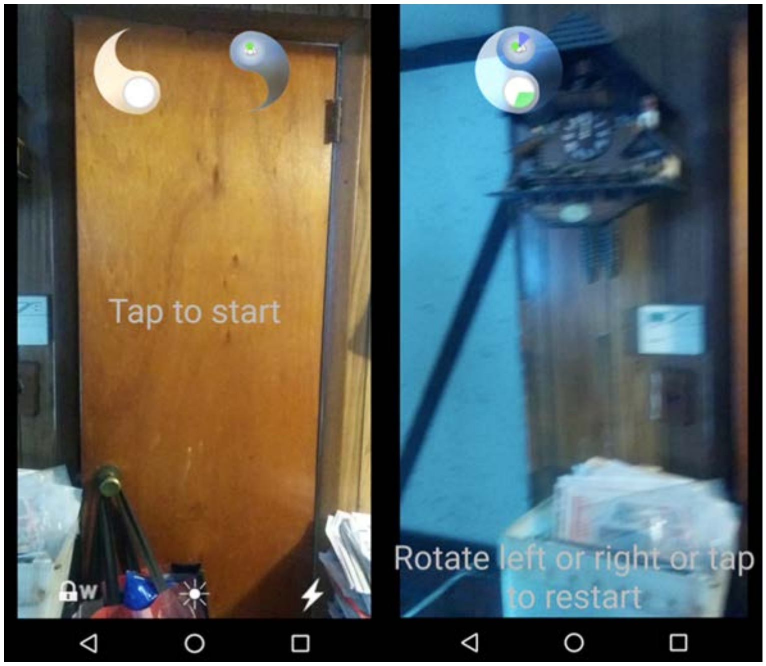

Fig. 2. Turning interface of taking panorama.

User Interaction and Interface

A standard case procedure of using the system is as follows: (1) User activates and launches the application on their phone. (2) Application greets user with voice-directed cues and menu options. (3) The user will speak the name of the item they are looking for to the phone. (4) The client will poll the compute system to see if the item had already been detected by the 360 Camera subsystem. (5a) When an item is found, the application will direct the user to the location of the item via voice cues. (5b) If item is not found, the user is presented with a wide-angle photo (Panoramic photo) interface (Figure 2), where the user is directed via voice cues to capture a wide-angle photo. (6) Upon completion of the wide-angle photo capture, the image is uploaded to the Compute System, where it is processed by the Object Detection subsystem. (7) Once a match is found, the server returns the location of the object to the user's smartphone client, which will navigate the user to the object.

Fig. 3. Capturing object placement and differences.

Motion Detection Algorithm

The motion detection algorithm takes 360 photos from the 360 Camera client input stream. The first image that this motion detection algorithm receives on startup becomes its *baseline* image. This means that every subsequent image will be compared against the baseline image. For particular environments, a reset threshold can be set and applied which will trigger a baseline image reset if a particular motion threshold is exceeded between the baseline image and the current image frame. Typically, the default reset for the baseline is done at the beginning of the work day and/or at the end of the work day, before the employees have arrived or after the employees have left. In Figure 3, we show an example of where objects have moved from their initial positions being detected by the motion detection algorithm. For each object that has moved we draw a bounding box around it using thresholding to get a binary black and white image. We then capture a cropped image of the object that had moved. These sub images are then sent to the Object Detection Subsystem to be detected and given a tag name, which will be used to identify it when a user comes, asking to find an object.

Object Detection Algorithm

The object detection algorithm is the core component of how objects get identified in our system. This algorithm utilizes four commercial APIs for object recognition, identification, and classification. For this prototype, Cloudsight (Taptapseeapp, 2016) is primarily used because their API returns a single human-readable plaintext description of the object you give it. The primary disadvantage of Cloudsight is the speed taken to process and identify each object. A key issue is that APIs create bottlenecks due to usage restrictions, speed of processing, and pricing.

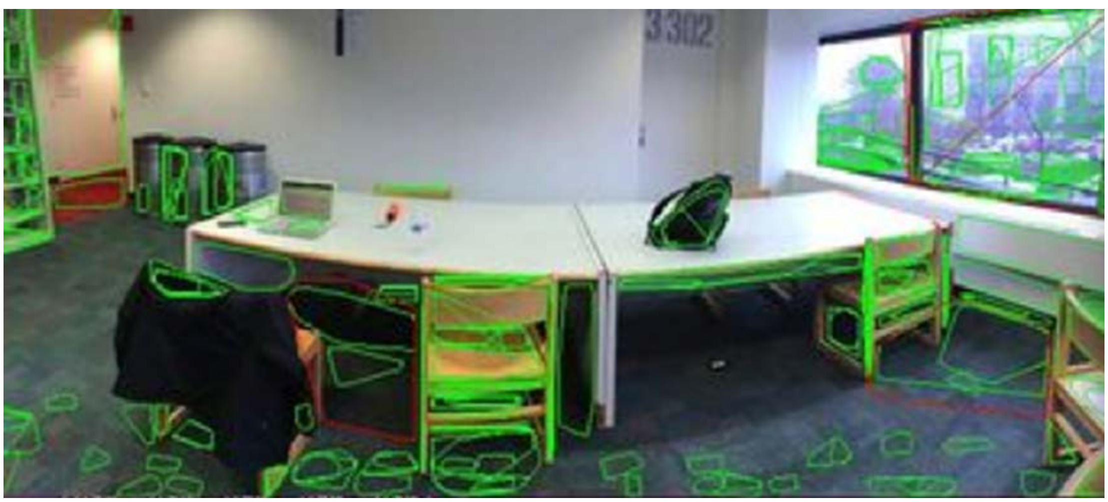

Fig. 4. Preliminary testing on MSER algorithm to fine-tune input parameters.

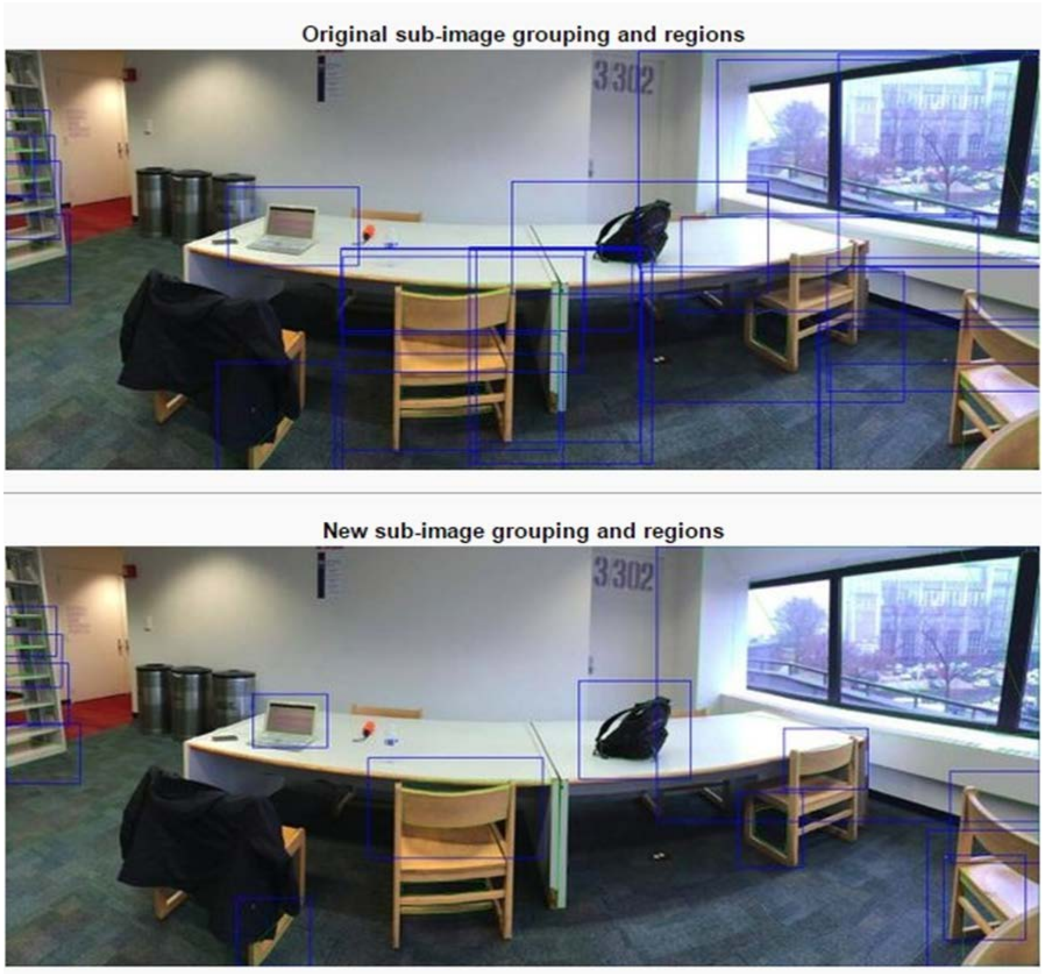

Fig. 5. Clustering effects, before and after.

In the final prototype, the image recognition will be done on-server using a templating system, which will be faster and more accurate to detect objects of interest. The algorithm gets its input from both the smartphone client and 360-camera client. For panorama images, they are pre-processed through a feature detector called MSER (Maximally Stable Extremal Regions) (Forssén & Lowe, 2007), which gives us regional data in the panorama image (Figure 4). From there, we take the region data, and begin preliminary filtering. We filter out regions which are too large (larger than 50% of the original image size) and too narrow (ratio of length to width or vice versa less than 1:20). These regions are considered bad because the likelihood and fitness of these regions for detecting regions is very poor. After this point, we further filter our region data set through clustering, combining regions that share characteristics (e.g. overlapping regions of similar size and shape) so that we reduce the rate of redundant identifications. The clustering saves processing time and processing resources (Figure 5). At this point, regions are converted into sub-images, and join the 360-camera client input stream. These sub-images are then sent out one by one to the image recognition API's for recognition.

Implementation and Evaluation

A large bulk of time was spent on optimizing the MSER algorithm input parameters, as well as to resolve overlapping regions via clustering. Adjusting and fine-tuning the algorithm to run fast and flexibly was important for the object detection algorithm. It was also important to have it scalable, so that multiple users can interact with the system independently of each other.

We also worked on optimizing and combining multiple API's for object recognition. This included the 4 main APIs we looked into, which were Google Cloud Platform, IBM Bluemix, Microsoft Azure, and Cloudsight. An example of the results gathered from each of the APIs can be seen in Figure 6. Microsoft, Google, and IBM gave more generalized information such as tagging (and their respective confidence levels) and categories. We also began utilizing a motion detection algorithm for the 360 camera. OpenCV was used to cross-compare differences between two image frames. By this point our product was near finalization, and testing was needed to ensure that the system worked as intended.

We had the opportunity to present our work at the CREATE Symposium during the end of April at the Legislative Office Building in Albany, New York to many curious onsite onlookers. Many viewers were interested with how the omnidirectional 360-degree camera worked together with the smartphone panoramic app.

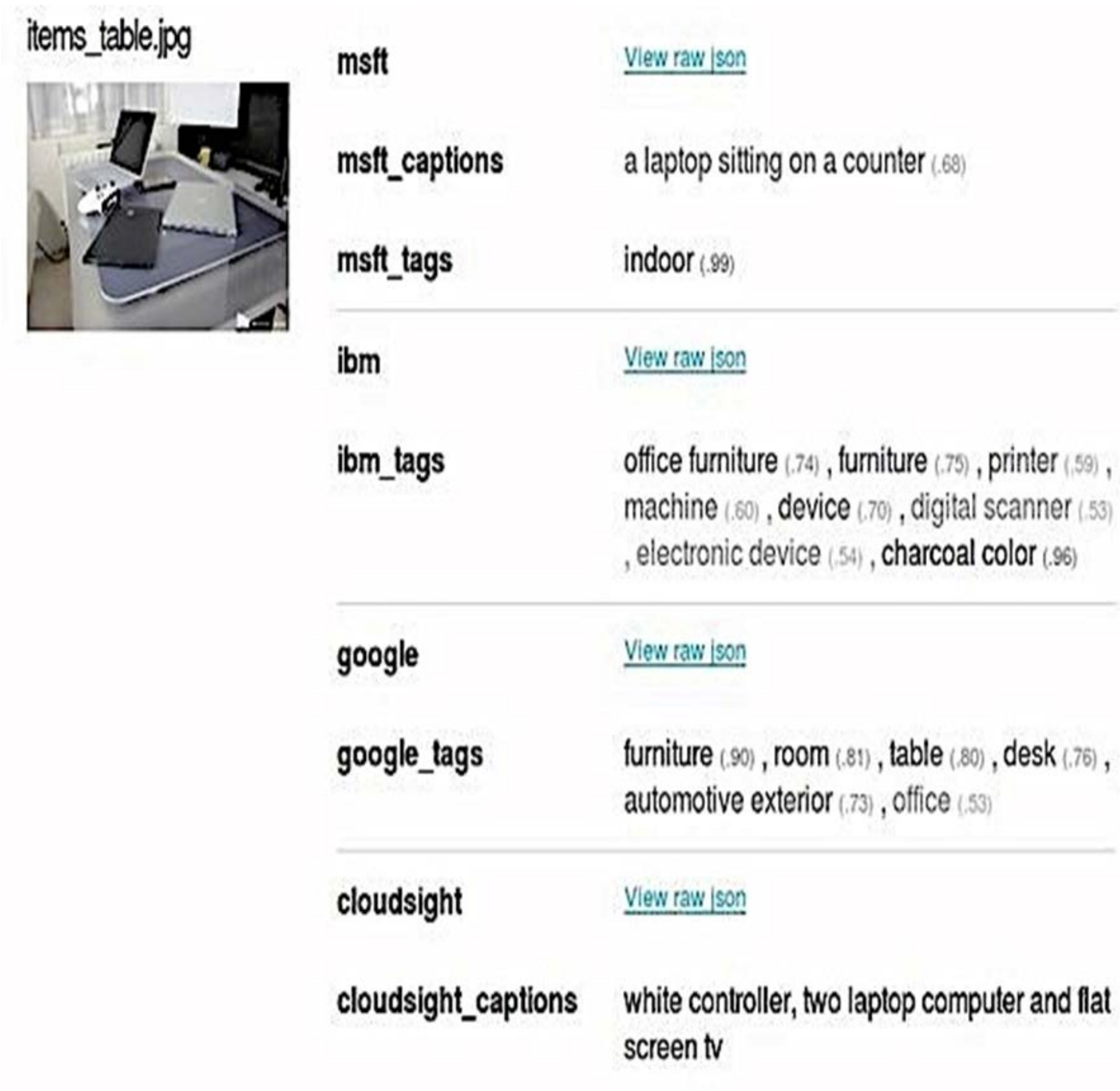

Fig. 6. Results from the 4 APIs for a sub-image.

We were also given the opportunity to visit Goodwill's Visually Impaired Program in Harlem to talk with visually impaired individuals about our project. Some suggestions included taking a panorama covering the floor angle because many of their misplaced items fell onto the floor and they cannot see what is on the floor. We generally received positive feedback as well as remarks about when the application would be on the market, the cost of using, and if we were developing an iOS application as well.

Conclusion

The camera-based system will be easy to use and affordable. Being both iOS and Android-compatible will further increase the target audience for the application. By using the panoramic feature in phones and the 360-degree field-of-view camera, we will be able to target and locate objects. This system will greatly benefit many visually impaired people by increasing productivity and independency. It will not only increase the efficiency in locating misplaced objects but also give visually impaired individuals the ability to become more comfortable in dynamic environments. By building this system, we plan on reducing every day struggles of the visually impaired and ease their mental and physical life.

The current implementation has focused on computer vision processing and combining results from multiple object recognition cloud services. We have also talked with end users about using such a system. In the future, we aim to focus on user requirements gathering with blind users, and on the evaluation of such a system with users who are blind. In doing these, we will be able to answer some questions with regard to the proposed system design, such as: How would users train the system to know which objects they care about in their environment? Can users give names to the things in their environment, e.g. "Bob's Laptop" ? What should be the appropriate voice cues, i.e. how do these guide someone to an object?

With the current modular framework in place, it is relatively trivial to replace the source of object recognition from using external cloud-based services to a localized template approach similar to that of Alam et al. 2015. Localized templating will address one of the key feedback requests we had gotten from visually impaired individuals at Goodwill as well as visiting visually impaired individuals from the Student Assistive Tech Exposition event at CCNY.

Acknowledgements

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The EasyReading Framework – Keep the User at the Digital Original

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Abstract

The “Easy Reading” framework improves cognitive accessibility of original digital documents by providing real time personalization through annotation (using e.g. symbol, pictures, videos), adaptation (using e.g. layout, structure) and translation (using e.g Easy-to-Read, Plain Language, symbol writing systems). The framework provides these (semi-)automated services using HCI techniques (e.g. pop-ups/ Text-To-Speech (TTS)/captions through mouse-over or eyetracking) allowing the user to remain and work within the original digital document. This fosters independent access and keeps the user in the inclusive discourse about the original content. Services adapt to each user through a personal profile based on the level of performance, understanding, preferences, mood, attention, context and the individual learning curve of a user.

Keywords

User interface personalization, web accessibility, cognitive accessibility, assistive technologies

Introduction

People with disabilities use assistive technologies (ATs) as a key asset to communicate and to participate in the (digital) information society. There is a focus of ATs in supporting people with physical, communication and sensory disabilities [1]. Accessibility for "perceiving" and "operating" content is well understood and the identified general principles and tools (e.g. WCAG 2.0) are known and widespread. Several accessibility functionalities became key usability features and were implemented in mainstream software and devices for personalized multimodal / multimedia access. The situation is considerably different for cognitive accessibility or the understandability principle of WCAG 2.0. Furthermore, it is way more challenging to design and implement (digital) content that supports people with weak language and reading skills in understanding, navigating, using and interacting. Requirements, concepts and techniques to support understanding and content processing are less obvious and in particular diverse - differing in target group and also from person to person. Individual skills and know-how are based on the personal learning and support history, often embedded in difficult socio-psychological settings. In this paper we want to present a new generic framework for assistive technology supporting people with cognitive disabilities to better understand and operate web content by providing personalized information, adaption of content and help to the individual user when working with digital original content, what differs considerably from traditional approaches tending towards more general translation and adaptation of content and tearing the user away from the digital original.

State of the Art and Motivation

People with cognitive disabilities can be supported with assistive technologies that help them to understand and comprehend content that they do not understand and with accessible content. Current guidelines like the WCAG 2.0 or the IBM Accessibility Checklist for Software do only consider cognitive accessibility in general terms. However there is an ongoing trend to also include cognitive accessibility in these guidelines. The W3C/WAI is currently updating WCAG to version 2.1 (https://www.w3.org/TR/WCAG21/), to improve the standard for people with cognitive and learning disabilities, low vision, and using mobile devices. Several new success criteria are proposed for cognitive and learning disabilities.

Besides guidelines for accessibility a broad spectrum of concepts, methods, techniques and tools to support people with cognitive disabilities has been developed, mostly in settings for medical diagnosis and therapy or education and training. They all provide important and useful features but lack in personalization for individual users and adaptation to changing contexts:

- Plain language and Easy-to-Read tools: Linguistics, language technology and Natural Language Processing (NLP) research grammar and style-checking (sometimes called Controlled Language), translation, annotation and enhancement and summarizing of content (Miesenberger, Klaus and Andrea Petz. Easy-to-Read on the Web: State of the Art and Needed Research.) (McCarthy, Philip M., and Chutima Denecke. Applied natural language processing: identification, investigation, and resolution).
- Annotating content with alternative expressions, images and multimedia: (e.g. explanatory text, symbols, pictures, graphs, animations, videos) is a key feature in R&D in speech disabilities and Augmentative and Alternative Communication (AAC) (Fager Susan, et al. “Access to Augmentative and Alternative Communication: New Technologies and Clinical Decision-Making.”).
- Text to speech / speech to text: Switching from written format to audio or vice versa or using both formats in parallel is beneficial for many users with cognitive disabilities.
- Structure and layout adaption: The demand for adapting structure and layout for accessibility has been high on the agenda since long (e.g. in WCAG) and many aspects have entered mainstream due to the demand for responsive design in particular

related device independence and usability issues (Mohorovicic, Sanja. “Implementing responsive web design for enhanced web presence.”).

Other supportive functionalities and tools:

- Memory support (recorder, collections as dictionaries, wikis and marker),
- Conceptualizing and problem solving (forms, mind maps, templates, concept tools, summarizing tools, tables of content, lists)
- Workflow support tools (for e.g. daily living, job), attention/motivation
- Writing tools: recording, editing, speech/handwriting recognition, spelling/grammar checkers, word/concept prediction, predictive typing

These guidelines and tools help improving accessibility, however they have drawbacks:

The guidelines are directed towards content creators and although legislation in several countries is more and more demanding accessible webpages, the percentage of webpages not conforming to WCAG2.0 is still very high. Even if WCAG2.1 would develop new guidelines that support cognitive accessibility, it is highly unlikely that many webpages will implement them, as this would only imply more requirements on content creators.

Also, most of today’s tools do not adapt to the personal users’ needs and preferences and are made as a solution of one aspect of cognitive accessibility. Cognitive accessibility is very personal and based on the personal knowledge, skills and preferences some users with cognitive disabilities prefer to read text with symbol annotation, while others get distracted by those symbols. Some prefer to read by themselves or listen to synthetic speech, or even have a combination of text with symbol annotation and synthetic speech. Therefore many different tools have to be used which then might conflict with each other and are difficult to setup.

As a result there is a demand for AT that automatically adapts to the users’ needs converting content on demand into a version that is optimized and understandable for the individual user when working with original content.

The Easy Reading Framework

To overcome the mentioned drawbacks we are currently implementing a new scalable framework of Assistive Technologies for people with cognitive disabilities that will combine many solutions to a saleable and adaptable framework of solutions. The “Easy Reading” framework will provide real time personalization through annotation (using e.g. symbol, pictures, video), adaptation (using e.g. layout, structure) and translation (using e.g Easy-to-Read, Plain Language, symbol writing systems) at the digital original. The framework provides these (semi-)automated services using HCI techniques (e.g. pop-ups/ Text-To-Speech (TTS)/captions through mouse-over or eye-tracking) allowing the user to remain and work within the original digital document. This fosters independent access and keeps the user in the inclusive discourse about the original content.

The architecture of the EasyReading framework consists of three parts:

- Profile server: Stores user profiles that cover the abilities and preferences of a user in a secure way
- Client: Users will be able to use the framework by installing an app on their mobile device or by installing a browser plugin.
- Cloud Service: Cloud services host engines that will convert content, structure and layout/presentation of web pages into a different easier to understand forms. The conversion engines can be something very basic like a dictionary for loanwords or something very complex like engines that analyze the meaning of a sentence or rearranging display and interaction modalities. The engines are controlled by the user profile allowing a personalized response.

Based on the user profile, the user-interface and HCI paradigms used in the client change for the individual user. Users of the framework will be able to convert content that is not understandable with the use of the cloud service. The result is then displayed within the client or the webpage itself.

Another advantage of this architecture is that engines that up to date are no feasible to implement can be simulated. For example a conversion into plain language or Easy-To-Read can be made for a single page and then be used as output of a static conversion engine.

By this new features can validated before an engine has to be implemented. If the simulated engine proved to be a valuable asset for people with cognitive disabilities, real research and development of the engine can be triggered.

Working with the Digital Original

Finally we see it as the core advantage of EasyReading that the personalized support functionalities are provided at the digital original. State of the art support features tend to set up a separate user experience, mostly static translations. The EasyReading solutions intends to allow the user to get personalized support at the original, stay with the original and to become step by step more independent as the framework and the user learn. This also provides a new way of service provision in terms of working towards more independence of the user and transferability of developed digital skills.

Interface and Interaction Design

As the abilities, preferences and knowledge domain differ very much from user to user, it is not feasible to create a standardized user interface that would suit every user. Therefore the EasyReading framework allows to build a customizable dynamic user interface that adapts to the skills and preferences stored in the user profile. To achieve this, the user interface builder within the framework consists of three components:

- Presentation Engine: This engine host different, configurable and combinable concepts of user interfaces that are presented to the end user.
- HCI Engine: The HCI engine stores different ways of triggering actions and interaction within the user interface

- Result Renderer: Like the presentation engine the result renderer hosts different, configurable and combinable concepts, to render conversion results of the framework and present it to the user.

Depending on the user profile the user interface builder combines suitable concepts of the components to create a personalized user interface. For the presentation of the user interface currently 4 concepts are implemented:

- Overlay within the webpage: A customizable container with controls that is injected in the current webpage, allowing users to trigger actions
- Sidebar: Controls rendered in the sidebar of the browser. Currently this is only supported in Firefox as Google Chromes extension API does not allow a sidebar.
- Slide in interface: This is a variant of the overlay interface mentioned before. This interface is minimized embedded in the webpage and slides in from one side on demand.
- Avatar based: An avatar is rendered that interacts with the user whenever he has a problem. Within a dialog mode, the different options are shown that allow the user to convert content.

These interfaces can be used in combination with different concepts of the HCI engine, allowing the user to interact with the UI in the preferred way. Currently these concepts are separated into active (users trigger an action) and passive (actions are triggered based on the users' behavior) concepts:

- Active:
    - Click/Touch elements within the user interface are triggered by mouse/touch down or mouse/touch up
    - Keyboard/Switches: For users that are not able to operate standard pointing devices a keyboard or switch access scanning mechanisms can be used.

- o Natural language interface: Users are able to trigger an action by using simple voice commands
- Passive:
  - o Actions can also be passively triggered. The framework uses sensors that estimate the current focus of the user, and according to the profile and a threshold, trigger an action.

After a conversion the result is then rendered depending on the user preferences using the result renderer. Currently these 4 concepts are implemented:

- Tooltip: The result is rendered as a tooltip within the user-interface.
- Replacement: Actual content is replaced with the simplified content.
- User Interface: The result is displayed within the current user interface of the user.
- Audio feedback: The result is transmitted with audio utilizing a text to speech engine.

EasyReading Prototype

The framework is currently in development with the first user tests being made. Figure 1 shows one of the many possible user interfaces that the client of the framework offers.

Fig. 1. EasyReading framework used on the German Wikipedia entry for bird.

Here the user interface is directly embedded into the webpage allowing the user to increase decrease font size and to get additional information. The user searched already for an alternative image for the word Vögel (German word for bird) that was displayed as a tooltip over the word visible when hovering. He also searched for more information on the word "Merkmale" that was displayed inline in the user interface itself.

Acknowledgment

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A Toolkit for User-Centered Design of Assistive Technology Solutions

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Abstract

The needs and capabilities of persons with disabilities are manifold and ICT-based Assistive Technologies (AT) support many people with severe physical or mental restrictions today. Although ICT-based AT is on the agenda in ICT, Rehabilitation Engineering, service provision for people with disabilities and related disciplines more than 40 years, tools and frameworks for highly customizable assistive solutions do not exist on the market, nor are they described in scientific literature. Furthermore, highly specialized solutions are out-of-reach for many clients due to their high price. As a consequence, many people with disabilities cannot be adequately supported with Assistive Technology - and their full potential remains untapped (WHO 2011). The motivation behind this work is to develop and evaluate a component-based software framework and dedicated hardware modules for an efficient creation of personalized assistive solutions – ranging from specialized computer access to Augmentative and Alternative Communication (AAC), from environmental control and Internet-of-Things (IoT) to accessible gaming. By providing a set of reusable components for the integration of novel sensor- and actuator technologies, a cost-effective and rapid personalization of AT solutions is fostered. In this article, we present the software framework and hardware modules and discuss the results of evaluations done with end users.

Keywords

Assistive Technology, User Centered Design, Personalization, Motor Disabilities, Human Computer Interface

Introduction

Modern Assistive Technology (AT) solutions cover a wide range of applications and strengthen rehabilitation, wellbeing and autonomy of persons with disabilities by providing means for communication and interaction with people and the environment. Traditionally, these tools and solutions have been designed for distinct domains of application and used for proprietary interfaces. Thus, off-the-shelf AT-solutions can hardly be combined or adapted to individual capabilities and needs of a particular person. ATs today are still general purpose tools for groups of users, other than personalized solutions implemented with the user. This leads to abandonment of AT or demands for a lot of cost intense redesign to tailor solutions to the actual needs of users. AT is to be seen more as a service implemented at a user based on individual assessment than general purpose products (Desideri et al.).

To address these issues, the AsTeRICS open source AT-construction set and accompanying hardware modules have been developed and evaluated in a series of R&D-projects (Nußbaum et al.). These tools can be combined and parameterized in user-centered design processes, in order to create unique AT solutions that match individual needs and capabilities of a particular person. By using a graphical system design approach, solutions can be modified even during field-tests, together with end users and without programming effort, thereby reducing the development costs while increasing the flexibility of application. It is the ultimate goal of our developed toolkit to make the process of implementing AT solutions an integrated part of the service/support process which can be performed as much as possible by formal or informal service and support staff.

Background and State-of-the-Art Overview

ICT-based technological aids for persons with disability comprise a plethora of devices and software-based solutions - supporting communication, visual- or hearing capabilities, movement and interaction with the environment as well as cognitive abilities and learning, see for example Pinheiro et al. In the following, we discuss some examples focusing on mouth-controlled alternative input devices for people with severe motor disabilities, and we demonstrate the innovative aspect of a toolkit-based implementation of ATs using component-based Visual Programming Languages (VPL).

Tongue-controlled input devices are well documented in scientific literature (e.g. Kim et al., Houm & Ghovanloo or Lund et al.). Surprisingly, very few scientific publications cover mouth-based systems that are controlled via the user's lips or chin movement. One related work by Jose & Lopes presents a human-computer interface controlled by the lips, which is head-mounted and captures the lower lip muscle movements via a joystick. Nevertheless, several commercial mouth-controllers are available, including the *TetraMouse* (http://www.tetramouse.com), the *Integra Mouse* (http://www.integramouse.com), the *Lipstick* (http://www.shannonelectronics.nl), *Quadjoy* (http://www.quadjoy.com), *Jouse* (http://www.compusult.net/assistive-technology/our-at-products/jouse3), *HAPP-100* (http://www.celticmagic.org) and the *QuadStick* (http://www.quadstick.com). These devices establish mouse-replacement functionalities via different sensing technologies like magnets, force sensors or optical sensing. *QuadStick* offers the most comprehensive set of user-adjustable settings, including sensitivity- and acceleration parameters for mouse- or joystick control, changeable profiles for keyboard emulation, mapping for gestures to desired actions and compatibility with major gaming console controllers.

Visual Programming Languages (VPL) and model-based design are established paradigms in scientific computing and engineering – with well-known examples like *Simulink* by *MathWorks* (https://www.mathworks.com/products/simulink.html) or *Labview* by *National Instruments* (http://www.ni.com/de-at/shop/labview.html). In the domain of bioelectric signal processing, several frameworks utilize model-based design and VPL, foremost the OpenVibe designer for BCI applications (Renard et al.) and the BioExplorer neurofeedback suite (http://www.cyberevolution.com). The most versatile VPL designer for near-real time processing of multimodal data we are aware of is the *EyesWeb* framework which focuses on computer vision and audio data processing for interactive art performances (Volpe & Carmurri et al.). EyesWeb offers a great number of processing elements and even allows utilization of multiple CPU-cores for parallel signal processing tasks. Although VPL and graphical model design seem a "best-match" for prototyping highly individual AT-solutions, to our best knowledge such an approach has not been applied for Assistive Technology development before.

Methods and Framework

In this chapter, we briefly introduce the AsTeRICS framework for component-based, graphical design of AT-solutions and the FlipMouse and FABI hardware modules, and we will describe a methodology how these open source tools can be utilized in single subject experimental designs.

AsTeRICS – a Component-Based Software Framework for Assistive Technology

AsTeRICS - the Assistive Technology Rapid Integration and Construction Set - is a software framework which has been created in a collaborative research project co-funded by the European Commission (Nußbaum et al.). AsTeRICS uses a component-based software approach and an open architecture with interfaces for sensor-, processor- and actuator-plugins that offer building blocks for AT- , AAC- and environmental control solutions. A Java/OSGi middleware handles the lifecycle of the plugins and the data exchange, see Veigl et al. (2013). Using a graphical editor for visual programming (the AsTeRICS Configuration Suite – ACS), plugins can be combined into end-user-ready solutions also by non-experts like computer literate care persons or family members. Using the ACS, assistive solutions can be designed or adapted directly at the user's site in close cooperation with the clients, and without the need of programming knowledge. Figure 1 shows the main components of the AsTeRICS framework and their interconnection: the ACS communicates with the runtime environment (ARE) via an open protocol (ASAPI) for exchange of model data (xml) and plugin parameter settings. The ARE holds the functional OSGI plugins and services, and exposes a Webserver for easy configuration of features via desired web-enabled devices.

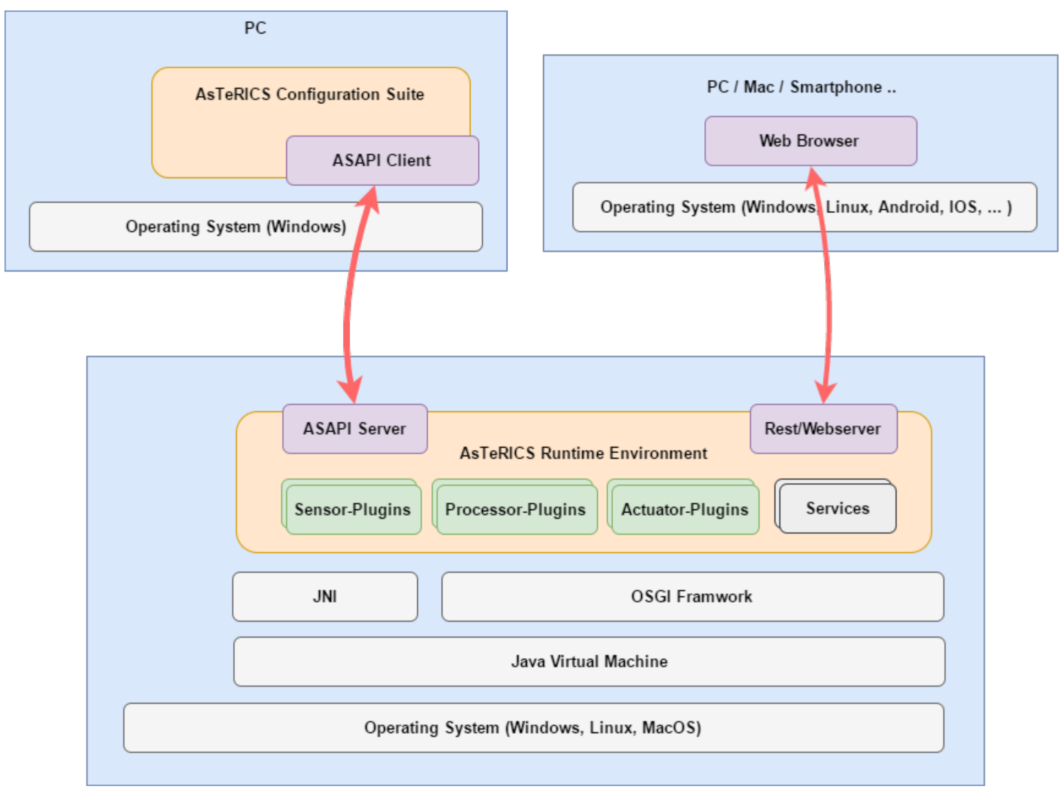

Fig. 1. Key components of the AsTeRICS framework. Source: Veigl et al. (2017)

Currently 191 plugins are available, offering mathematical operations, feature detection and classification algorithms and interfaces to various off-the-shelf hardware modules for sensing (e.g. inertial measurement units, computer vision or bioelectric signal acquisition) and actuation (e.g. building automation standards like KNX or EnOcean, speech synthesis or mouse emulation). By connecting plugins and adjusting their parameters in the ACS, signal- and event pathways are defined and unique assistive functions can be created, integrating diverse sensing technologies with existing AT-products or the Smart Home. The system architecture is capable of handling concurrent data streams of multiple signal channels and the data can be processed under near-real-time constraints. For further details please refer to Weiß et al. and Acedo et al.

FlipMouse and FABI – low-cost versatile Input Devices

In order to provide highly sensitive and configurable alternative input variants for persons with limited motor control, the FlipMouse and FABI devices for computer- and smart-phone access were created (Aigner et al). The FlipMouse is a microcontroller-based device which emulates mouse-, keyboard and joystick functions via the USB HID standard. All functions can be controlled via lip-movements, sip-and-puff actions or minimal finger movements (see Figure 2). The mouthpiece acts as a zero-way-joystick which can be operated with extremely low forces of about 0,02N. The FlipMouse offers manifold configuration options including sensitivity, acceleration, maximum speed, press/release key combinations, phrase writing, command macros and more. Different sip/puff threshold levels and gestures can be defined, giving a maximum of 112 user-actions (16 actions per profile, up to 7 profiles which can be stored into the internal EEPROM memory).

Fig. 2. The FlipMouse (left), used via lips (middle) or finger interaction (right)

The FlipMouse can also act as a universal infrared remote control for environmental control applications and learn IR-codes from arbitrary consumer electronics (Figure 3). Using the Bluetooth-add-on module allows switching between two controlled devices (e.g. the PC connected by USB and a smartphone or tablet connected by Bluetooth). The raw values can be processed within the AsTeRICS framework, using a dedicated plugin for the FlipMouse. This data can easily be combined with EyeTracking, voice recognition or other modalities in order to achieve desired functionalities. An example was presented in the work by Aigner et al., where a versatile musical instrument was developed for a user with late-stage muscular dystrophy by combining the FlipMouse with gaze tracking hardware in a dedicated AsTeRICS model. The FlipMouse is available as a construction kit and related design plans and documentation can be downloaded from GitHub (https://github.com/asterics/FLipMouse).

The FABI module (Flexible Assistive Button Interface) is a configurable interface box for up to 9 momentary switches which offers a rich set of mouse- and keyboard actions and can be manufactured at very low cost. Similar to the FlipMouse, the button activities can be freely configured in a dedicated software GUI, multiple memory slots for configurations are available and a Bluetooth module can be added if desired. A standard FABI switchbox can be built in about one hour, material cost is about 15 €. Both devices (FlipMouse and FABI) can be used stand-alone or in combination with the AsTeRICS framework.

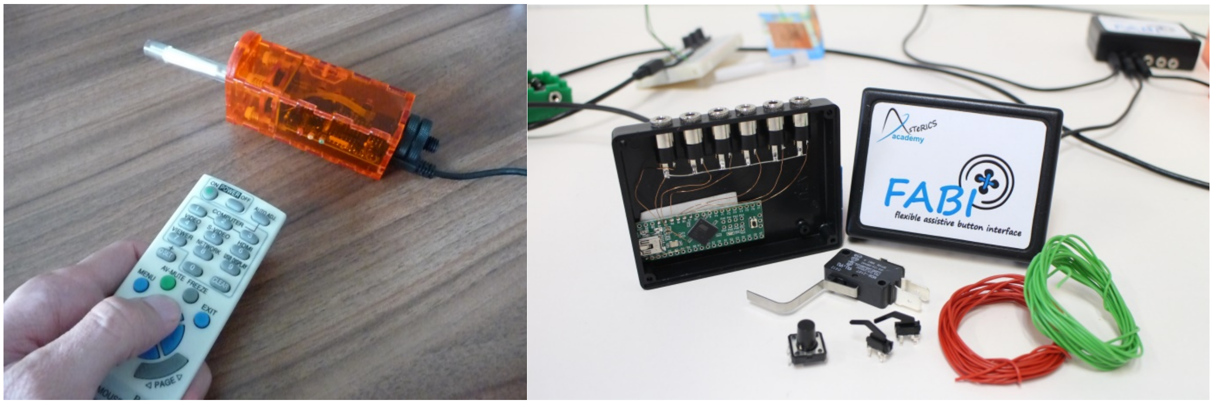

Fig. 3. The FlipMouse recording IR-codes (left). The FABI low cost switch interface (right).

Scientific Methodology: Single Subject Design and Participative Action Research

Although the Randomized Controlled Trial (RCT) represents an essential methodology to elucidate cause and effect in clinical studies and user evaluations, RCT can hardly be applied in situations where user characteristics differ significantly and thus a consistent sample group cannot be established, or if experimental setups are exclusively created for a particular person. Such Single-Subject Design (SSD) is also known as the “n-of-1 trial”, “single-system design”, or “single-case experimental design” and has been thoroughly described by Guyatt et al., Horner et al., Backman & Harris (1999) and others. SSD provides the flexibility to fit an intervention to the specific characteristics of an individual and represents a reasonable methodology for the evaluation of results. For rating methodological quality of single subject designs, Tate and colleagues developed the Single Case Experimental Design (SCED) scale (Tate et al.). Although not all criteria of the SCED scale could be applied in the user studies presented herein (omitting inter-rater reliability, independent assessor and generalization), the scale was helpful for shaping the study designs. For developing the assistive solutions together with the end-users, a Participatory Action Research (PAR) method was applied, where the clients are directly involved in the formative evaluation and indirectly involved in the system/software development process, see Veigl (2017).

Changing Service Practice: User-centric and Personalized AT Solutions and Evaluation

Using the AsTeRICS open source framework and toolkit, a wide range of assistive applications can be created with minimum cost and efforts, including computer control for persons with severe motor restrictions, environmental control systems for interaction with Smart Home infrastructure, Augmentative and Alternative Communication solutions or accessible gaming setups. In the following, we demonstrate the creation of a functional AAC-solution using AsTeRICS, FABI and the FlipMouse.

Design Example: An AAC-Grid with Environmental Control Functions

To illustrate the creation of AT-solutions using the AsTeRICS framework, we demonstrate the design of a simple AAC communication grid with graphical symbols (organized in a tree hierarchy). The grid offers stepwise scanning for selection, speech synthesis and infrared environmental control for home entertainment devices. The FABI interface allows the connection of a momentary switch and the FlipMouse is used for infrared remote control.

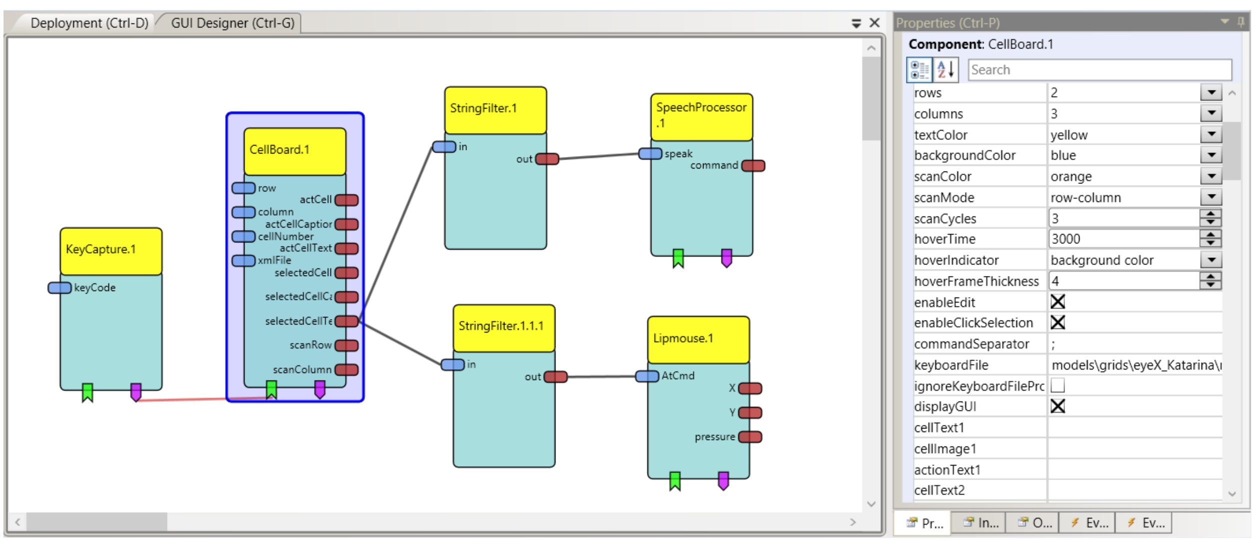

Fig. 4. AsTeRICS graphical model design of the AAC grid in the Configuration Suite (ACS).

Figure 4 shows the underlying AsTeRICS model in the ACS editor: the primary plugin is the *Cellboard* processor, its settings are depicted in the property editor on the right. This plugin provides a configurable on-screen grid with a desired number of rows and columns. The grid elements can be filled with text or graphical symbols. The selection method for choosing a cell can be set to direct (mouse-click) selection, hover selection or stepwise scanning (row/column, column/row or directed scan). When a cell is selected during runtime, events or command strings are sent to connected plugins. In this example, a *SpeechProcessor* and a *FlipMouse* plugin are connected to the *CellBoard* and receive command strings only when respective cells are selected. This is realized via 2 *StringFilter* plugins which detect dedicated tokens in the command strings. The *SpeechProcessor* creates synthetic speech via an adjustable voice. In this use case, the FlipMouse is used solely as an actuator for sending Infrared Remote codes. IR-Commands were pre-recorded from IR-remote control units of desired home entertainment devices. Finally, the FABI switchbox is configured to generate a *Spacebar*-key when a connected momentary switch is pressed. Whenever the keycode for the *Spacebar* is detected by the *KeyCapture* plugin, an event is sent to the *Cellboard* so that the scanning- and selection process can be controlled via the connected switch. Figure 5 shows the finalized user interface with symbols and text captions. Unless the *Cellboard* is locked via a dedicated property value, the cell content can be changed via a right mouse click, which opens a pop-up window where command strings, image files or xml-files of sub-grids can be chosen. Thus, a comprehensive multi-layered grid can be created.

Fig. 5. Main panel of the finalized AAC- and environmental control grid (captions in German).

Evaluation with End-Users

Over a period of two years, the component-based AsTeRICS software framework and the accompanying hardware modules FlipMouse and FABI have been evaluated with different persons (with and without disabilities). A quantitative evaluation of the FlipMouse has been performed with 10 users. In course of this evaluation, timing and precision have been measured during selection of non-moving targets on a computer screen. For the presentation of the on-screen targets, the *Aimbooster* tool was used (http://aimbooster.com). *Aimbooster* allows adjustment of different parameters including the size of clickable targets, the size of the presentation window, the presentation time, moving or stationary targets and more. The settings can be saved in an online database in order to provide identical setups for later evaluations. The utilized settings for this evaluation are available via the URL http://aimbooster.com/s/z1hdpNS.

Ten persons participated in the study, where 6 had a motor disability in the upper limbs and 4 had no motor disability. All participants were first-time-users of the FlipMouse, controlled the mouse cursor via mouth/lip interaction and used puff activity for clicking. Every person performed 3 test runs, where one test run took 2 minutes to complete. The board size was set to 800 x 600 pixels and the board was presented on a 21” LCD screen, where screen resolution was set to 1280 x 720 pixels. Single targets of 20 pixel diameter were presented at randomized locations on the board. Timing and click performance were measured. In Table 1, the averaged time for hitting a target, the number of hits and misses (and their ratio) as well as the count of center hits (where the participant succeeded in clicking the very small center of the target) are shown. A comparison between the averaged performance results of the users without disability (U1-U4, hit rate: 69.75%, center hits: 39.5, average time: 3226ms) and the users with physical limitation (U5-U10, hit rate: 65.83%, center hits: 18, average time: 3119.5ms) reveals similar target hit rates and timing. The rather big difference for the center hit counts (39 for the non-disabled persons vs. 18 for the persons with disability, suggesting a higher target precision for the first group) should be examined in a dedicated study setup with a bigger sample size in order to obtain significant results.

Table 1. Averaged Scores for FlipMouse Target Hit rating for 10 users (U1-U4 without motor disability, U5-U10 with a motor disability in upper limbs)

	U1	**U2**	**U3**	**U4**	**U5**	**U6**	**U7**	**U8**	**U9**	**U10**
Avg. Time	2649 ms	2804 ms	4524 ms	2927 ms	4206 ms	3341 ms	2607 ms	2808 ms	3174 ms	2581 ms
Center Hits	34	43	39	42	12	17	19	15	19	26
Hits	54/65	58/70	42/70	47/72	36/68	25/36	33/46	27/42	29/46	38/48
Hits Percent	83%	82%	60%	54%	52%	69%	71%	64%	60%	79%

Furthermore, multiple single subject user studies have been performed, probing the potential of the AsTeRICS framework with FlipMouse or FABI hardware modules in individual application scenarios. These studies implemented a Participatory Action Research (PAR) methodology and were realized together with persons with unique capabilities and needs. Before starting evaluations, informed consent documents and a data protection agreement were discussed with the participants and signed by clients and assessors. The clinical history, prior used assistive tools and the goals of the intervention were determined in a preliminary interview. Where applicable, baseline measurements were taken with existing AT. In the following, we will describe setup and results of one of these studies in more detail.

User Evaluation with T.W.:

T.W. is a 15 year old boy with Dychenne Muscular Dystrophy who has a very limited range of upper and lower limb movements (fingertips can be moved about 2 cm, hands cannot be lifted). Due to the decreased hand-/finger force, T.W. cannot use a standard computer mouse anymore and also experiences increasing problems when using his special joystick for wheelchair control. Because T.W. relies on breathing support through the nose, mouth-controlled input devices could only be applied with difficulties. The primary goal of the intervention was to improve the input capacity of T.W. in order to revive his computer gaming activities and enable internet browsing. With the AsTeRICS framework, an off-the-shelf eyetracking device (*Tobii EyeX*, http://tobiigaming.com) and a unique 5-switch controller (based on the FABI device), a unique input solution was established. The switch controller was specifically designed to fit T.W.'s left hand (see Figure 8). The location of 5 low-force momentary switches matches the position of the fingertips of his left hand. The actuation force is less than 0,07 N. *Instamorph* moldable plastic (http://www.instamorph.com) was used to model the shape of the controller. The FlipMouse is utilized as a finger-joystick for the right hand (see Figure 6). An AsTeRICS model provides 20 different key mappings for the FABI device which can be changed by the user during operation, supporting different computer games and other use cases. T.W. is now able to fully use his computer (running the standard *Windows-10* operating system), browse the internet and play various non-trivial state-of-the-art computer games.

Fig. 6. T.W. using FlipMouse, Fabi and AsTeRICS for gaming.

In a series of quantitative measurements, the reaction time and key selection performance of the tailored FABI interface was evaluated. For this purpose, a dedicated AsTeRICS model has been designed, which presents 1 out of 5 target keys and measures the time until this key is successfully pressed. The keys are selected randomly, and after a correct keypress was detected a randomized idle time of 3 to 8 seconds is applied in between the trials to avoid anticipation of the next stimulus. One trial session consisted of 20 trials. The time to hit the correct key was measured in milliseconds and added to a dedicated CVS file for each key for later statistical computation. T.W. performed 7 sessions over a period of several days. A total of 140 values were measured and after removing some measurement errors which resulted from unintended interruptions of the measurement procedure, 125 values could be used for the evaluation. The results can be viewed in the box plots in Figure 7. The median reaction time is located below one second, except for finger 1 (pinky finger) with slightly slower reaction. The box plots indicate a good overall performance of the interface and a high usability for the intended application areas (gaming and computer control).

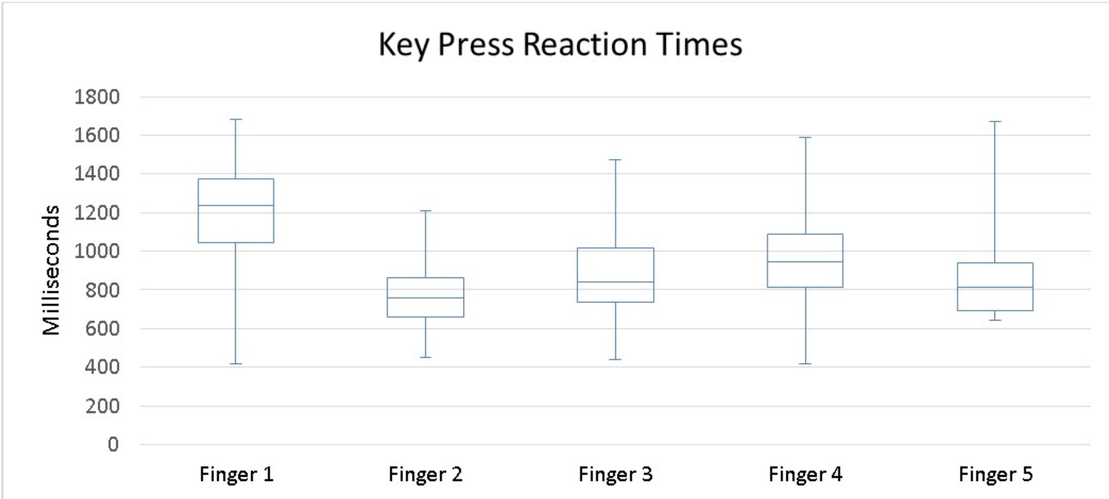

Fig. 7. Box plots of the key press reaction times for 5 fingers of the left hand

(1: pinky, 2: ring, 3: middle, 4: index, 5: thumb)

Conclusion

The developed software framework and hardware modules offer a rich set of reusable, configurable open source components for an iterative construction of unique assistive solutions that are tailored to capabilities and needs of individual persons. In course of the scientific evaluation a Single Subject Experimental Design, it could be shown that rapid prototyping of personalized solutions is cost effective and can considerably increase the interaction efficiency and the sphere of activity of people with severely limited motor control. The developed solution is still in use by the test subject on a daily basis, for up to 8 hours per day.

It is suggested that therapists and care personnel receive training with similar tools so that personalization can become an integral part of everyday service provision. This demands for an organizational shift of focus towards using the potential of personalized AT at larger scale: AT should not be considered as an external resource to be ordered - but more as a solution to be built together with the users in the service process, based on shared components and know-how.

In accordance with general recommendations for AT service delivery practice (Andrich, R., et al.) we suggest that more hands-on training is needed for service delivery professionals so that AT solution implementation can become part of their daily routine. AT solutions must be driven by end users and their formal and informal care/support team. This on the one hand asks for a change in AT engineering to be more understood as a component provider and consulting unit than as a solution provider. On the other hand this asks for according change management in the service sector - to take AT on board and making it part of service practice with according implications on strategy, investment and staff (recruiting, competence formation).

Acknowledgements

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A Hybrid Indoor Positioning System for the Blind and Visually Impaired Using Bluetooth and Google Tango

The Journal on Technology and Persons with Disabilities

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Abstract

Blind & visually impaired individuals often face challenges in wayfinding in unfamiliar environments. Thus, an accessible indoor positioning and navigation system that safely and accurately positions and guides such individuals would be welcome. In indoor positioning, both Bluetooth Low Energy (BLE) beacons and Google Tango have their individual strengths but also have weaknesses that can affect the overall usability of a system that solely relies on either component. We propose a hybrid positioning and navigation system that combines both BLE beacons and Google Tango in order to tap into their strengths while minimizing their individual weaknesses. In this paper, we will discuss the approach and implementation of a BLE- and Tango-based hybrid system. The results of pilot tests on the individual components and a human subject test on the full BLE and hybrid systems are also presented. In addition, we have explored the use of vibrotactile devices to provide additional information to a user about their surroundings.

Keywords

Indoor navigation; indoor positioning; Bluetooth Low Energy (BLE); beacons; Google Tango; assistive technology.

Introduction

Blind & visually impaired (BVI) individuals often face challenges in wayfinding and navigation, especially in unfamiliar indoor environments. There is, therefore, a great need for reliable, indoor location-based services to assist BVI users in unfamiliar indoor environments. To address this need, we assessed the utility of combining Bluetooth Low Energy (BLE) beacons and a Google Tango device as a robust system for indoor positioning and navigation. Both BLE beacons and Tango have their respective strengths; however, their individual weaknesses prevent them from being fully used in indoor assistive navigation. We hypothesize that a hybrid of the two systems could form an extremely accurate and useful indoor localization system for the visually impaired. We also hypothesize that users can benefit from a supplementary system that can alert them of obstacles in their vicinity (such as walls and people). We tested this using vibrotactile sensors placed on the user's wrists. The paper follows the following outline:

1. We describe the approaches and implementations of the individual BLE and Tango systems, as well as those of the hybrid and supplementary vibrotactile systems.
2. We discuss the results of pilot tests and identify the technical limitations and advantages of the individual BLE and Tango systems.
3. We report the results of and discuss the conclusions drawn from a human subject test on the standalone BLE and the hybrid systems (and the vibrotactile supplement).

Related Work

Recent advances in computer vision have provided platforms for developing assistive technologies for the visually-impaired, particularly using Google Tango. Li, *et al* (2016) have proposed ISANA, context-aware indoor navigation implemented using Tango. Work by Winterhalter, *et al* (2015) utilized a Tango device and particle filter localization, instead of the

Tango onboard SLAM, to estimate the 6DOF pose of the Tango device within a 2D floor plan, which eliminates an initial mapping phase with the Tango. External RGB-D cameras have also been used to build a vicinity map based on 3D data and perform path planning to provide 3D traversability (Schwarze, *et al*, 2016).

There have also been numerous projects which have used BLE beacons in assistive navigation. Perhaps the most relevant is NavCog, a "smartphone mobility aid" which solely used BLE beacons to provide turn-by-turn navigation and information about nearby points-of-interest (Ahmetovic, et al, 2016). Another system (Bohonos, et al, 2007) proposed the use of BLE beacons as part of a system to provide the visually impaired with information about the topology of an approaching urban intersection. Further work proposed beacons as part of an indoor "traffic sign system" for the cognitively-impaired that downloads images with directional instructions onto a device when the user reaches a hallway intersection (Chang, *et al*, 2008).

Discussion

In the following section, we discuss the system components used in our proposed hybrid system and present the results of human subject experiments.

System Components

For our preliminary evaluation of the system components, we performed pilot tests at Lighthouse Guild, a center providing vision and healthcare services for BVI in NYC. The pilot tests with the BLE system were performed using a Samsung Galaxy S4, and the tests with the Tango system were performed using a Lenovo Phab 2 Pro.

BLE Beacons

BLE beacons broadcast an identifier and other relevant information to nearby receiver devices. Specifically, we used Proximity and Location Beacons from Estimote (shown in the inset in Figure 1). These beacons have a small form-factor, long battery life, and are relatively low-cost.

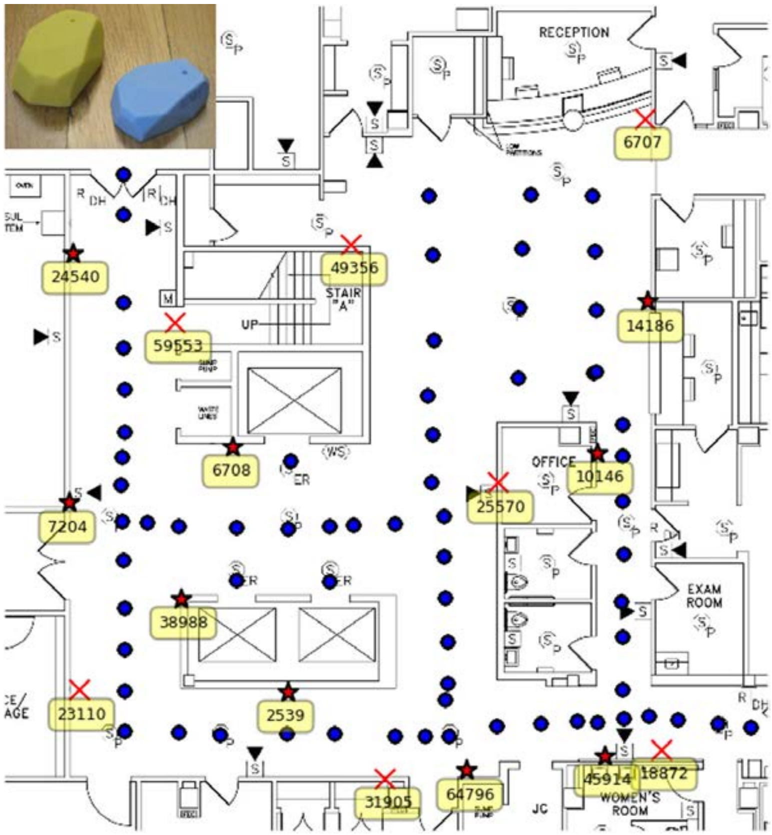
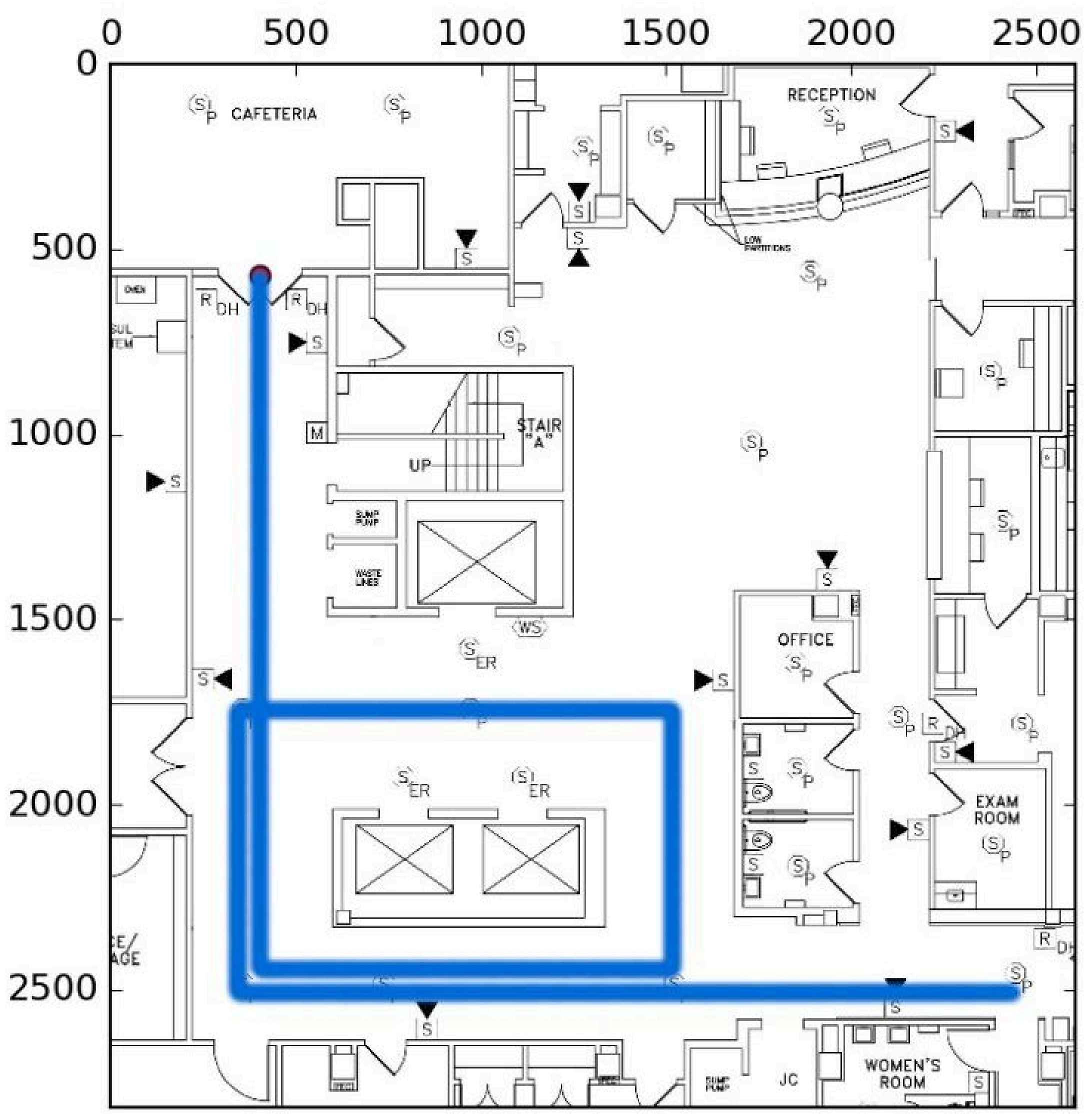


Fig. 1. The BLE Beacon component. Floor plan of Lighthouse Guild C-Level marked with fingerprinting locations (as blue dots) as well as locations and IDs of installed Proximity (red X's) and Location (red stars) beacons. Top left inset: A Location beacon (left) and a Proximity beacon (right).

With these beacons, we could use one of many different methods to utilize the Received Signal Strength Indicator (RSSI) value of each beacon and, thus, localize a device. We found that BLE signals are extremely noisy, because they are easily attenuated by materials commonly found in a building (Kara and Bertoni, 2001). Thus, we opted to use the "fingerprinting" method, which compares the current RSSIs with pre-built snapshots (or "fingerprints") of the area's radio landscape (Subhan, et al, 2011). Fingerprinting inherently looks for similarity and not exactness in RSSIs and is, thus theoretically, very suitable for rapidly fluctuating signals.

Figure 1 shows a detailed map of our beacon testbed. Our test system used fingerprints which were captured in an offline run before our tests. During localization, the current signal conditions were compared to the pre-recorded fingerprints using a custom variation of the k-nearest neighbor algorithm, which assigned different weights to fingerprints based on reliability and calculated the uncertainty of the final position.



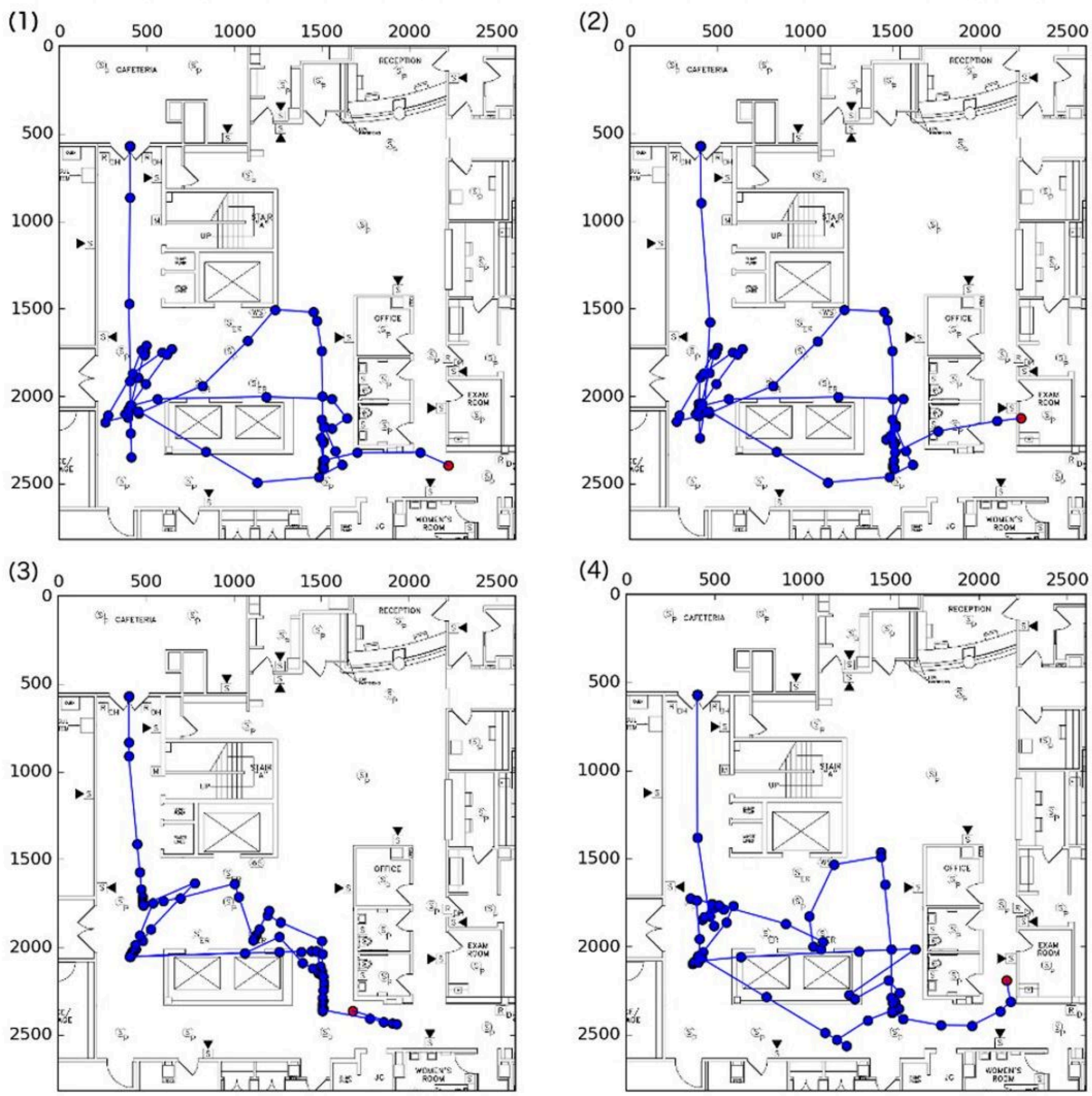


Fig. 2. Real path and predicted paths calculated from a single set of BLE data. We recorded the RSS data the phone sent while walking along a predetermined path. We then ran the data through several variations of our algorithm. Left: The real path that was taken during the recording of the data. Right, calculated paths: (1) Full algorithm, (2) No fallback to regular KNN if uncertainty in measurement too large, (3) Pure KNN with no weighting, no fallback, and using only closest physical (not RSS) neighbor to predicted position, (4) Only deal with the closest RSS neighbor (not multiple) + no fallback.

Due to the noisy nature of the RSSIs, we observed that the predicted location tended to jump around. We also saw that even slight variations to our algorithm produced different results with varying degrees of accuracy (Figure 2). However, we also saw that the system seemed to be trying to follow the general trend found in the true path. Thus, the beacons may prove useful in calculating a coarse location for the user; however, greater accuracy would be required for a fine location application.

Google Tango

A Google Tango-enabled device contains an RGB-D camera that has been integrated into an Android device (Li, *et al*, 2016) with capabilities of 6-degrees-of-freedom VIO (visual-inertial odometry) and feature-based indoor localization, which allows the device's pose (orientation and position) to be estimated as it moves through a 3D environment, without the use of GPS or other external signals. Tango also includes functionality for recording an Area Description File (ADF), a feature map of an indoor environment in a compressed format, which allows for re-localization within that environment. By utilizing these built-in capabilities of the Tango device, we could create detailed 3D models of indoor environments (Figure 3) and achieve extremely accurate real-time indoor localization.

During our pilot tests, we found that the Tango device was prone to small errors during the estimation of each camera position. (Sensors are sensitive to some noise and are not 100% accurate.) This made the estimated position of the device drift over time, causing drift error (maximum = 0.38 m, average = 2.9 cm). The Tango API itself attempts to correct some of this drift error by utilizing a loop closure approach. While an ADF is being recorded and the device returns to the origin of the ADF (thus closing the loop), Tango will attempt to correct the accumulated drift errors by adjusting the estimated trajectory to match the real trajectory.

Furthermore, we encountered another limitation with the Tango device in that there is a limit on the size of an ADF (approximately one floor of a building).

Fig. 3. 3D model of Lighthouse Guild C-Level as created by Tango.

BLE-Tango Hybrid System

In order to overcome the technical limitations of the individual systems, a hybrid localization system that utilizes BLE beacons and a Google Tango device was implemented:

A Tango device was used to record an ADF (feature map) for each floor in a building. Given that a 2D floor plan of each floor was available, an affine transformation was utilized to translate, scale and orient the 3D ADF to align with the floor plan (Figure 4). The affine transformation function in the OpenCV library was used, which given 3 pairs of corresponding 2D points, returns a 2 x 3 transformation matrix M. We assumed that all 3D pose information returned by the Tango API was on a plane (the floor), and therefore the *z*-component of the 3D coordinates could be discarded. The 2D affine transform could now be applied. The position of the user was then tracked on an adaptive app interface consisting of the 2D floor plan of the environment that the user was currently in.

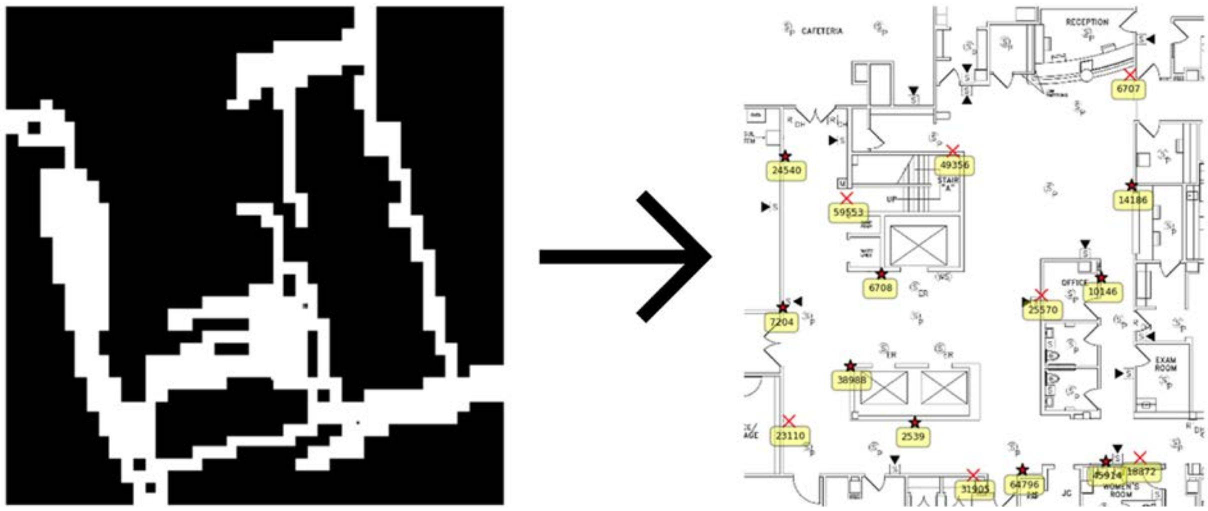


Fig. 4. 2D binary representation of Tango-recorded ADF (left) aligned with 2D floor plan corresponding to area recorded by ADF (right).

As mentioned previously, the ADF size limitation is approximately one floor. However, since beacons have proven to be reliable in determining a rough location, they could be used to determine the floor a user is on and automatically load the corresponding ADF. Alternatively, if the floor is too large (and thus consists of multiple ADFs), we could use the location returned from the beacons to select the ADF that is closest to this coarse location.

Map Annotation

A map annotation module was developed in order to place waypoints on the 2D floor plan associated with the ADF. Once Tango has mapped a floor and is localized, waypoints can be marked on the 2D floor plan using the app’s adaptive interface. The waypoint on the map will correspond to the real-world location in the 3D ADF (Figure 5, left).

Navigation

An application was developed for blind and visually impaired individuals, consisting of a fully-developed “Navigator” component, which provided turn-by-turn navigation using either BLE beacons, Google Tango, or BLE-Tango hybrid localization (Figure 5, right). Using the waypoints set by the map annotation module on the 2D floor plan, a visually impaired user can receive turn-by-turn audio directions to navigate to any destination. When the user selects their destination, the app executes Dijkstra's algorithm (Dijkstra, 1959) to determine the shortest path between the origin and destination nodes; it is this path that the Navigator will guide the user along.

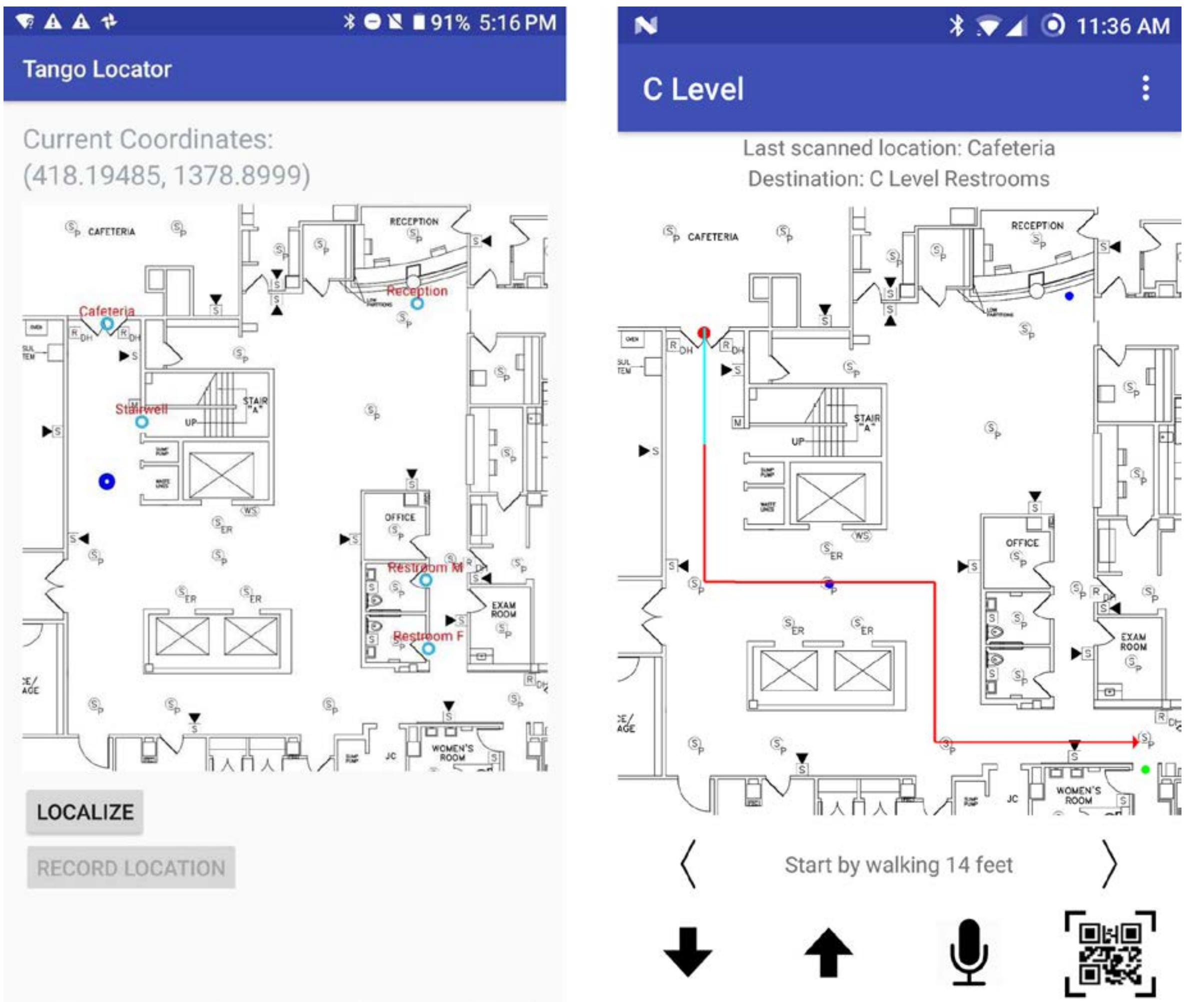


Fig. 5. Screenshots of the map annotation module showing some recorded landmarks (LEFT) and the Navigator component of our test app (RIGHT), currently providing turn-by-turn directions from the cafeteria to the restrooms in our test area.

Vibrotactile Assistance

We also examined the use of vibrotactile devices as a supplement to our application so that a user could gain an awareness of their immediate surroundings. We used simple, small 3D-printed devices that have infrared sensors that point straight out of the top portion of the device. The devices are attached to the user's wrists using straps. When the device's infrared sensor detects a close object, it vibrates (with the vibration speed dependent on the proximity of the object to the sensor). By moving their wrists, a user could gain an idea of how close they are to various objects/obstacles (such as walls) in addition to their relative orientation to these obstacles.

Human Subject Experiments

In order to evaluate the usability of the BLE and hybrid systems and the vibrotactile supplement by BVI individuals, we performed human subject experiments at Lighthouse Guild's new building. For these experiments, we exclusively used the Lenovo Phab 2 Pro for both pure BLE and hybrid navigation. This study was approved by the Institutional Review Board of the City University of New York.

Participants & Materials

A convenience sample of 11 adults who were diagnosed as totally blind, legally blind, partially sighted, or low vision were offered participation in the study. There were 9 (81.8%) participants 55 years old or older, 1 (9.1%) participant 45-54 years old, and 1 (9.1%) participant 18-24 years old. In our study, we had 4 (36.4%) females, and 7 (63.6%) males. In total, 6 (54.5%) participants were diagnosed with total blindness, 4 (36.4%) participants were diagnosed with low vision, and 1 (9.1%) participant was partially sighted. We administered two types of surveys, a pre-experiment survey and a post-experiment survey. The pre-experiment survey included a demographics section, which asked the participants to disclose their gender, age, level of visual impairment, and a section to assess the participants' familiarity with smartphones and their difficulty in indoor navigation. The post-experiment survey was divided into two sections assessing the perceived helpfulness, safety, ease of use, and overall experience of (1) the BLE and hybrid navigation apps and (2) supplementing hybrid navigation with vibrotactiles.

Procedure

The participants were divided into two groups, and both groups completed 6 navigation trials (paths) as shown in Table 1 below. The participants used their white cane or guide dog in all but one trial. The purpose of the navigation experiments was to compare different methods: (1) hybrid navigation vs. BLE navigation; (2) hybrid navigation vs. hybrid navigation supplemented with vibrotactiles; and (3) hybrid navigation vs. hybrid navigation supplemented with vibrotactiles *only* (without a white cane or guide dog). Each pair of paths (1 + 2, 3 + 4, 5 + 6) were virtually identical (equal distance, amount of turns, and narrowness) which allowed us to record 11 data points for each method.

Table 1. Navigation experiments.

Path	**Group 1**	**Group 2**
1	Hybrid	BLE
2	BLE	Hybrid
3	Hybrid	Hybrid (+ vibrotactiles)
4	Hybrid (+ vibrotactiles)	Hybrid
5	Hybrid	Hybrid (+ vibrotactiles ONLY)
6	Hybrid (+ vibrotactiles ONLY)	Hybrid

Results

The pre-experiment survey found that most of the participants relied on others for assistance in navigating indoors, with over 50% stating they relied extremely on others. As can be seen in Figure 6, although most of the participants claimed to find it easy to navigate indoors in familiar environments, almost all of them found it difficult to navigate in unfamiliar indoor environments.

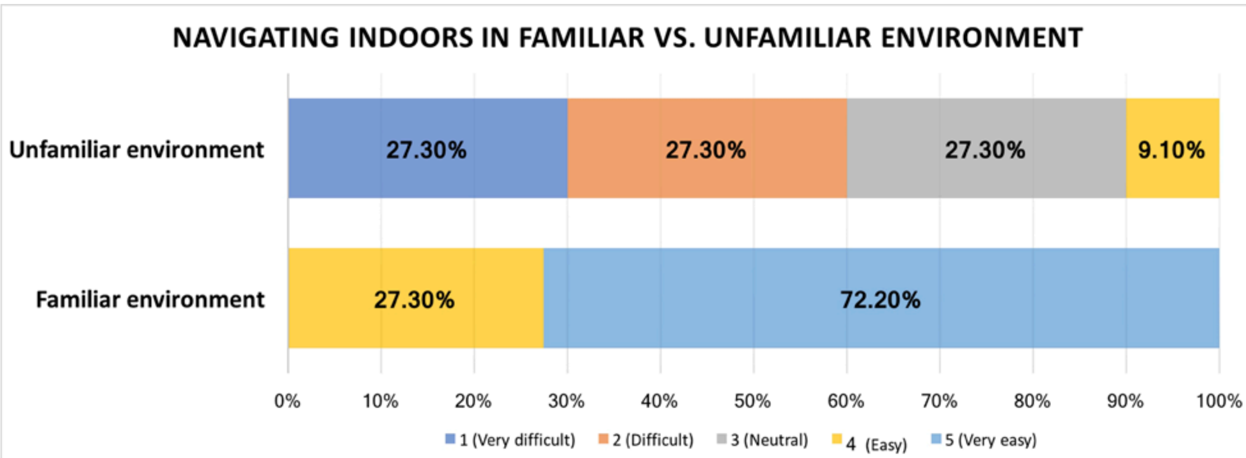


Fig. 6. Perceived difficulty in indoor navigation.

Fig. 7. Sample (estimated) trajectories captured by the apps during a navigation experiment. (Top: BLE; bottom: Hybrid). Users followed the instructions given by the app in walking forward (a certain number of meters/feet/steps), turning (left or right), and stopping; however, their actual trajectories differed from the estimated ones in that users did not bump into walls by using their cane/dog or our vibrotactile devices.

Figure 7 shows the trajectories taken by one subject using BLE and Hybrid navigation. Paired-samples t-tests were conducted to compare duration, total bumps, and total researcher interventions (reminders) between methods. Comparisons were made between (1) BLE-based navigation and hybrid-based navigation, (2) hybrid-based navigation and hybrid-based navigation supplemented with vibrotactiles, and (3) hybrid-based navigation and hybrid-based navigation supplemented with vibrotactiles *only* (i.e., without a white cane or guide dog).

We made the following findings: (1) Our primary finding was that hybrid-based navigation required significantly less interventions and assistance from the researchers than BLE-based navigation ($p = 0.0096$); there was no significant difference in trip duration and total number of bumps between BLE- and hybrid-based navigation (Table 2). (2) We found no significant differences in trip duration, total number of bumps, and total number of researcher interventions and assistance between hybrid-based navigation supplemented with and without vibrotactiles (Table 3). (3) We found no significant differences in trip duration, total number of bumps, and total number of researcher interventions and assistance when comparing the hybrid navigation app and replacing the user's usual aid (cane or guide dog) with vibrotactiles against not replacing the user's usual aid with vibrotactiles (Table 4).

The post-experiment survey found that six participants (54.5%) stated that they preferred the Hybrid app, three (27.3%) preferred the BLE app, and two (18.2%) had no preference. About two-thirds (54.5% - somewhat worse and 9.1% - much worse) of the participants agreed that the BLE app was worse than the Hybrid app, but approximately 80% (45.5% - somewhat better and 27.3% - much better) of the participants agreed that the BLE app was better than no navigation app for indoors at all.

Table 2. Results of t-test and Descriptive Statistics for BLE and Hybrid navigation (M = mean, SD = Standard Deviation, n = sample size, t = test statistic, p = probability value, df = degrees of freedom; *95% confidence interval*).

	BLE M	**BLE SD**	**BLE n**	**Hybrid M**	**Hybrid SD**	**Hybrid n**	**t**	**p**	**df**
total interventions	1.27	0.64	11	0.36	0.50	11	3.19	0.0096	10
trip duration (s)	75.18	17.12	11	64.72	15.13	11	1.65	0.12	10
total bumps	0.09	0.30	11	0.18	0.40	11	-1.00	0.34	10

Table 3. Results of t-test and Descriptive Statistics for Hybrid Navigation supplemented with Vibrotactiles (in table: "Vibros") (M = mean, SD = Standard Deviation, n = sample size, t = test statistic, p = probability value, df = degrees of freedom; *95% confidence interval*)

	Hybrid M	**Hybrid SD**	**Hybrid n**	**Hybrid + Vibros M**	**Hybrid + Vibros SD**	**Hybrid + Vibros n**	**t**	**p**	**df**
total interventions	0.36	0.50	11	0.54	0.52	11	0.80	0.44	10
trip duration (s)	37.18	11.36	11	46.45	31.13	11	0.97	0.35	10
total bumps	0.36	0.50	11	0.18	0.40	11	-1.00	0.34	10

Table 4. Results of t-test and Descriptive Statistics for Hybrid Navigation supplemented with Vibrotactiles (in table: "Vibros") ONLY. (M = mean, SD = Standard Deviation, n = sample size, t = test statistic, p = probability value, df = degrees of freedom; *95% confidence interval*)

	Hybrid M	**Hybrid SD**	**Hybrid n**	**Hybrid + Vibros *only* M**	**Hybrid + Vibros *only* SD**	**Hybrid + Vibros *only* n**	**t**	**p**	**df**
total interventions	0.36	0.50	11	0.54	0.68	11	0.69	0.50	10
trip duration (s)	45.54	12.54	11	50.09	16.50	11	0.63	0.53	10
total bumps	0.09	0.30	11	0.27	0.46	11	1.00	0.34	10

Approximately 90% of the participants agreed that the Hybrid app was helpful, 90% agreed that using the Hybrid app felt safe, and 100% agreed that they could easily reach their destination when using it (see Figure 8). Supplementing the Hybrid navigation system with vibrotactiles for obstacle avoidance was well-received by the participants. Approximately two-thirds of the participants (see Figure 9) felt safe when their canes or guide dogs were replaced with the vibrotactiles.

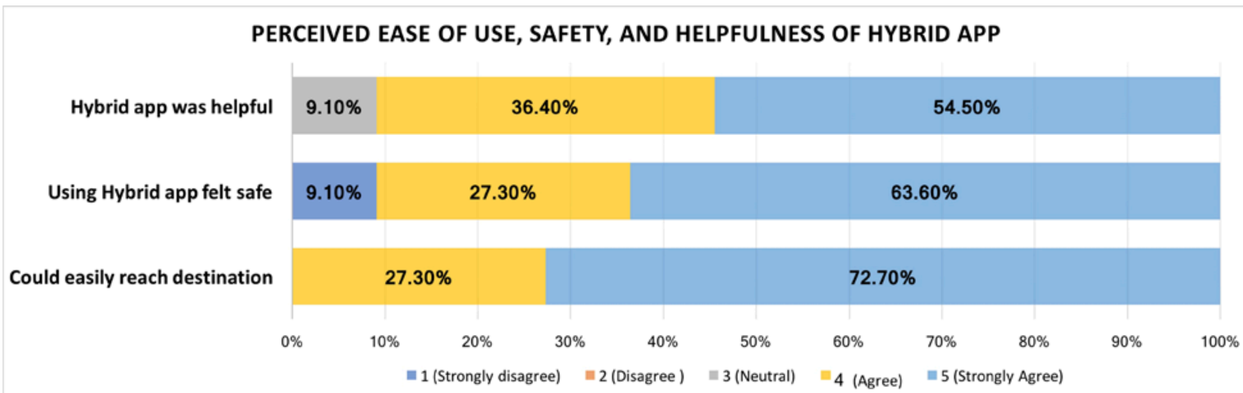


Fig. 8. Perceived ease of use, safety, and helpfulness of Hybrid app.

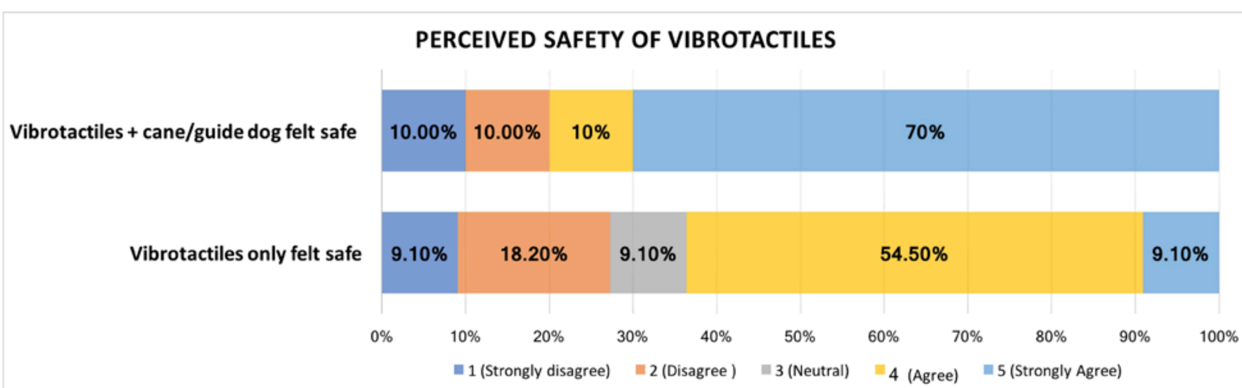


Fig. 9. Perceived safety of vibrotactiles.

Conclusions

Through our work, we have determined that a hybrid system composed of both BLE beacons and Google Tango was both accurate and robust. Tango is capable of providing a highly accurate, fine location; however, it can only create feature maps of approximately one floor at a time. Since the BLE beacons are excellent at coarse location detection, we used them to determine which ADF Tango must load in order to report the correct position to the user. According to subject evaluations, users felt that the BLE-Tango hybrid system helped them reach their destinations easily and safely. Although users perceived the hybrid system as better than the standalone BLE system, the BLE system was equally successful in guiding users to a destination quickly, safely, and with little assistance from the researchers. This finding is noteworthy since with a BLE system alone, a Tango sensor is not needed, the smartphone’s power consumption would be less, and any device (not just a Google Tango device) could be used for navigation. The vibrotactiles supplement proved to be a promising avenue for future work – as no decreases in speed and safety were observed when the standard cane or guide dog was replaced with vibrotactile devices.

Acknowledgments

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RingBoard - A Dynamic Virtual Keyboard for Fist Based Text Entry

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Abstract

The combination of a touch sensitive mat and a projector allow a dynamic keyboard to be projected around a user's fist for text entry. RingBoard is a soft keyboard approach using standard off the shelf components that allows people with motor impairments to interact with a computer. The research presented here focuses on increasing the accessibility of text input to a computer utilizing an innovative dynamic keyboard approach. Two different input methods were analyzed for speed and accuracy in a user study consisting of 20 participants. The results of this study show a fist based touch interaction method is as effective as a finger pointing interaction method when using a large touch mat with a top facing projected image.

Keywords

Input, Keyboard, Accessibility, Typing

Introduction

Interaction with an electronic computing device such as a phone or a computer is typically done through the use of a keyboard. Mobile devices traditionally use an onscreen virtual keyboard, while computers use a physical keyboard. The research in this paper focuses on creating a virtual keyboard for use with a personal computer such that a person with a mobility disability who cannot utilize a standard physical keyboard would be able to better interact with a standard computer.

Background

Computer users with upper mobility issues may have difficulties using a standard computer keyboard. It has been shown that people with physical disabilities such as Cerebral Palsy, Spina Bifida, and tremors due to stroke or Parkinson's disease take longer to complete typing tasks on a standard keyboard (Trewin 1999). Results of the Trewin study showed that users with motor impairments committed errors that can be summarized by the following characteristics:

- Long key press – holding a key longer than the designated key repeat delay.
- Additional key – pressing a key adjacent or near to the intended key in addition or instead of the intended key.
- Missing key – the intended key was not pressed either because it was missed or not pressed hard enough.
- Dropping – two keys were failed to be held at the same time (using the shift key).
- Bounce – the intended key was accidentally pressed more than once.
- Remote – a key different from the intended key was pressed by a body part other than the one being used for the intended key.
- Transposition – two keys were transposed.

There have been attempts to correct these issues through the use of technology. Some modifications have come through software solutions using standard keyboards such as adjusting the repeat time of a key, looking for sticky keys, and using CAPS Lock (Trewin 2002). A soft keyboard application was developed for a floor based touch interface such that the users would be able to input data into the computer through the use of the feet (Nguyen 2012). This type of interface would be useful to someone who had no use of the hands. Another approach (Ahsan 2014) was to print out a keyboard on a physical piece of paper, and then attach a laser pointer to a user's head. A web cam combined with visual analysis would determine where on the keyboard the laser pointer was highlighting and use that as text input. Onscreen soft keyboards have attempted to allow people to interact with keyboards in different ways. For example, a graphical keyboard (Missimer 2010) that allows the user to change the size and location of virtual onscreen keyboard buttons was created. In addition to customizing character input, alternative onscreen keyboards have been created for specific applications where commonly typed phrases specific to an application (Norte 2007) are already populated on the virtual keyboard, and where the underlying system determines commonly typed phrases for each user (Wandmacher 2008) and prepopulates the keyboard with user specific common words and phrases.

In addition to research papers, there are some commercially available products to assist with typing for people with motor impairments. Keyguards are hard plastic covers that frame the outside of each key. This allows a user with tremors to rest the hand on the keyboard without pressing any keys, then locating the correct key and pressing down. This still requires fine motor control of the fingers but the ability to rest the hand without pressing any keys does lessen the typing effects of tremors. Mac and Windows operating systems also have built in software functionality such as Sticky Keys (eliminates required simultaneous key presses like ctrl-alt-delete), filter keys (handles debouncing of multiple simultaneous presses of the same key) and custom keyboard shortcuts to perform frequent tasks. The settings for sticky and filter keys have been made adaptive (Trewin 2004) such that a user does not need to find the correct values – the underlying software can adjust and tune itself. It has been suggested (Dietz 2009) that standard keyboards receive and upgrade such that the force applied to each key could represent the font size. This type of interaction will be difficult for someone who already has issues interacting with a standard keyboard.

Although the research presented in this paper focuses on creating new methods of text input for regular computers, the results of this could be applied to mobile computers with touch interfaces through the use of an external Bluetooth touch keyboard as it has been shown (Armstrong 2016) that users are OK with using an external keyboard for interaction on a mobile device. Another approach (Gkoumas 2016) to mobile device input includes predictive typing where the keyboard is altered such that letters that are likely to appear next (Goodman 2002) are enlarged. Predictive typing on virtual keyboards can be improved by taking into account the position of the hand (Yin 2013) as well. It has also been suggested (Rashid 2008) that a virtual onscreen keyboard for mobile devices be relative to the location where the user starts typing instead of having the keys always in the same location.

Solution

This paper presents a soft keyboard approach using standard off the shelf components that allows people with motor impairments to interact with a computer. The research presented here focuses on increasing the accessibility of text input to a computer utilizing an innovative dynamic keyboard approach. Two different input methods are analyzed for speed and accuracy.

The dynamic keyboard described here was implemented on an HP Sprout all in one computer. The HP Sprout is a computer running Windows 10 with a touch sensitive mat, a touch screen, a built in down facing projector and camera. The idea was to have the projector show a new style of virtual keyboard such that the user could enter text via the touch mat instead of a traditional keyboard. The touch mat lays flat on a desk surface like a traditional keyboard. The projector could change the keyboard layout as needed. In order to test the effectiveness of this style of input and to determine any potential limitations of the projector and touch mat setup, two different input methods were used - Fist and Finger. In Fist, users would interact with the keyboard using the dominant hand shaped into a fist, and in Finger, users would interact with the keyboard using the index finger on the dominate hand. The purpose of this study was to see if the Fist method was as good or better than the Finger method. The Fist method could be used by someone who has tremors and would benefit from being able to rest the full hand on a solid surface while typing as the key guard allows, but to not require fine motor movements like using your finger to press through the key guard.

The software for this experiment was created in Unity3D and the code was written in C#. A full keyboard was designed including numbers and special characters, however this user study focused on lower case character entry. When a user puts his fist or finger to the touch mat, a keyboard would be shown in a ring shape around the center of the touch point. Evenly spaced throughout the ring were the vowels A,E,I,O and U (Figure 1). If the user wanted to type an A, he would slide his fist or finger over to the letter A. When it was determined that the user's touch area had centered on the A, a letter A would be typed. The user would then remove his hand from the touch pad and re-touch to begin the process over again and type the next letter. If the user wanted to type a consonant, he would once again place his fist or finger on the touch mat, when the ring of vowels was drawn, he would drag his fist or finger between the vowels where the constant would be in alphabetical order. For example if the user wanted to type a C, he would drag his fist or finger to the space between the A and the E (Figure 2). Or if the user wanted to type an M, he would drag his fist or finger to the space between the I and the O. When the system determined that the user had intended to type a consonant that alphabetically fell between two vowels, the ring of vowels would be erased, and the new ring of consonants would be shown around the current position of the hand. At this point the user would drag his finger or fist over the desired consonant. If at any point the user made a mistake, lifting the hand would start the process over again, and if an incorrect letter was typed a large BACKSPACE virtual key was always visible.

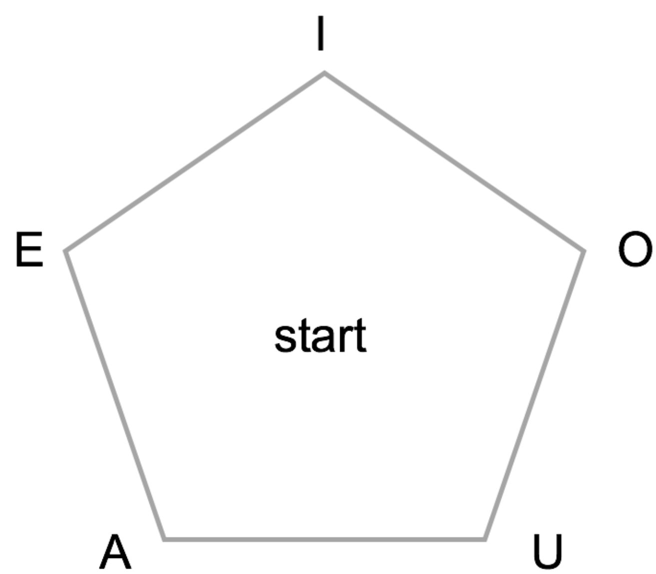

Fig.1. Primary Keys

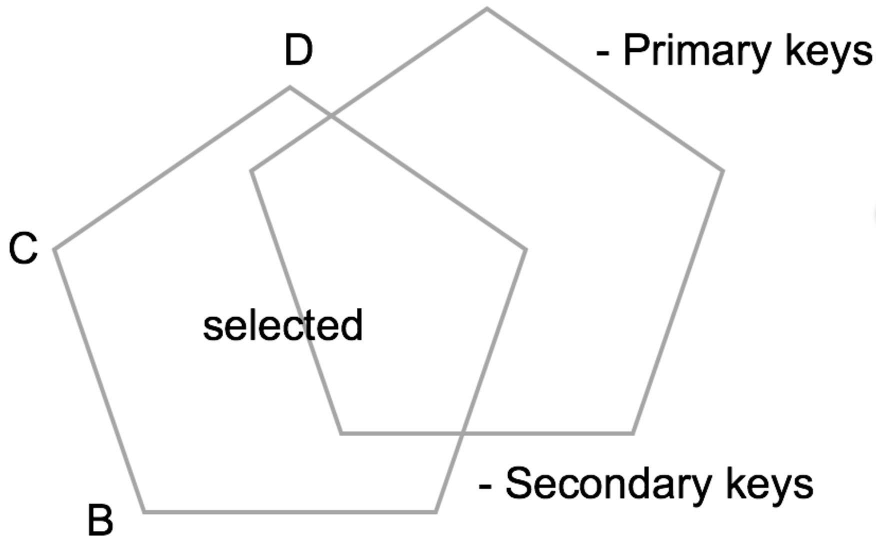

Fig. 2. Secondary Keys

The system as designed should assist with the multiple presses as the user is only allowed to type one character at a time and tremors should be less of an issue as the user is resting his hand on a solid surface in order to interact with it.

Once all the characters were implemented it was noted that several common pieces of keyboard input were missing. For example there was no method to input numbers, or special characters such as punctuation. There was no method to differentiate between capital and lower case letters. There was also no method for entering tabs, spaces, or back spaces. To handle these situations, several buttons were created that were placed on the far left and far right of the touch area. Future versions of the RingBoard may incorporate these into the ring layout. A final screenshot of the RingBoard can be seen in Fig 3.

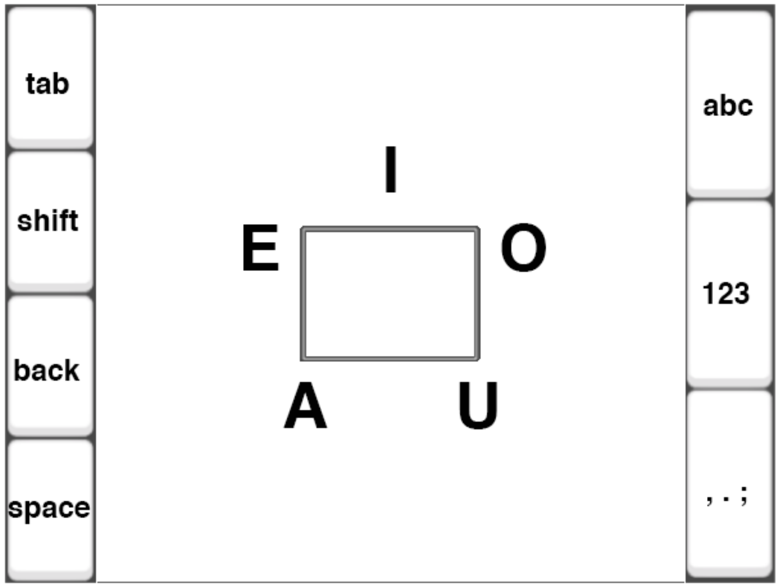

Fig.3. Complete RingBoard Layout

User Study

In order to test the feasibility of such a system, a 20 person user study was conducted. None of the users reported any mobility related disability. Each user was asked to type out a list of 10 words using the finger, then asked to type out a different list of 10 words using the fist. The sequence of the finger and the fist was chosen at random, and sequence of which list was given to the user first was also chosen at random. At the conclusion of each trial, an individual had typed 20 words, 10 with the fist and 10 with the finger. The data was then analyzed for speed and accuracy. Using a small pointing device such as the finger is expected to be more accurate and faster due to it not obstructing the projected image as much as the fist and it is a more natural way to type as most people interact with their index finger on touch screens as opposed to their entire fist. If the fist method is not significantly slower or more error prone than the index finger, this type of interface could potentially improve the accessibility of a computer by a person who has motor impairments or tremors. The results are broken down into speed and accuracy based on individual characters.

Results

As far as speed goes, on average the finger method was faster than the fist method by taking 96.89% (SD=16%) of the time. This was not a significant difference, however. A paired-T test shows $t(29)=1.86$, $p > 0.05$. The speed of the first level characters (vowels) versus the second level characters (consonants) was also compared. Vowels had an average seek time of 0.156 seconds (SD=0.006) for fist and 0.160 (SD=0.01) for finger. Consonants had an average seek time of 1.00 seconds (SD=0.17) for fist and 0.91 seconds (SD=0.14) for finger.

Error rates were measured as the percentage of characters that were incorrectly chosen when compared to the next character in the given word. On average finger pointing error rates were 85.5% (SD=128%) of the fist method. Average vowel error rates for the fist method were 0.019 (SD=0.02) and for the finger method were 0.034 (SD=0.037). For consonants, error rates for the fist method were 0.046 (SD=0.044) and for the finger method 0.056 (SD=0.053).

Conclusion

The results of this study show a fist based touch interaction method is as effective as a finger pointing interaction method when using a large touch mat with a top facing projected image. This shows promise that a touch based mat could be used as an alternative to hardware based key guards for users who need the support of resting the typing hand but who also lack fine motor movements of the fingers. Future improvements of this type of interaction could be using the touch mat as an external input mechanism for mobile devices. A follow up user study should be performed that analyzes the speed and accuracy of utilizing the special characters on the keyboard and to determine if the special characters are better placed within the ring, or having them on the outside of the touch area is sufficient.

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Modeling the Use of Space for Pointing in American Sign Language Animation

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Abstract

Based on motion recordings of humans, we model grammatically appropriate locations in space for a virtual human to point during American Sign Language animations.

Keywords

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

Introduction

American Sign Language (ASL) is a primary means of communication for over 500,000 people in the United States (Mitchell et al., 2006), and standardized English reading-skills testing has revealed that many deaf adults in the U.S. have lower English literacy than their hearing peers (Traxler 2000), which can lead to accessibility barriers when these users are faced with English text online, which may be at too high a reading difficulty level. Given the challenges in re-recording videos of human signers (to update information content in ASL on websites), providing *animations* on websites is a more maintainable way to provide information in ASL.

In ASL, signers associate items under discussion with locations around their body (McBurney 2002; Meier 1990), which the signer may point to later in the discourse to refer to these items again. For instance, if a signer were discussing a favorite book, she might mention the title of the book once, and then point at a location in space around her body. For the remainder of the conversation, she would not mention the title of the book again, but instead she would point to this location in space to refer to it. In this work, we model and predict the most natural locations for these spatial reference points (SRPs), based on recordings of human signers' movements. We evaluated ASL animations generated from the model in a user-based study.

Problem Statement

We would like to automate the creation of ASL animations as much as possible (to make it easier to provide ASL content online), yet prior sign language animation systems do not automatically predict where signers should place SRPs in space so that the animation appears natural. Linguists debate whether ASL signers constrain their selection of SRP locations to a semicircular arc region around their torso or use a wider variety of locations (McBurney 2002; Meier 1990), but in any case, there is no finite set of points in space where SRPs may be established. Given this complexity, rather than defining a simplistic rule for where an animated human should establish SRPs, we investigate a data-driven prediction model. Specifically, in this work, we have extracted and modeled the locations of all SRPs established by human signers who were recorded in our pre-existing ASL motion capture corpus (Lu and Huenerfauth 2012b).

Literature Review

To justify why designers of ASL animations must accurately model the use of SRPs, Lu and Huenerfauth (2012c) conducted studies in which native ASL signers evaluated ASL animations with and without the establishment of SRPs. The authors found that adding these pointing-to-locations-in-space phenomena to ASL animations led to a significant improvement in users' comprehension of the animations – and to more positive subjective ratings of the animations' quality.

While early work on sign language animations utilized rule-based approaches, as more sign language corpora have become available, recent work has turned to data-driven modeling (Lu and Huenerfauth 2010; Morrissey and Way 2005; Segouat and Braffort 2009), e.g. using ASL corpus data to predict the movements of signer's hands during "inflecting verbs" (Lu and Huenerfauth 2012a). However, no previous research has predicted SRP locations using data-driven modeling.

Modeling Methodology

From 2009-2013, our lab recorded 246 unscripted multi-sentence single-signer ASL performances (Lu Huenerfauth 2010) from 8 human signers during 11 recording sessions, and the first 98 of these recordings were released with linguistic annotation of the timing of individual words and SRPs (Lu Huenerfauth 2012b). In this work, using these 98 annotated recordings, we have extracted the right-hand index-fingertip location and 3D-vector where the finger is pointing, during the time-periods in the corpus when the human signer was pointing to establish an SRP location in the 3D space around the body.

We reduced the dimensionality of the modeling task as follows: We imagined a 2D plane in front of the human signer (at a distance of twice the human's arm-length), and we identified where the 3D finger-pointing vector would intersect with this 2D plane – thereby producing a 2D coordinate on the plane that represents where the human was pointing. (See the side-view image in Figure 1.)

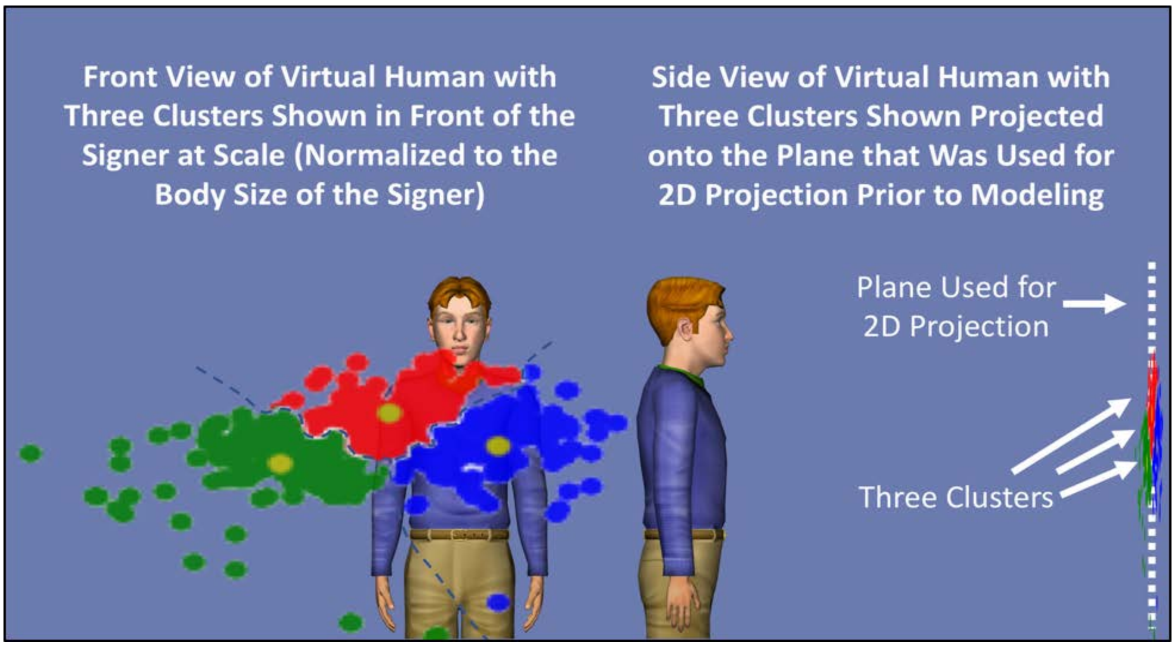

Figure 1: Clusters Projected onto 3D Virtual Human Space (see Figure 2 for Detail)

To combine data from multiple human signers of different body size, we normalized based on: the human's shoulder width (in the left-right axis), the human's shoulder height (in the up-down axis), and the human's arm-length (to determine the position of the 2D intersection plane in the forward-backward axis). To model this 2D data representing where the human pointed when they set up individual SRPs, we use a Gaussian Mixture Model (GMM), implemented in R, to identify clusters in the signing space where signers tended to place items. A GMM with three clusters was the best fit to the data.

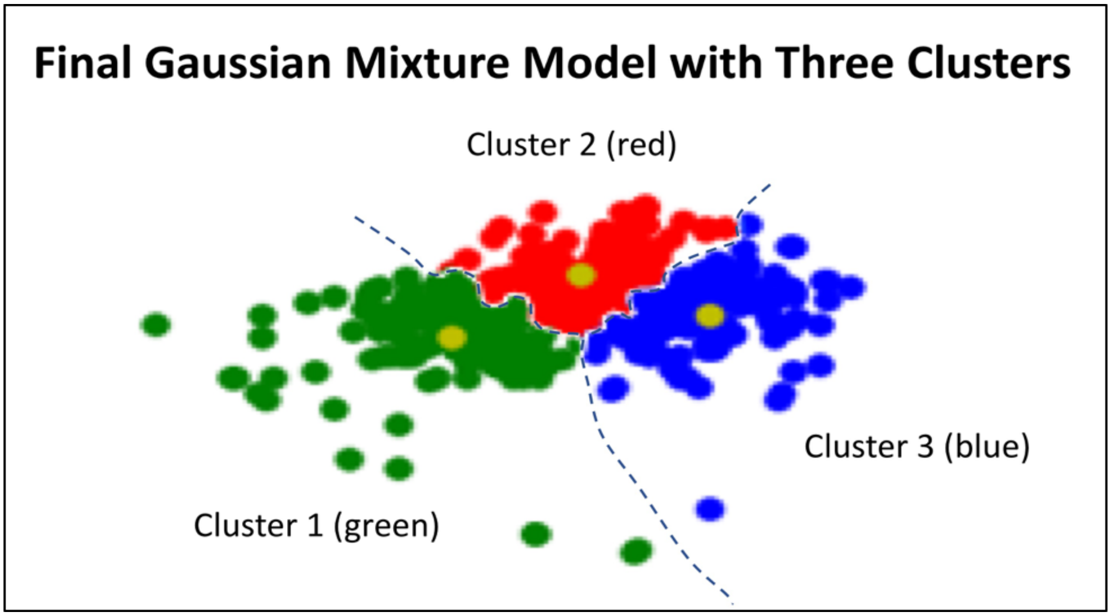

Figure 2: Visualization of the Shape of GMM Clusters (see Figure 1 for scale)

While Figure 1 visualized the clusters overlaid on a virtual human character, to convey scale, Figure 2 provides a more detailed view of the clusters, to better convey their shape. In Figure 2, the color of data points (and redundant dotted-line boundaries) indicate cluster membership. The centroid of each cluster is indicated in a lighter yellow-color dot within each. A slightly smaller proportion of points were in cluster 2 (red).

Evaluation Study

A user-based study was conducted to evaluate animations produced using this model, with participation from fluent ASL signers who self-identified as Deaf/deaf, recruited at Rochester Institute of Technology. Out of the 30 participants who were recruited for the study, 20 were male and 10 were female. Their ages ranged from 19-30 (average: 24). Out of the 30 participants, 18 had started using ASL since birth. Eleven participants grew up in a household with parents who knew ASL, 6 participants have parents or family members who are deaf, 28 participants use ASL at college, and all participants reported Deaf community connections (e.g. friends, significant other, social groups).

During the study, each participant viewed animations of ASL with a virtual human character performing 16 short (5-10 sentence) stories, originally created as stimuli in (Lu Huenerfauth 2012a). Each story was produced in the following three versions:

- ***ARTIST*****:** The first version was designed by an ASL-expert 3D artist using a commercial animation tool, as described in (Lu Huenerfauth 2012a). These were intended as an "upper baseline" (topline), i.e. high-quality animations carefully produced by a skilled human.
- ***NO-POINTING*****:** In this version, all pointing to SRP locations (to refer to previously mentioned people or things) was replaced with the virtual human simply re-stating the name of the person or thing throughout the story. These were intended as a "lower baseline," i.e. as produced by an animation system that could not select SRP locations.
- ***GMM*****:** The ARTIST version of the story was edited so that all of the SRP pointing in the story (originally specified by the artist) was instead replaced by pointing to locations sampled from our GMM model.

Each participant saw all 16 stories, but they saw a third of the stories in each of the 3 conditions, counterbalanced across the study. After viewing each animation, the participant answered 4 comprehension questions about the information in that story (total 64 questions), and the participant was asked three 1-to-10 scalar-response subjective questions about three aspects of the animation's quality: its grammatical correctness, how easy it was to understand, and how natural the movement of the animation appeared.

We hypothesized that: (H1) the subjective ratings and the comprehension question scores for the GMM condition would be higher than for our NO-POINTING baseline animations, and (H2) the ARTIST and GMM would have statistically equivalent scores. To evaluate H1, we conducted a Mann-Whitney Test for the subjective scores and a t-test for comprehension question scores, but we did not observe any statistical difference ($p>0.05$) in the scores between our GMM model and the NO-POINTING baseline condition. H1 was not supported.

To evaluate H2, a Two One-Sided Test (TOST) revealed equivalence between the ARTIST and GMM conditions for both the comprehension question scores (comparison margin = 10% response accuracy) and for the subjective questions (comparison margin = 1.0 units on the 1-to-10 scale). H2 was supported. This result indicates that animations with pointing based on the GMM model were perceived as similar in quality to the ARTIST animations – and led to similar comprehension-question scores.

Conclusion and Future Work

We have presented a method for modeling where human signers tend to point in 3D space when performing spatial reference in ASL, and we demonstrated how the model can predict pointing locations when generating ASL animations. Fluent ASL signers rated these animations as being similar in quality to animations in which the pointing that had been selected by an ASL-expert animation artist. This result contributes to our lab's overall goal of automating the process of synthesizing animations of ASL, which could lead to greater availability of ASL content on websites, to improve information accessibility for ASL users. In future work, we plan on modeling additional phenomena from our motion-capture recordings to synthesize ASL animations.

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Basic Identity Tags (BITs) in Tactile Perception of 2D Shape

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Abstract

Effective design of tactile graphics in education of the blind and visually impaired has long been debated by researchers, particularly whether pictorial sources are required. This work demonstrates that users of tactile graphics recognize distinctive abstract features (as the authors call them, "basic identity tags" or BITs), to differentiate, identify and remember embossed 2D shapes. A series of experiments which were conducted in New Delhi, India and Indianapolis, USA have been discussed. Understanding BITs can expand strategies for the design of effective tactile graphics.

Keywords

Tactile Graphics, Assistive Technology, Blind and Visually Impaired, Tactile Perception, Education

Introduction

Tactile graphics (TGs) are two-dimensional images raised slightly above a flat surface. Although common, tactile translations of pictorial images can be baffling for the BVI because pictorial images can contain perceptual artifacts with no basis in tactual or haptic experience. One popular guidebook for TGs recommends that TG designers avoid such artifacts, e.g. that cubes be presented as squares and not depicted with angled lines (BANA 6-98). This raises significant questions about the pedagogical value of pictorial TG design strategies. Bentzen states, “students seemed to find them (TGs) difficult and sometimes uninformative” (Schiff and Foulke 387).

Morash and Mckerracher summarize, “tactile graphics can be difficult to interpret for both blindfolded-sighted participants and those with visual impairments…” This reinforces Berla, who states, “…producers of tangible graphic displays know little of tactual perception” leading to poorly designed graphics (Schiff and Foulke 364). Such perceptual difficulty is compounded by the fact that information acquisition via vision is global and immediate, while acquisition via touch is local and sequential (Moscatelli et al.). The perceptual acuity of touch, and thus the ability to interpret tactile pictures, is arguably lower than vision (Schiff and Foulke). Other researchers disagree. D’Angiulli, Kennedy and Heller reported that “like the sighted, the blind possess cognitive and perceptual abilities that can be employed by pictorial aids.” James et al. found that both visual and haptic exploration of three-dimensional objects significantly activates the extrastriate visual cortex. Other studies have demonstrated that parts of the visual cortex show activity during tactile perception of both 2D and 3D stimuli (Amedi et al.). Also, (Chang et al.) suggest that Gestalt principles of proximity, similarity and continuation apply to both visual and haptic grouping of elements. Similarly, (Heller et al.) note the ability to segregate figure/ground and the principle of closure apply to tactile perception (Overvliet et al.). Despite such visual-haptic neural linkages, the “pictorial debate” remains unresolved.

Although BVI students can recognize tactile-pictorial images of common objects with practice, it may be pointless when such objects (e.g. cup, hammer) are available for direct manual experience. Beyond the earliest grades, pictorial TGs of common objects could function as metaphors or symbols of more abstract ideas associated with those objects (e.g. a TG of a car = the idea of transportation). However, abstract TGs might also fulfill this function, particularly to represent ideas that lack obvious pictorial examples or tangible references (e.g. a timeline of European history), or that explain intangible phenomena (e.g. photosynthesis). This current research addresses the challenge of finding tactual/haptic design principles for abstract TGs that students can easily recognize and remember as distinct from, similar to, or the same as other TGs. E.g., when designing separate TGs to signify French history and English history, assuming that these TGs should be distinct yet similar. Armed with design principles to facilitate perception of TG discriminability and/or similarity, researchers can then ask how to design abstract TGs to best signify external semantic meanings.

This work evolves from important findings by Nolan and Morris, which developed three sets of abstract, semantically neutral TG elements (categorized as points, lines and areal textures) that BVI users easily discriminated in pairwise comparisons. Later work by James and Gill enlarged these sets and identified TG characteristics that contribute to discriminability (e.g. dotted vs. continuous lines). Rather than replicate that prior work, this current work explores the idea of shape, defined here as discrete areas bounded by a continuous contour outline. This work then focused on the perceptual-cognitive territory between, on one side, the realm of content-free, abstract TG elements and, on the other, the realm of content-full pictorial TGs.

Experiments

The first round of experiments was conducted with blind students at the Capt. Chandanlal Special School for the Blind, operated by the All-India Confederation of the Blind (AICB) near Delhi. A second round of experiments occurred at the Indiana School for the Blind and Visually Impaired (ISBVI), in Indianapolis. Researchers came from the Assistech Lab at the Indian Institute of Technology-Delhi (IIT-D) and the School of Informatics and Computing (SoIC), at IUPUI in Indianapolis. The study received IRB approval from Indiana University. At both test sites, all students were very familiar with TGs, and used their own preferred methods to explore the test TGs. TGs were designed with continuous lines and manufactured as thermoformed TGs from 3D-printed molds by the Assistech Lab IIT-D.

First Round of Experiments (India)

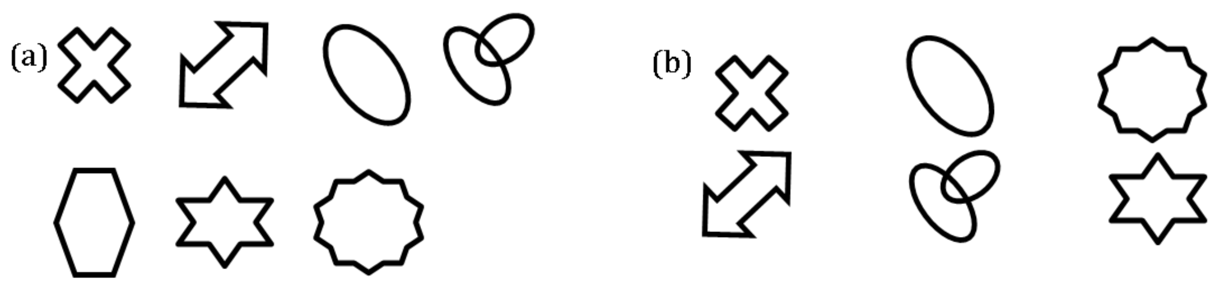


Fig. 1: (a) Stimulus Shapes, (b) Cousin shape pairs

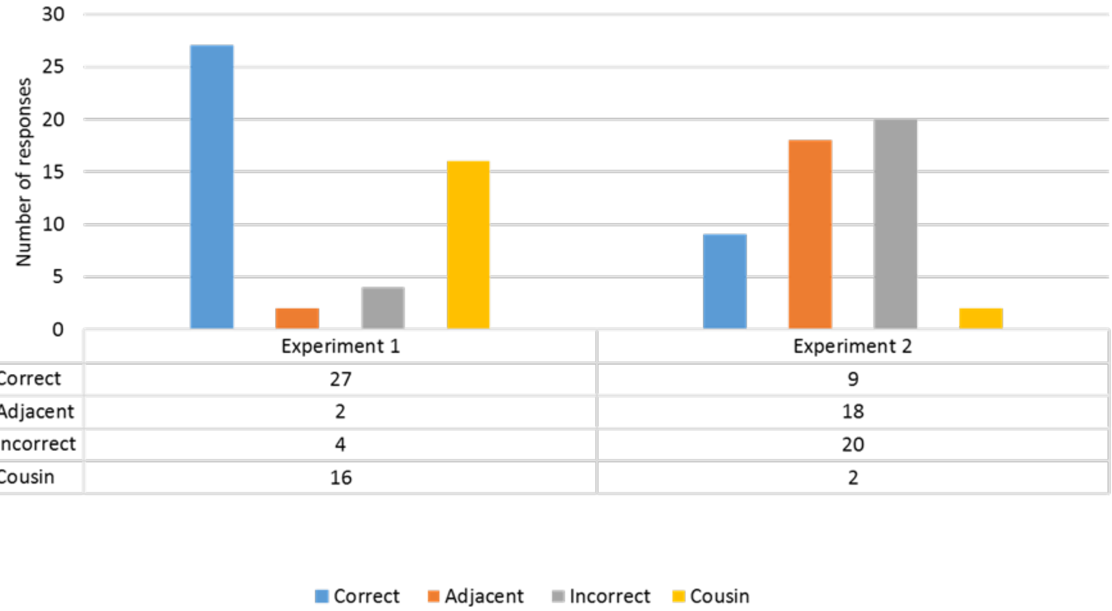
It was hypothesized that participants could easily recognize and remember unique target shapes (Fig. 1), and also remember the position of each shape in a 4x5-square TG grid, with target shapes and matching options presented at the same or different sizes. A set of 7 shapes was designed (Fig. 1a). As researchers soon realized, shapes were distinct yet had a “cousin” resemblance to at least one other shape, e.g. a similar curve or identical angle (Fig. 1b). All shapes were produced in 2 scales: 5cm x 5cm and 25cm x 25cm.

Experiment 1: 7 children (3 female, 4 male) aged 8-9 years (*M= 8.25, SD= 0.462*) participated. Six were congenitally blind and 1 had light perception, with no additional disabilities or cognitive impairments. They were given a 4x5 TG grid with target shapes randomly positioned within it. Then, bigger TG versions of the shapes were presented one at time, and participants were asked to match these with the corresponding small shape in the grid.

Experiment 2: 7 children (1 female, 6 male) aged 8-10 (*M=8.42, SD= 0.786*) years participated in this experiment. All participants were congenitally blind with no additional disabilities or cognitive impairments. Participants were familiarized with the grid. Researchers verbally and manually guided participants through the grid, from top left to the right, then on lower rows. Participants acknowledged each shape. Participants were given an empty grid and a grid-less sheet on which small shapes were presented in random positions, then were asked to touch a shape and then touch its respective position on the empty grid.

Results from Experiment 1 (see Table 1) suggested that participants had difficulty discriminating "cousin" shapes (Fig. 1, b). This suggested the idea of "Basic Identity Tags" or BITs, defined as a contour passage containing a salient change of vector. Researchers hypothesized this recognition may be based on a single salient BIT rather than the entire contour. As shown in experiment 2 results, the influence of BITs in remembering shape grid position is not clear.

Table 1: Number of responses in Experiments 1 and 2. Total responses 49 (7 shapes x 7 participants)



	Experiment 1	Experiment 2
Correct	27	9
Adjacent	2	18
Incorrect	4	20
Cousin	16	2

Second Round of Experiments (Indianapolis)

Results in India prompted a clearer focus on BITs for Indianapolis, exploring questions such as: Do participants recognize types of shapes according to their BITs? Do they recognize sequences of BITs? When comparing TGs of different sizes, does the change in scale affect perception of BITs to identify shapes? For this round, three basic BITs were identified: round, pointed and square. Stimulus shapes were created by repeating, scaling or combining BITs. Shapes in Set A were created using only one type of BIT while those in Set B,C and D were created using a combination of two types of BITs. Four sets of test shapes were designed: 1) shapes with one type of BIT (Set A); 2) hybrid shapes with a balanced blend of two BITs (Set B); 3) hybrid shapes in which one BIT is more prominent that the other (Set C); and 4) the same hybrid shapes from Set C, but with the other BIT now more prominent. To test the impact of scale in shape discrimination, the shapes were prepared in 4 scales: 1) 3.5cm x 3.5cm; 2) 7cm x

7cm; 3) 12 cm x 12cm; and 4) 21cm x 21cm. Eleven students and 1 teacher of ISBVI participated in these experiments. The students ranged between 8 – 21 years *(M= 14.17, SD=3.639)* and all were congenitally blind or severely impaired with no additional disabilities or cognitive impairments.

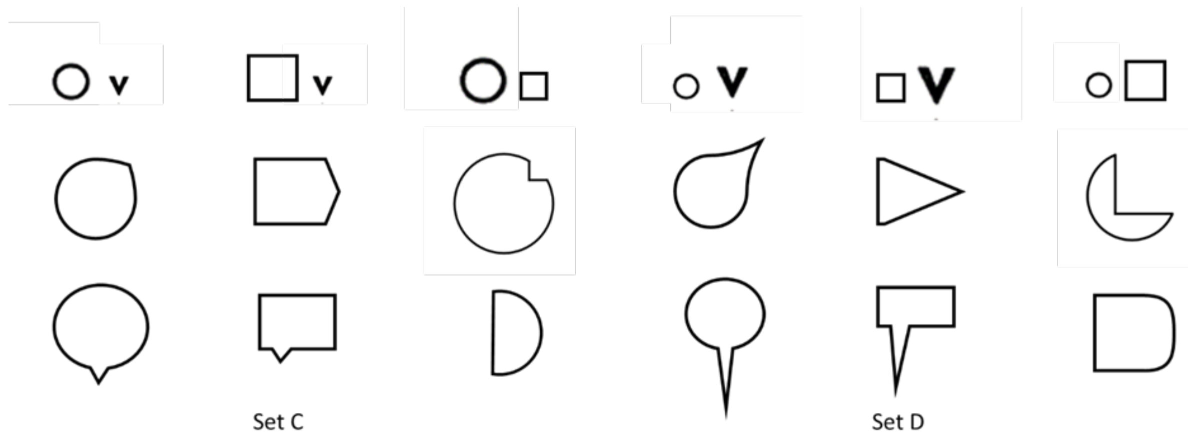


Fig. 2. Stimulus Shapes

Experiment 1: Participants were asked to touch three plastic bins arranged in a row while the experimenter named them as generally rounded, pointed and square-ish. They then sorted a series of 60 TG shapes in the bin that best characterized that shape. This experiment used shapes from all sets with sets A and B presented in 4 scales, and sets C and D in only scale 1.

Experiment 2: Researchers presented 12 target shapes from Sets A and B which were batched in groups of 4. Shapes were taped near the edge of a table top, and participants encountered each shape in a fixed orientation. Participants were told to remember the shapes as shape number 1, 2, 3 or 4 for each batch. After a resting time of 15 minutes, participants were presented with clusters of 4 potential matching shapes for each numbered target shape, also taped down near the table edge. The participants were guided through the clusters sequentially and asked to recall the shape and match it with one of the options or say “none of these” if the correct match shape was not present. Different combinations of scale and orientations of target/matching shape were used. Four of 12 target shapes were not present among their respective matching options, so “none of these” was the correct response in those cases.

Fig. 3 (a, b, c, & d) show the results of experiment 1. Fig. 3 (a & b) show the distribution of categories chosen for each shape from Sets A and B respectively. It is interesting to note that despite the fact that the experimenters encouraged participants to use their judgment in sorting, the participants innately identified shapes with right angles and vertical or horizontal lines as square-ish, though the responses are mixed with pointed (e.g. shapes A2, A5, A6, B3, B4). Shapes with oblique lines and acute angles were unanimously categorized as pointed (e.g. A3, A4). In hybrid shapes with two types of BITs, most participants generally used one type for categorizing (e.g. B1, B2). Shapes with oblique lines and acute angles were unanimously categorized as pointed (e.g. A3, A4). Sets C and D were created to see the impact of changing emphasis of a BIT in a shape. Fig. 3 (c) and (d) show how by shifting the hybrid blend towards one type of BIT, the majority choice of category also shifts (most prominently in B3). The results show the mean of category responses given for the 4 tested scales, with no significant difference noted between scales. Fig. 4 shows the percentage correct responses in experiment 2. The results indicate that generally, participants were able to recognize and match shapes from memory even with changes in shape scale and orientation. Salience of scale or orientation is not statistically evident in matching performance. A Friedmann test comparing the four groups did not yield a statistically significant difference ($\chi^2(3) = 4.920, p = 0.178$). However, the set with both different scale and different orientation had lowest performance percentages *(mean rank = 1.33)*.

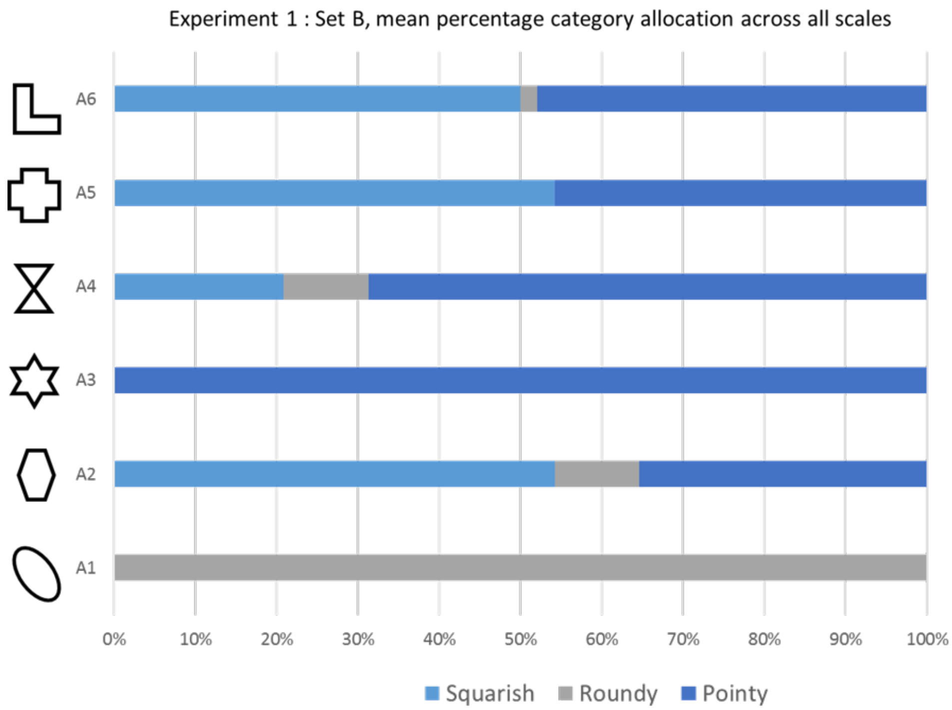


Fig. 3a. Set A - Mean percentage category allocation across all scales.

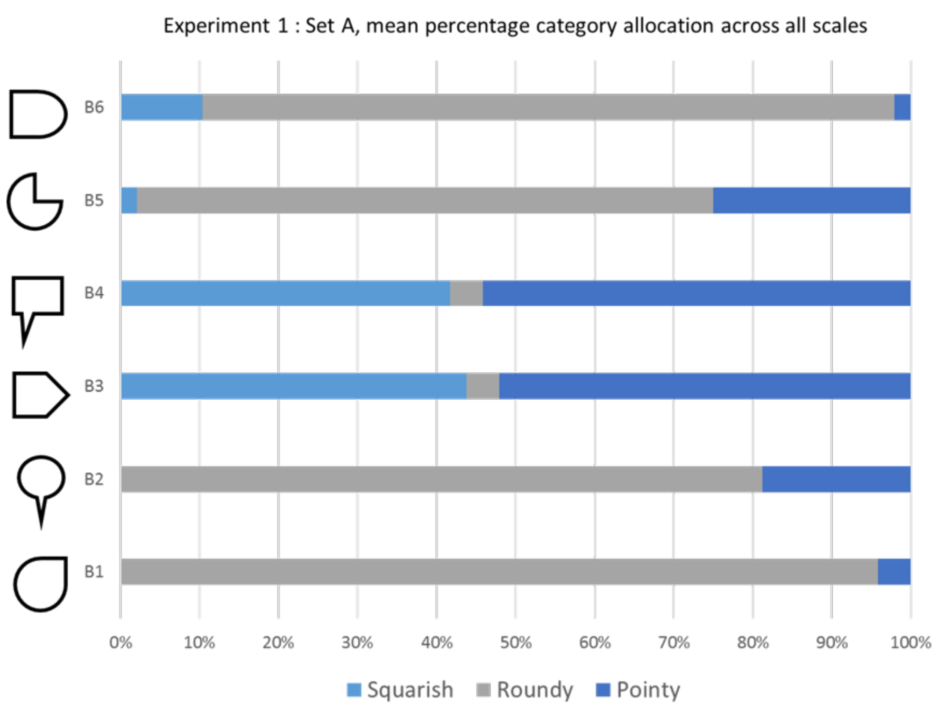


Fig. 3b. Set B - Mean percentage category allocation across all scales.

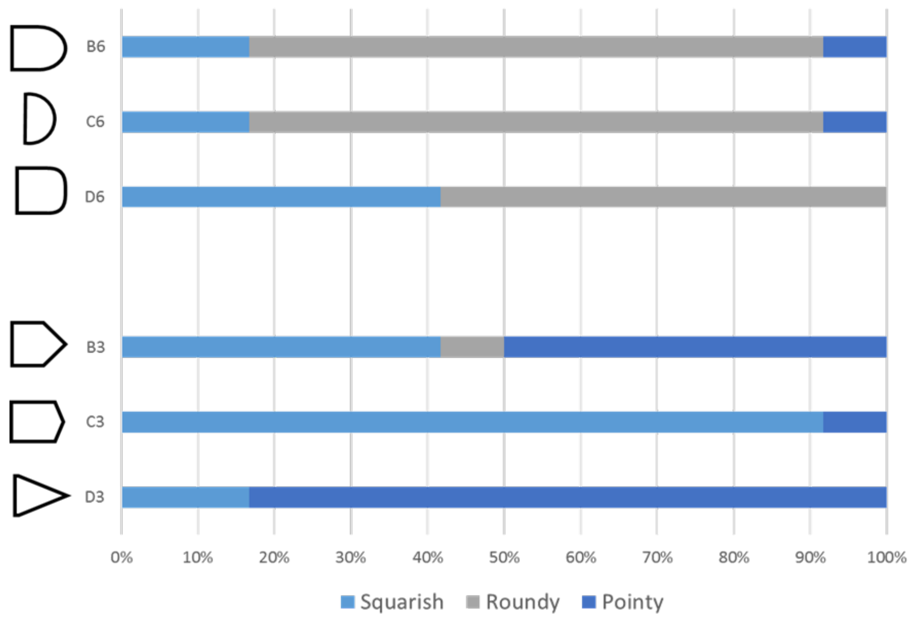


Fig. 3c. Change in sorting preference with change in emphasis on one of the two comprising BITs.

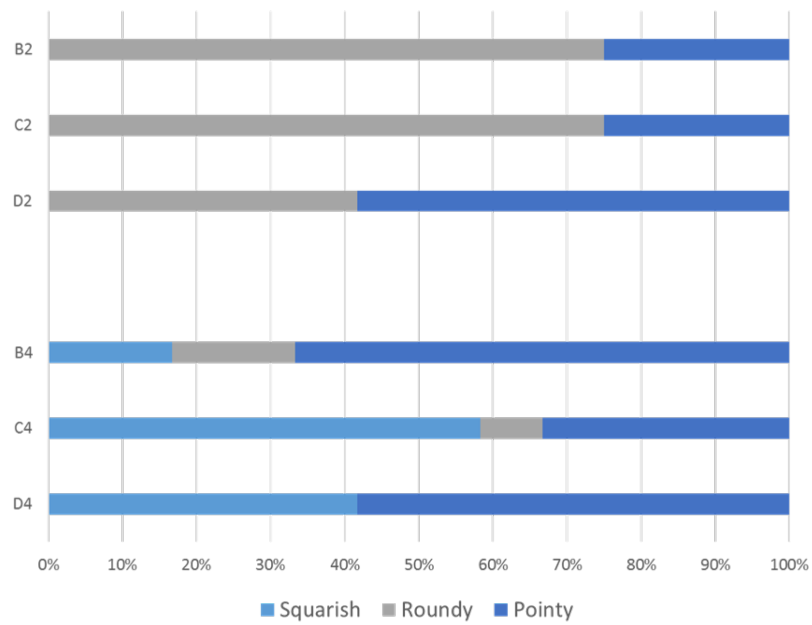


Fig. 3d. Change in sorting preference with change in emphasis on one of the two comprising BITs.

Discussion

After the first round of experiments in India, researchers hypothesized that students often confused the test shapes, and reasoned these shapes were too complex, with too many salient vector changes that also appeared in different shapes. This analysis led to the novel idea of the “Basic Identity Tag” or BIT: a salient vector change along a shape’s contour perceived as a defining characteristic of that shape. This idea was reinforced by researchers’ visual observations of the first cohort of students (in India) in their manual explorations of the test TGs. Students often verbally identified these shapes (either correctly or incorrectly) after manually focusing on a relatively short section of the contour containing a single salient feature (e.g. an acute angle) rather than patiently exploring the total contour. For the second round in Indianapolis, researchers identified three BIT types: rounded, pointed square-ish, but also speculated that other BITs might be developed (e.g. loop, waves, zig-zags), or other salient design features could serve as identifying tags, e.g. a point within a larger shape. Further experimentation will be necessary to better understand the degrees of vector change that produce tactile/haptic salience, and the number of BITs a shape can contain while maintaining a coherent identity – and if there are exceptions for well-known shapes, e.g. a symmetrical star.

This process may be related to the youth of the Indian students, and the possibly age-related stage of the fine-motor skill needed to recognize smaller-scale TGs. This speculation was reinforced by the observation that older students (15-18 years old, available only in Indianapolis) seemed quicker and much more confident in their explorations of the test TGs. This suggested that combined processes of perceiving, recognizing and remembering TGs comprise a cumulative skill that improves with years of practice.

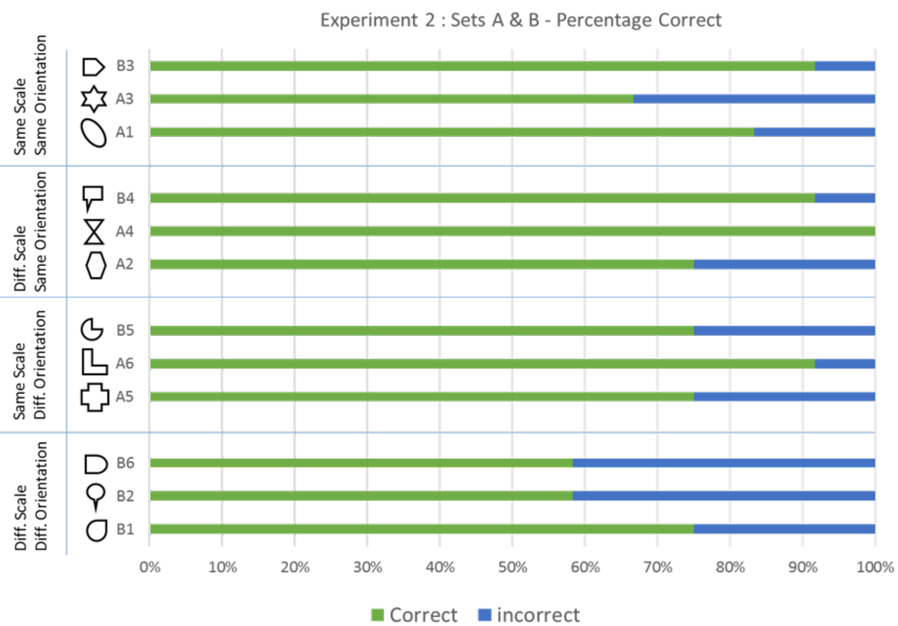


Fig. 4. Experiment 2: Sets A & B – Percentage correct response for different types of match sets (diff. is used as short for different).

Conclusion and Future Work

This initial research demonstrates the need for more extensive investigations along two interrelated research directions: 1) the basic perceptual processes by which BVI students recognize and remember abstract TGs; and 2) the extent to which abstract TGs can signify semantic meaning to enhance pedagogy.

The first research direction includes questions about various Gestalt design factors, e.g. how the proximity, relative size or grouping of several abstract TGs might influence their recognition as distinct, similar or the same. The second direction includes questions about how TG shapes might distill or echo the tactual/haptic qualities of signified objects to best convey their literal, metaphoric or symbolic meaning, e.g. how well a pointed TG might signify a knife, the act of cutting, or metaphorically convey the idea of dividing parts of a whole. If non-pictorial TGs can be useful in education, such questions of tactile/haptic semantics must be addressed.

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Mobile Learning: Device Ownership, Usage, and Perspectives of Post-Secondary Students with and Without Disabilities

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Abstract

The use of mobile devices is rapidly spreading throughout the world, and post-secondary environments are gradually moving toward implementation. There is a growing body of evidence on post-secondary students and mobile devices and m-learning. However, research has focused primarily on use of mobile devices by post-secondary students without disabilities. There has been little to no research on mobile devices and m-learning with post-secondary students with disabilities. This paper discusses a research project that focused on surveying post-secondary students with, and without disabilities, as to the mobile devices they currently own, how they use their mobile device(s), and their perspectives on using mobile devices for learning. The results show that one hundred percent of the students with and without disabilities own one or more mobile devices that they use for many purposes including learning activities. Students with and without disabilities also indicated that they are interested in using mobile devices in their learning.

Keywords

Mobile learning, mobile devices, post-secondary students, disabilities, device ownership

Introduction

There are a growing number of post-secondary students with disabilities. Mobile devices may offer post-secondary students with disabilities opportunities to overcome their learning challenges with intuitive touch screens, simple operating systems, built in accessibility features, and apps that can support learning challenges. There is little information available on the ownership and use of mobile devices by students with disabilities compared to students without disabilities. This paper compares post-secondary students with and without disabilities surveyed as to the mobile devices they currently own, how they use their mobile device(s), and their perspectives on using mobile devices for learning.

A number of studies in the literature have focused on mobile device ownership of post-secondary students. Zidoun et al. (82) found that 98.8% of students surveyed owned and used mobile devices. Briz-Ponce et al. (617) found 96.8% of the post-secondary student participants at the University of Coimbra owned a mobile device such as a smart phone or tablet. In Canada, in a survey at four universities, 92.6% of the students owned a mobile device (Boruff and Storie 24). Almaiah (33) reported that 86.8% of post-secondary students in a Malaysian university had access to a smart phone/mobile phone and 11.0% had access to a tablet PC. In an Australian study, Farley et al. (3) found that less than 5% of the post-secondary students did not have access to a smart phone and the majority of students had access to more than one mobile device.

Mobile devices may provide practical solutions for post-secondary students with disabilities who require technology support to overcome their learning challenges. Unfortunately, little research data can be found on mobile learning and students with disabilities. The purpose of the study to investigate mobile device ownership, usage, barriers to use, and perceptions on mobile learning by post-secondary students with and without disabilities.

Method

The focus of this research was on the use of mobile learning by post-secondary students with and without disabilities studying at a distance. The research questions focused on the following: what mobile devices do students own; and what tasks do students complete on their mobile devices and for how long? This study also looked at: the barriers students perceive to the use of mobile devices for learning; the activities students would like to be able to do on their mobile devices; the factors students think are important in mobile device use; student interest in m-learning; and the supports students require to participate in m-learning.

An online survey in Lime Survey was created to collect both qualitative and quantitative data related to these areas. The survey consisted of Likert scale items and open-ended questions. The survey was composed of three parts: demographic information, device ownership and use, and student perspectives on m-learning.

Results

Two groups of post-secondary students were surveyed using identical surveys during the same period. Group 1 was comprised of forty-six students with disabilities receiving educational supports from the university. Group 2 was comprised of forty-six students without disabilities participating in a research option in an undergraduate psychology course that were randomly chosen from a pool of over 500 research participants.

One hundred percent of the students in Group 1 and Group 2 reported that they own a smart phone. In addition, in Group 1, 90% own a laptop, 54% own a tablet, 17% own an e-Reader, and 11% own an iPod. In Group 2, 87% also own a laptop 48% own a tablet, 20% own an e-Reader, and 4% own an iPod.

The primary device used by 67% of students in Group 1 was the smart phone. Twenty-two percent use a laptop as their primary device and 11% use a tablet. Eighty-seven percent of students in Group 2 also use their smart phone as their primary device, 11% use a laptop, and 2% use a tablet. The students in both groups engage in a wide range of different activities on their primary device including learning activities. Thirty-six percent of students in Group 1 use their primary device to engage in research activities two to ten hours a week and 35% engage in research more than ten hours a week. Twenty-eight percent spend two to ten hours a week learning and studying, and 30% spent more than ten hours learning and studying. Forty percent of students in Group 2 engage in research activities two to ten hours a week and 20% engage in research more than ten hours a week. Twenty-two percent spend two to ten hours a week learning, and 15% spent more than ten hours learning and studying.

Seventy-four percent of the students in Group 1 reported that they own a second mobile device. The second most frequently used device used by students in Group 1 was: a laptop 56%, a tablet 29%, and smart phone 15%. Eighty-seven percent of the students in Group 2 reported that they own a second mobile device. The second most frequently used device for students in group 2 was: a laptop 65%, a tablet 28%, and smart phone 13%. The second most frequently used device by students in Group 1 and Group 2 is also used by students for a range of activities including studying and learning.

The top three m-learning activities that students in Group 1 would very much like to be able to do on their mobile devices are as follows: 85% would like to check assignments, 82% check grades, and 81% read course content. Students also had comments as to the activities they would like to engage in on their mobile devices. One student said, “I think it would be very helpful to find apps to help with studying, ability to create your own schedules to keep you accountable." The top three m-learning activities that students in Group 2 would very much like to be able to do on their mobile devices are similar to Group 1: 89% check assignments, 93% check grades, and 85% read course content.

The students with disabilities in Group 1 identified several factors regarding mobile devices and m-learning that are very important or important to them. The top factors in terms of importance were: 98% the ability to use the device anywhere, 96% the ability to use the device anytime, and 91% multi-functionality of the device. In Group 2 the top three factors identified were: 89% the ability to use anytime, 87% the ability to use the device anywhere, and device multi-functionality 87%.

Students in both groups were asked as to what would help them use their mobile devices for m-learning. In Group 1 identified the following areas as their top choices: 87% knowing what apps to use, 87% learning how to use mobile devices to support their learning challenges, and 83% access to information on how to use mobile devices for learning. Students in Group 2 rated these items in a similar fashion. They identified the following top choices: 86% identified knowing how to use mobile devices for learning, 83% knowing what apps to use, 78% access to information on how to use a mobile device for learning.

Students in both groups were asked what barriers existed for them in using their mobile devices for learning. For students in Group 1, the top areas identified as a barrier or significant barrier were: 67% cost of data, 63% cost of devices, and 63% small screen size. Students in Group 2 identified similar items as a barrier or significant barrier: 79% identified access to high speed internet, 74% the cost of data, and 63% small screen size. One student commented, "We simply cannot afford to purchase another sort of mobile device for me. I feel like I am missing out on a vital experience in terms of mobile learning."

Overall, 78% of the students in Group 1 and 78% of the students in Group 2 were interested or very interested in using mobile devices to access their course content. Eighty-nine percent of the students in Group1, and 87% of the students in Group 2 were interested or very interested in using their mobile devices effectively for m-learning. Finally, 85% of the students in Group 1 and 61% of the students in Group 2 indicated that they were interested or very interested in learning more about how to use their mobile devices for learning.

Discussion

Student ownership of mobile devices in Group 1 and Group 2 is identical, with both groups reporting 100% ownership of one or more mobile devices. This is similar to, but slightly higher than data reported by Zidoun et al. (82), Briz-Ponce et al. (617), and Almaiah (33). One hundred percent of students in each group own a smart phone. Seventy-four percent of the students with disabilities, and 87% of the students without disabilities indicated that they own a second mobile device. The post-secondary students with disabilities in this study reported very similar device ownership to students without disabilities. This suggests that post-secondary students with disabilities are not disadvantaged in their ability to own multiple mobile devices.

No specific patterns of use by students with and without disabilities were identified in how students use their mobile devices. It appears that students use their devices for a range of activities including those related to learning, and that the choice on how to use each device is predicated by need and personal preferences. Students with disabilities are using their mobile devices for learning in similar ways to students without disabilities. However, they did not report using their mobile devices as assistive devices to overcome learning challenges.

Similar to studies in the literature (Zidoun et al. 83 and Farley et al. 7), students in the present study with and without disabilities reported that they would like to use their devices to engage in m-learning activities. This suggests that post-secondary educators should be looking at how to maximize on the fact that students own mobile devices, spend a considerable amount of time on their devices, and want to use their devices for learning. Educators need to consider how support students in this learning and examine how to deliver course content and activities in an effective way to mobile devices.

Although positive attitudes towards m-learning were reported by Alenezi (111) and Yorganci (184), Farley et al. (7) reported that 18% of the students they surveyed did not want to use devices to learn. In the present study, several students expressed negative opinions towards m-learning. One student with ADHD indicated that mobile devices were a distraction and that they needed to be avoided. It is important to consider that some students with disabilities have learning challenges that may not be compatible with mobile device use. It is also possible that some students may need support to find ways to use mobile devices to overcome their learning challenges.

Both groups of students identified the high cost of data and lack of access to high speed internet as a significant barrier to mobile device use. Unfortunately, many students experience very limited access to high speed internet outside of urban centres, and students in rural areas are at a disadvantage. Even when internet is available, the cost of data can be prohibitive for students. As more course content and learning activities are moved online and made available for mobile devices, post-secondary institutions need to be cognizant that students in rural areas made need alternative ways to access what they require. Both groups of students also identified the cost of devices as a barrier although it was rated as more significant by students with disabilities. The solution may be to provide subsidized access to mobile devices for learning, or provide some sort of loaner program so students, particularly those with disabilities, have more ready access to m-learning.

Students with and without disabilities reported on the tasks that they would like to be able to do on their mobile devices. The top three tasks that students would like to be able to engage in on their mobile devices were identical for both groups. They would like to be able to check assignments, check their grades, and read course content. It is important for post-secondary institutions to look at the provision and formatting of online materials that would facilitate this type of learning. Students also provided many comments regarding tasks that they would like to be able to do on their mobile devices. One student with organization difficulties was interested in finding apps to help with studying and the development of schedules. One student felt that an app that could convert his handwriting to text would be very helpful. Still another student with reading challenges was interested in audio format and felt that having this option would be life changing. There are many apps available that could support students with disabilities in the areas that they identified. There is a need to disseminate this information to students. Students in this study reported that that knowing what apps to use for learning and how to use mobile devices to support their learning challenges would be very beneficial for them. The effective use of mobile devices may be an area student support services for students with disabilities need to consider.

The top three supports that would help students with and without disabilities had slight differences. Both groups of students indicated that knowing what apps to use, knowing how to use mobile device for learning, and access to information were important to them. Students with disabilities also indicated that having access to support in the use of mobile devices for learning would be very helpful for them. This indicates that information needs to be available for students with and without disabilities on the use of mobile devices for learning. This need may be greater for students with disabilities who may also benefit from specific supports in addition to information.

The results of this study are limited. Very few subjects participated in the survey as there are still relatively few post-secondary students with disabilities enrolled in post-secondary institutions. However, this small sample of students did provide a glimpse as to mobile device ownership, use, and attitudes towards mobile learning.

Conclusion

It is evident that post-secondary students with and without disabilities own one or more mobile devices and currently use them for a multitude of tasks including those related to studying and learning. Many of these students are interested in engaging in further m-learning activities but face a number of barriers. With further research and greater understanding, post-secondary institutions can come to learn how to support students with and without disabilities to overcome learning challenges and to use mobile devices effectively for learning.

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Smart Speaker Usability by Military Service Members with mTBI and PTSD

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Abstract

This paper describes the research protocol and results from exploratory usability testing of Amazon Echo and Google Home, voice-activated smart speakers, by military service members with mild traumatic brain injury (mTBI) and post-traumatic stress disorder (PTSD). Usability testing of emerging technology by people with disabilities is critical to gain insight into accessibility of the product design as well as to identify use cases and opportunities the product may offer as an assistive technology. This study was conducted with 12 U.S. military veterans and service members with mTBI and PTSD, all of whom were receiving comprehensive rehabilitation services in the SHARE Military Initiative at Shepherd Center in Atlanta, Georgia, USA. Devices were installed in the temporary residences provided to the participants during their participation in the SHARE program. Participants tested each device for 2 weeks and completed electronic diary entries about their experience. Following study completion participants completed a summative interview about their experience which detailed preferences and usability challenges and identified opportunities for development of in-home smart home speaker assistive technology solutions for this population.

Keywords

Brain injury, stress, smart speaker. assistive technology, usability, military

Introduction

Smart speakers, such as Amazon Echo and Google Home, are among a budding group of emerging consumer electronics that offers potential as assistive technology (AT) for people with disabilities. Smart home technologies, including speakers, plugs, appliances and other Internet of Things (IoT) Wi-Fi and Bluetooth connected home technologies, provide multiple ways to collect and retrieve data and control the home environment. Usability testing with people with disabilities is a critical step both in understanding the accessibility of a product's design as well as in identifying use cases and opportunities the product may offer as AT.

Amazon Echo and Google Home are internet connected, voice-activated smart speakers that provide users with hands-free access to voice-controlled intelligent personal assistants (i.e., Amazon's Alexa and Google Assistant). These digital assistants provide information, play music, audiobooks and podcasts, set timers and alarms, integrate with to-do lists and calendars, and allow users to control smart home devices through voice commands. The functionality of the smart speakers can be expanded through enabling or linking applications or "apps"; Amazon Echo apps are called "skills". Since these technologies are intended to aid users, they are logical candidates as AT for a variety of populations.

Post-traumatic stress disorder (PTSD) and mild traumatic brain injury (mTBI), both of which can impact independent living and quality of life, are conditions frequently experienced by military service members returning from recent conflicts in the Middle East (Tschiffely, et al. 2015). Common features of PTSD include anxiety, avoidance, hyper-vigilance or instances of re-experiencing a traumatic event (American Psychiatric Association 2013). People with persistent mTBI symptoms often report experiencing challenges with memory, attention, executive functioning, pain and dizziness. Those who experience both PTSD and persistent symptoms of mTBI commonly report depression and emotional disturbances in addition to significant challenges managing symptoms of each condition (Tanielian, et al. 2008, Chen, et al. 2011).

While smart speakers may have potential for use as AT by service members with mTBI and PTSD, the usability of these devices and user-preferences in this population is not fully known. A literature review of publications investigating the usability of Echo and Home by users with cognitive and psychological disability yielded limited results, and none of them addressed usability by military service members with TBI and PTSD. A few popular science media outlets have reported that smart speakers are being adopted by some older adults to reduce loneliness, provide supportive reminders, simplify access to audiobooks and offer those with tremors or arthritis a hands-free method of accessing the Web (Woyke 2017, Persuading Your Older Parents 2017, Amazon Echo for Dementia 2017). The opportunities smart speakers might offer to people with disabilities may be attenuated by accessibility and design barriers, especially since rapid advances in technological innovation often lead to frequent redesigns and releases of new generations (Wentz and Lazar 2016; Schroeder and Burton 2010). Systematic assessment of the usability of smart speakers by people with disabilities is needed to help designers and developers ensure equitable access to these technologies as well as inform and guide consumers.

Discussion

An in-home usability diary study of Amazon Echo and Google Home smart speakers was conducted with 12 military service members with mTBI and PTSD. Electronic diary entries were used to gather information about usability, user preferences and potential for development of new apps or skills to increase the role of smart speakers as AT in military service members with mTBI and PTSD.

Participants were recruited from the SHARE Military Initiative program, a comprehensive outpatient day rehabilitation program for military service members with mTBI and PTSD at Shepherd Center, a rehabilitation hospital in Atlanta, Georgia. Purposive sampling was utilized to identify participants with mTBI and PTSD who were smartphone users with functional language, speech, hearing and vision. A psychologist and speech-language pathologist in the SHARE Military Initiative assisted the research team with identification of appropriate candidates for the technology testing. Sixteen potential participants were identified; two declined to participate in the study. Of the two that declined, one reported reluctance to having a speaker in his apartment that was “listening to everything” while the other stated he was “not big on technology” because he felt learning to use new technology was frustrating. In total, 14 participants were enrolled in the study; however, two participants discharged from the therapy program before they could complete the study.

Twelve participants, 11 males and 1 female, completed the study. Average age of participant was 45 (ranging from 30 to 57 years) and average time since initial onset of injury was 17 years (ranging from 1.25 to 37 years). All reported one or more trauma events resulting in PTSD and persistent symptoms attributed to mTBI. Many reported experiencing multiple mTBI, most of which were caused by blast exposure, falls or motor vehicle accidents. Several also reported sustaining an initial mTBI during youth, either through sports or violence/abuse. Most participants stated they experienced long-term ongoing difficulties with anger, aggression, anxiety, depression, isolation, memory, attention and pain. Information on each participant’s prior experience with computers and smart technology was collected prior to initiation of technology testing (Table 1).

Table 1. Participants' experience with and use of technology (n=12).

Do you use any of the following on a regular basis?	**Percent of participants who responded "Yes"**
Smartphone	100%
Laptop or desktop computer	67%
Tablet	42%
Fitness Tracker	42%
Smartwatch	17%
Regular cellphone	8%
Smart plug	8%
Amazon Echo, Dot or Tap	8%
Google Home	0%
Smart home appliance, security or thermostat	0%
Mp3 player (separate from another device)	0%
Google Glass	0%

Testing took place in apartments provided by Shepherd Center, where clients live while they participate in the SHARE Military Initiative rehabilitation program. Participants tested each smart speaker, either Amazon Echo or Google Home, for 2-weeks. This resulted in a total of 4 weeks of testing of the 2 devices per participant. Using a cross-over design to minimize bias related to which smart speaker was experienced first, we asked half of the participants to test Echo first and half to test Home first. Each participant was also given 2 TP-Link mini-smart plugs. Ten of the 12 participants used the smart plugs to control one or two lamps in their apartment, and one participant also used a smart plug to add voice and scheduling options for turning off the television. Two of the 12 participants declined use of the smart plugs, both reporting it felt overwhelming to learn two new technologies at one time. Participants were asked to set up the technology (smart speakers and smart plugs) in their apartments and were provided assistance if they were unsuccessful. They then completed one-on-one interviewing regarding their experience setting up each device.

Following device setup, participants tested each smart speaker for 2 weeks and were asked to complete electronic diary entries about their experience twice weekly. Collection of this information proved to be challenging as most participants completed on average only one diary weekly, despite email reminders and in-person encouragement from one of the researchers with the therapy clinic. Each participant also completed a summative interview about their experience at the end of testing. A combination of closed set questions (including use of a 5-point Likert scale ranging from "very hard" to "very easy" for usability questions) and open-ended questions (such as "What did you like most?", "What would you change?" or "What did you find most useful?") were used in both the electronic diary entry and the summative interview. The aim was to identify preferences and usability challenges to inform development of in-home smart home speaker assistive technology solutions for this population.

Results

Most users reported both Amazon Echo and Google Home were easy to setup. Although, 91% reported Echo was either "easy" or "very easy" to set up while only 52% reported Home was either "easy" or "very easy" to set up (see Table 2). Likewise, half of the participants required assistance to set up the Echo devices while two-thirds required assistance to set up the Home devices (see Table 2). The disparity in reports regarding ease of setup is likely attributed, at least in part, to difficulties some users experienced connecting to the Wi-Fi network maintained by Shepherd Center which required 2-step authentication of devices and did not consistently permit attempts to connect to Google Home.

Fifty percent of participants reported the TP-Link smart plugs were either "easy" or "very easy" to set up with Echo while only 30% reported the TP-Link smart plugs were either "easy" or "very easy" to set up with Home. Yet, a greater number of participants reported they required assistance to set up the smart plugs with Echo (55%) than with Home (45%).

When either Echo or Home are plugged in for the first time, the smart speaker prompts the user to download and install an app (either the Alexa app or Google Home app) on their smartphone which then guides the user to complete setup of the speaker. The apps are later used to add smart speaker apps, or enable "skills" as Amazon calls them, as well as connect to smart home devices (such as the TP-Link smart plugs) and access lists created with the speaker. The TP-Link smart plugs are also setup by downloading an app (the Kasa app) and then following the prompts in the app. Several participants stated they would have preferred to have had written instructions with pictures and/or video to guide set up of all of the devices in addition to the guidance provided by the smartphone apps. And one user reported significant anxiety regarding the inability to see how many steps were required to complete the setup of the smart speakers, reporting he did know if the setup would be completed in "2 minutes or 2 hours".

Table 2. User assessment of the setup process for Amazon Echo and Google Home and connection to TP-Link smart plugs

Questions	**Amazon Echo**	**Google Home**
How easy/hard was it to set up each device?	Easy or very easy – 91%	Easy or very easy – 52%
Did you require assistance to set up the device?	50%	66%
How easy/hard was it to set up smart plugs with each device?	Easy or very easy – 50%	Easy or very easy – 30%
Did you require assistance to set up the smart plugs with the device?	55%	45%

During and after the two-week trial using each smart speaker, 76% of participants reported Amazon Echo was easy to use compared to 65% for Google Home. One participant reported difficulty manually controlling the volume on Google Home, which requires fine motor use of a finger to swipe clockwise or counter clockwise on the top of the device. Another reported challenges with using the timers on both smart speakers, stating that some of the timers he set never went off and on occasions when a timer he set did go off, he did not always notice the timer alert until long after it went off because he was outside, in another room, in the shower, etc. However, several other participants reported high satisfaction with use of the timers on both devices and reported the timer was one of the most useful features. About halfway through study, the Echo received a software update from Amazon that allowed users to begin to label timers, a feature the study participants had already reported as desirable to help them recall what the timer was for and to distinguish multiple different timers.

Participants reported Home correctly understood their voice commands more often than Echo, rating Home at an average of 87% accuracy versus Echo at 80% accuracy. Despite high accuracy ratings, some participants expressed frustration with voice recognition and difficulty recalling specific wording required in some instances for the smart speakers to execute the commands. Participants reported a slight preference for Home's voice, rating it at average of 7.1/10 versus Echo's at 6.9/10. However, they collectively preferred the look and aesthetic design of Echo, giving it an 7.6/10 versus a 6.4/10 for Home. Interestingly, at study conclusion, 9 of the 12 participants stated they preferred Amazon Echo overall to Google Home. Qualatiative analysis of participant feedback revealed this may have been attributed to a number of factors including: 1) more intuitive navigation and clear labeling of functions within the Alexa App, 2) less fine motor control required for manual adjustment of volume of Echo than Home, and 3) greater personal connection with Echo felt by some due to use of a humanizing wake word for Echo ("Alexa", a person's name) versus Home ("OK Google" or "Hey Google").

All participants reported the smart speakers were useful in their daily life. They described a variety of functions they performed with both devices. Most of the participants used the smart speakers to stream music or play calming sounds, which many found aided them in relaxing, especially when attempting to wind down before sleep. Other functions commonly performed by participants included turning lamps off or on (with connected smart plugs), asking for information (e.g., the time, date, weather or sports scores) and using timers, alerts or calendar integration to recall and complete planned tasks. Several participants reported they sometimes interacted with the smart speaker for companionship, usually by asking interesting questions or requesting a joke or a story. When describing his experience with the smart speakers, one participant stated, "It was like having a personal assistant and sometimes a companion." Another participant said having a smart speaker "provided an unexpected sense of comfort," while another stated it made him "feel not so alone." All participants reported they would be very likely to continue to use one of the smart speakers at study conclusion.

When asked about what they wished the smart speakers could do, trends were evident in requests for more support for relaxation, memory and communication and sharing of important information with family and caregivers. A need for increased customizability when setting calendar events, reminders and alerts was reported, although greater current functionality in this area was reported for Echo versus Home. One participant also reported a desire to be able to choose from a selection of smart assistant voices, stating that some voices are more relaxing and easier to listen to than others. Several participants reported a desire for more integration with their smartphones and other technology in the home as well as functionality reliant on increased artificial intelligence and contextual awareness.

Conclusions

This study discovered some insights into smart speaker usability and the needs of military service members with PTSD and mTBI, and it supports conducting further exploration of usability challenges of smart speakers for this population.. Overall, most participants found both devices easy to use, which is critical for populations who may experience challenges with learning to use new technology and with handling stress associated with using technology perceived to be hard to use. All participants found both devices useful for helping them perform daily tasks and many reported the smart speakers provided them assistance with managing mTBI and PTSD related cognitive challenges and stress.

Several design opportunities were uncovered which could increase the usability of smart speakers for this population and possibly other similar populations. Changing the manual control feature on Google Home to require less fine motor coordination may be helpful. And for both Home and Echo usability could be elevated by providing written instructions for set up and use, improving the labeling and intuitive design of the companion apps, simplifying the process of adding apps and functionality, improving voice recognition and expanding the customizability of calendar and reminder features.

Rehabilitation clinicians and AT specialists should consider the usability and capabilities of smart speakers and connected home devices when feature matching to identify technologies they recommend for use by their patients. In instances when rehabilitation professionals recommend smart speakers and other smart home device options for this population, they should consider providing adequate support for set up of the devices as well as for learning to use them effectively. Finally, the results of this study imply designers and developers should consider exploring opportunities to further develop the assistive capabilities of smart speakers. For this population, in particular, they should explore opportunities to further develop the capacity of smart speakers to provide support for memory and stress management as well as companionship.

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Proposal of a Vibration Stimulus Start System for the Deaf and Hard of Hearing

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Abstract

In this research, we have proposed and developed the vibration stimulus start system suitable for deaf and hard of hearing (DHH) sprinters adapted for a crouch start, and have developed the reaction time measurement system for light stimulus and vibration stimulus. The experimental results show that the possibility that the vibration stimulus start system is suitable for DHH sprinters despite issues are remained to be solved: the thumb and finger placement limitation and the weakness of the strength of vibration.

Keywords

Deaf and Hard of Hearing, Sprinter, Light Stimulus, Vibration Stimulus, Reaction Time

Background and Objective

In general, deaf and hard of hearing (DHH) sprinters face the following problems:

DHH sprinters feel anxiety about listening to the start sound signal in a sprint race.

DHH sprinters who hardly listening to the start sound signal must look at the starter.

DHH sprinters who hardly look at the starter must look at the movement of the sprinter in the next lane.

To solve the above problems, a light stimulus start system is currently used in DHH sprint race. However, in general, visual reaction time (RT) is slower than auditory RT. On the other hand, tactile RT is almost the same as auditory RT (Welford, 1980; Woodworth & Schlosberg, 1995). Moreover, Ifukube have reported that tactile RT is faster than visual RT, where tactile RT is about 5ms slower than auditory RT, and visual RT is about 30ms slower than auditory RT (Ifukube, 1980). Therefore, we suggest that the tactile stimulus is more suitable for the start signal for DHH sprinters than visual stimulus, because the delay time of tactile RT is 5ms which is below the minimum time unit (which is 10ms) of the sprint race in the photo finish (IAAF Competition Rules, 2016-2017), whereas the delay time of visual RT is 30ms which is above the minimum time unit. That is, the light stimulus start system may affect the race time of DHH sprinters compared with that of hearing ones.

In this research, we have proposed and developed a vibration stimulus start system suitable for DHH sprinters adapted for a crouch start, and have developed the RT measurement system for light stimulus and vibration stimulus to confirm the effectiveness of the developed system by experiments.

DHH athletes cannot participate in the Paralympics. However, they can participate in the Deaflympics. In Deaflympics 2017 Samsun, 473 DHH athletes participated in it from 65 countries (“Athletics”, 2017). The sprinters of the participants and many other DHH sprinters all over the world would benefit from this system.

System Description

Figure 1 shows the diagram of the proposed system which consists of a controller, devices generating light and vibration stimulus, an embedded board, and a load cell attached to a starting block, on which a sprinter set both legs. A sprinter sets both hands on the vibration-generating devices in case of “On your marks” in a race. RT is measured by using the Yokokura’s detection method for the start operation of sprinters (Yokokura, 2000).

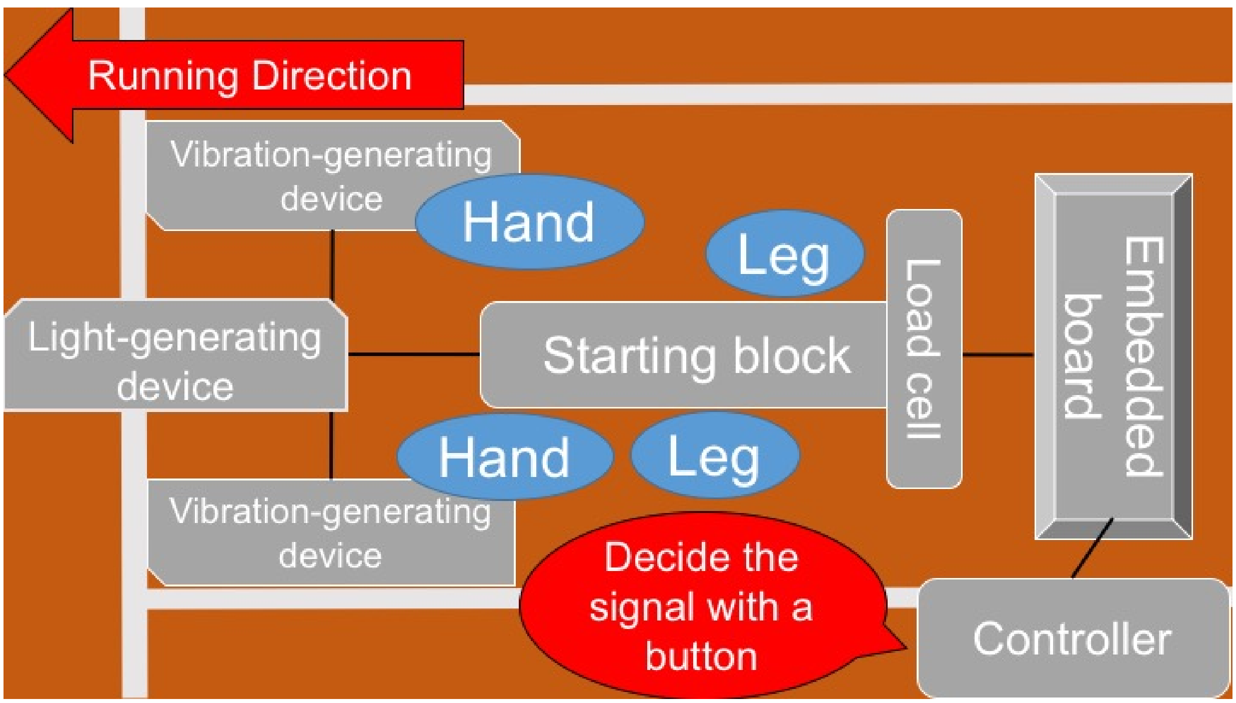

Fig. 1. The diagram of the proposed system (gray: devices, blue: sprinter, led: explanation).

In our system, RT measurement program runs on a “mbed” board, which is an embedded board, connected to the load cell. The maximum input of the load cell is 2kN, the maximum output voltage is 3.3V (obtained by using an amplifier) which is the same as the maximum input voltage of the board, the conversion precision of AD (analog to digital) conversion is 12bit, and the sampling rate is 1ms. Fig.2 shows the overview of the prototype of the developed system.

In the develop system, the light-generating devices consist of six red LEDs, six yellow LEDs, and six blue LEDs in order from top (Fig. 3a). The red LEDs, the yellow LEDs, and the blue LEDs emit corresponding to “On your marks” (Fig. 3b), “Set” (Fig. 3c), and “Start” (Fig. 3d), each other. The light intensity of a red LED, a yellow LED, and a blue LED are 6,000mcd, 4,500mcd, and 4,000mcd, each other. The vibration-generating devices only vibrate in case of “Start”, whereas the red LEDs and the yellow LEDs emit corresponding to “On your marks” and “Set”, each other. The vibration is generated by using DC (direct current) motors. The thumb and finger placement is shown in Fig. 4, where thumb and finger touch the plates attached to the vibration motors.

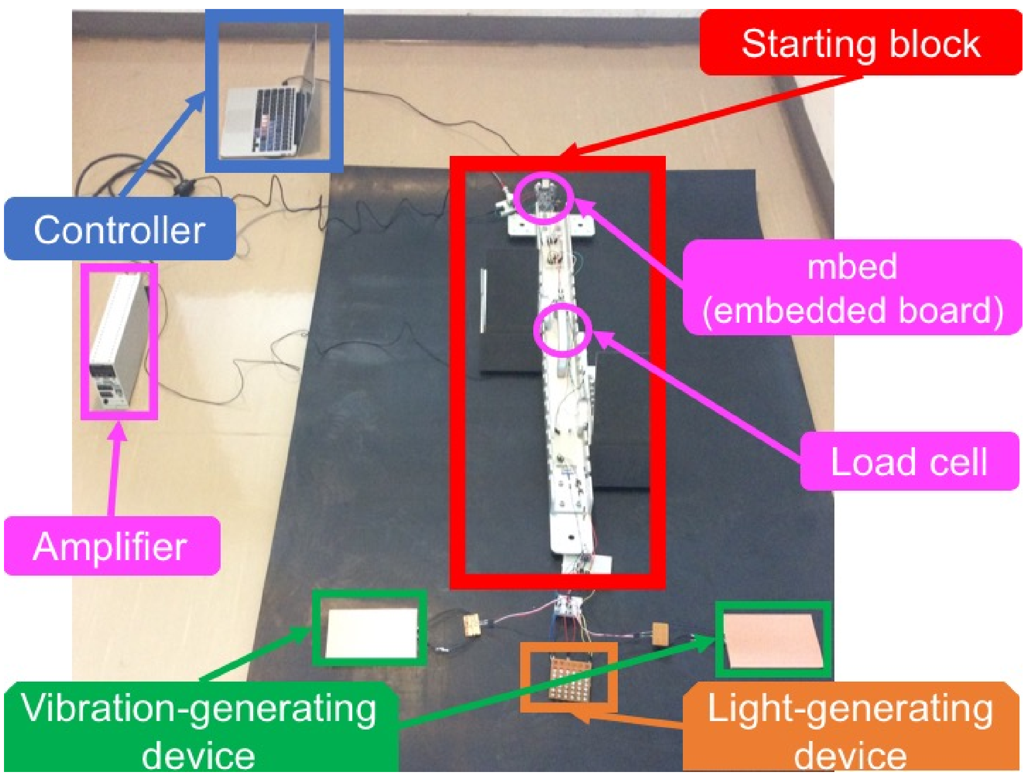

Fig. 2. The overview of the developed system.

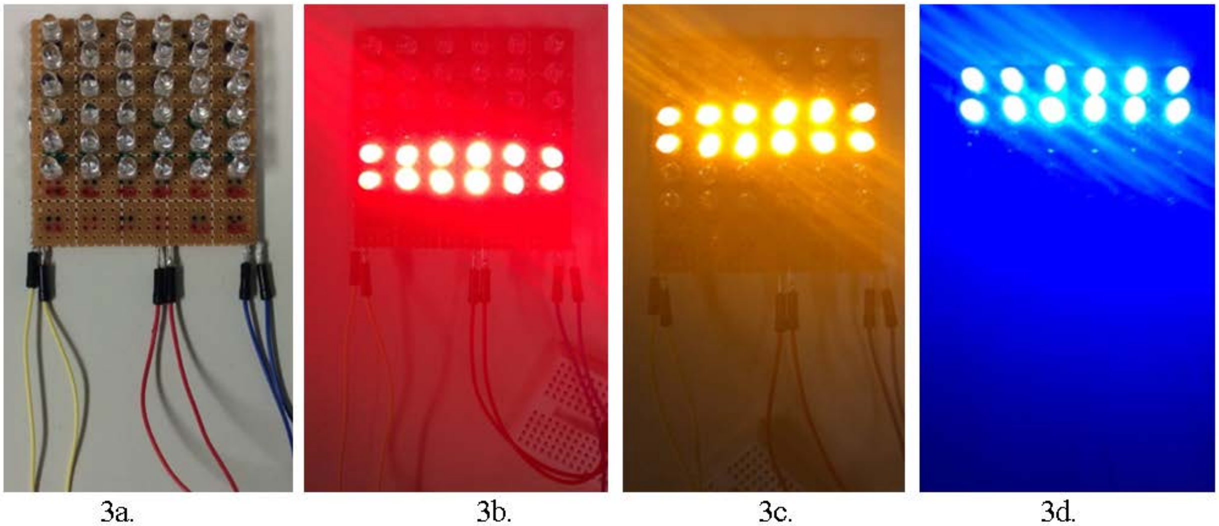

Fig. 3. Light-generating devices consist of six red LEDs, six yellow LEDs, and six blue LEDs.

3a. The light-generating devices ; 3b. “On your marks; 3c. “Set;” 3d. “Start”

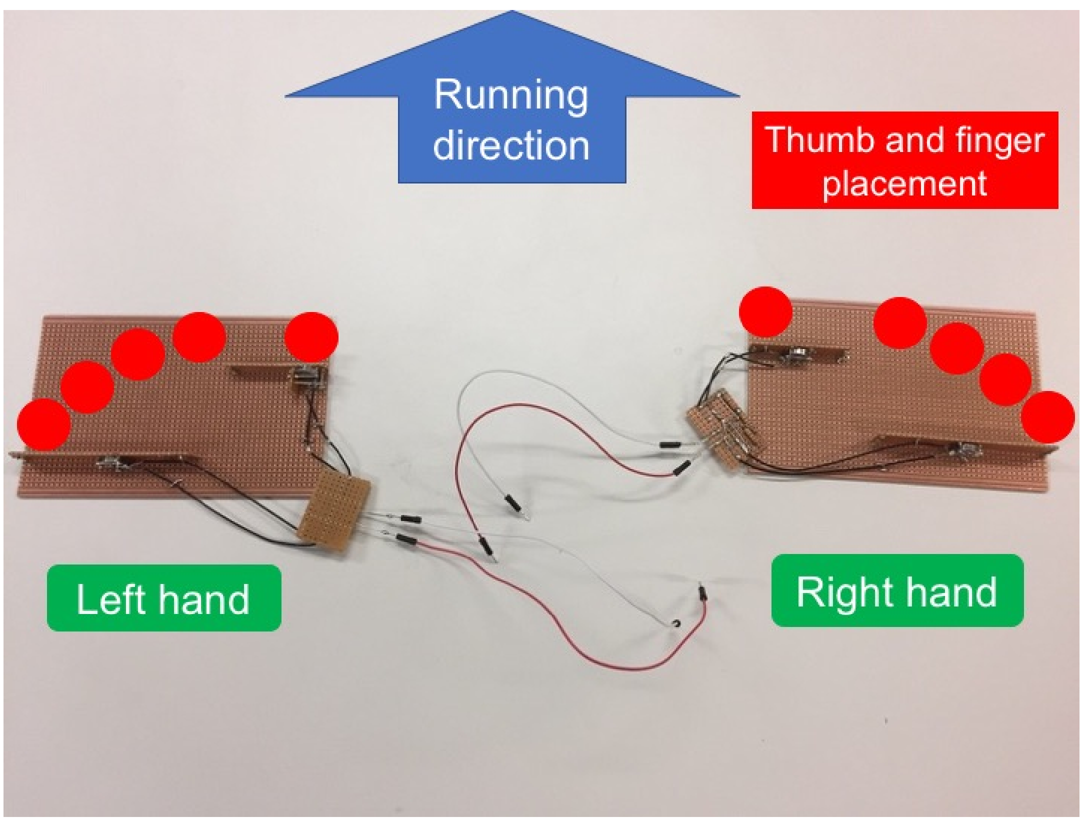

Fig. 4. The vibration-generating devices

Experimental Method

We examined the RT of light stimulus and vibration stimulus for DHH 13 people (70-130dB hearing level, 20-22 years old) limited to those who are athlete experienced as follows:

1. Prior explanation of the experiment (10min)
2. Measuring the light stimulus RT three times (10min)
3. A Break (10min)
4. Measuring the vibration stimulus RT three times (10min)
5. The questionnaire about the feeling of using the developed system (10min)
6. Interview based on the answer of the questionnaire (10min)

The method of measuring RT is based on the rule of the start in sprints (IAAF Competition Rules, 2016-2017), that is, we carry out the measurement in the order of “On your marks”, “Set”, and “Start” (then, the stimulus occur) each trial. After a participant finish the start operation, the trial is ended.

Experimental Results and Discussions

The average and standard deviation of the RT of light and vibration stimulus are shown in Table 1. The histogram of those is shown in Fig. 5. In this experiment, we subtracted the start-up time of the vibration DC motor shown in the date sheet from the vibration RT. We removed four data less than 0.100s from the vibration RT data because these are considered as “breakaway” by the timing rules of athletics (IAAF Competition Rules, 2016-2017).

Table 1 shows that the RT of light stimulus is a little bit faster than that of vibration stimulus. However, there were no significant differences between them performed by Student's t test ($p<0.005$). On the other hand, the questionnaire and the interview results are summarized as two voices: “The thumb and finger placement is limited by the vibration device” and “The strength of vibration is weak”. Even though issues are remained to be solved in the vibration stimulus system, the fastest time of the RT was the vibration stimulus not the light stimulus, which indicates the possibility that the vibration stimulus start system is suitable for DHH sprinters.

Table 1. The mean and standard deviation of the RT of light and vibration stimulus

Stimulus	**Mean (s)**	**Standard deviation (s)**
Light stimulus	0.185	0.0421
Vibration stimulus	0.200	0.0625

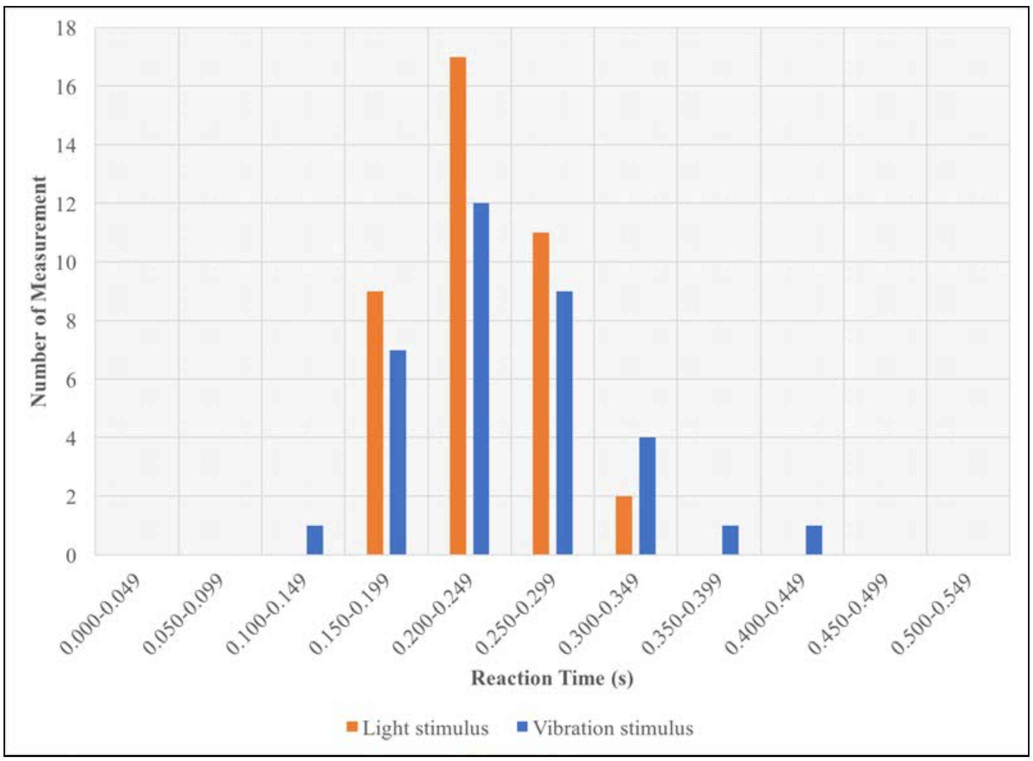

Fig. 5. The histogram of the RT of light and vibration stimulus.

Conclusions and Future Works

In this research, we have proposed and developed the vibration stimulus start system suitable for DHH sprinters adapted for a crouch start, and have developed the RT measurement system for light stimulus and vibration stimulus. The experimental results show the possibility that the vibration stimulus start system is suitable for DHH sprinters despite issues are remained to be solved: the thumb and finger placement limitation and the weakness of the strength of the vibration.

In future work, we plan to improve the developed system to resolve the above issues. Concretely, we will develop plural kinds of generating devices for vibration stimulus by using a 3D printer and various kinds of motors to identify the best vibration stimulus signal by experiment.

In the future, we will measure the RT for hearing sprinters, blind and visually impaired sprinters, and other handicapped sprinters using invalid chair, artificial arm, artificial leg, etc. After that, we want to develop the practicable prototype based on the universal design for everyone.

Acknowledgements

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Mobile Health Apps and Needs of People with Disabilities: A National Survey

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Abstract

This report summarizes data from a national survey on the experiences, needs and potential solutions for mHealth technology by people with physical, cognitive, sensory and emotional disabilities. Convenience sampling was used to draw a sample of 377 adults with disabilities. Data were collected from February to August 2017. The survey was conducted by the Rehabilitation Engineering Research Center for Community Living, Health and Function (LiveWell RERC). The survey instrument includes items on user experiences and needs for a wide range of mHealth solutions. This paper focuses on mHealth apps: 1) types of health/wellness mobile apps currently used by people with disabilities; 2) satisfaction levels with the use of health/wellness apps; 3) ease/difficulty in finding usable and effective health/wellness apps; 4) interest in an online repository of information/reviews of mHealth apps; 5) specific problems or challenges using health/wellness apps; and 6) "wish list" for health/wellness apps that currently do not exist.

Keywords

Health, information and communications technology, mobile apps, survey research, smartphone, wearable technology

Introduction

Mobile health (mHealth) technology is assuming an increasingly important role in fitness, health maintenance and healthcare delivery as maturing and emerging technologies grow increasingly capable of supporting the health monitoring and feedback, education and motivation needs of the population. Fitness and activity trackers, biosensor technologies, and tools for remote patient engagement by healthcare providers (and for general fitness tracking by consumers) can be especially useful in helping individuals manage their overall health and fitness and other chronic conditions. Consumers with disabilities could benefit substantially from these mHealth technology solutions. Disability is often accompanied by higher rates of sedentary lifestyles, obesity, lower levels of exercise and community engagement, and restricted access to transportation. At the same time, consumers with disabilities use mainstream information and communication technologies (smartphones and tablets) at rates similar to the mainstream population (Morris et al. 2016; 2017). These levels of use indicate that consumers with disabilities have the hardware, mobile ICT services and general abilities to use mHealth technologies.

The population of people living with a disability in 2010 was approximately 56.7 million (U.S. Census Bureau, 2012). Assuming growth of this population proportional to the 12.5% growth of the general population between 2010 and 2025, there will be roughly 63.8 million people in the US with disabilities in the middle of the next decade. However, population trends suggest this number will be much higher as people living with disability are living longer (Thomas and Barnes 2010). Between 1990 and 2013 the disability-adjusted life years (DALYs) for non-communicable diseases increased globally (Murray et al. 2015). Age related decline and higher incidence of disability and chronic conditions among older individuals is likely to push these numbers even higher. The U.S. Census Bureau predicts that the number of people in the United States age 65 and older will grow from 47.8 million in 2015 to 56.4 million in 2020 to 65.9 million in 2025, and continue rising to 82.3 million by 2040 (U.S. Census Bureau 2014). These older individuals have much higher prevalence of disability (Centers for Medicare and Medicaid Services 2012). Indeed, most people with any disability tend to have more than one disability (Ruggles et al. 2017), and older individuals with disability are more likely to have multiple disabilities than others.

People with disability utilize healthcare at substantially higher rates. Hospital re-admissions for people with spinal cord injury and acquired brain injury after 1 year post-injury are substantial – 31% and 26%, respectively (Choo 2015). Among older individuals, hospitalization admissions and readmissions are higher for those with multiple disabilities than with no or only one disability. Ongoing uncertainty regarding the status of national healthcare policy and the future of the Affordable Care Act increases further the need to extend precious healthcare resources, as many individuals face the possibility of losing coverage of "essential benefits" due to more lax requirements for health insurance policies, or losing health insurance coverage entirely.

Hospital admissions and readmissions however, are only one indicator of health and functioning for people with disabilities, and usually occur when chronic conditions worsen. What about the status of people with disability and chronic conditions between hospitalization and clinic visits? Are they exercising, socializing, sleeping well, taking their medications properly, minimizing risks and generally taking care of themselves? Can a model of care that includes ongoing intervention and collection of patient data between clinic or hospital visits enhance the health and functioning of individuals with disabilities, and in a cost-effective manner?

Although technologies that can support health and fitness are developing at a rapid rate, challenges persist. Though promising, these technology advances still are limited by narrow functionality (IMS Institute for Healthcare Informatics 2015), uncertain measurement accuracy of apps and sensors (Cadmus-Bertram et al. 2017; Pobiruchin et al. 2017), concerns over privacy (Filkins et al. 2016; Sajid and Abbas 2016), uneven durability and usability, and high rates of user abandonment (Gartner 2016). Narrow functionality – lack of integration into a more comprehensive model of care – is a particularly critical concern for people with disabilities and chronic conditions, who often suffer from multiple conditions, ailments and limitations.

This report summarizes data from a national survey on the experiences, needs and potential solutions for mHealth technology by people with physical, cognitive, sensory and emotional disabilities. The survey was conducted by the Rehabilitation Engineering Research Center for Community Living, Health and Function (LiveWell RERC). The survey instrument includes items on a wide range of mHealth solutions. This paper focuses on mHealth apps. Key questions addressed include:

- Types of health/wellness mobile apps used by people with disabilities
- Satisfaction levels with the use of health/wellness apps
- Ease/difficulty in finding usable and effective health/wellness apps
- Interest in an online repository of information/reviews of mHealth apps
- Specific problems or challenges using health/wellness apps
- “Wish list” for health/wellness apps that currently do not exist

Discussion

The reported survey data were collected from February to August 2017 using convenience sampling. The total number of respondents consisted of 377 adults with a specific disability. This report constitutes a preliminary analysis, as data collection is ongoing.

The mean age of respondents was 54 years with a standard deviation of 14.5 years. Females constituted 53% of the sample and 74% of the sample reported being white/Caucasian. Annual household incomes were reported below $50,000 for 47% of the respondents. Respondents were asked to identify whether they had difficulties in any of 9 general functional categories (Table 1). Most reported on average as having 2 functional limitations/difficulties with the most common being difficulty walking, climbing stairs and difficulty hearing.

Types of mHealth Apps Used

Respondents reported using a wide variety of mHealth apps. Fitness, exercise and activity tracking apps were the most commonly used type of apps (40% of respondents). Diet/nutrition/healthy-eating and lifestyle apps (including stress management and sleep quality apps) were less common with 27% and 17% reporting using these types of mHealth apps, respectively.

Table 1. Which of the following types of health and wellness apps do you use? (Check all that apply), by disability type.

Disability type	**Fitness**	**Diet**	**Lifestyle**	**Other**
Difficulty concentrating, remembering, deciding	60%	24%	22%	22%
Frequent worrying, nervousness, or anxiety	50%	24%	24%	29%
Difficulty seeing	44%	23%	23%	29%
Difficulty hearing	45%	30%	17%	18%
Difficulty speaking so people can understand you	47%	41%	29%	29%
Difficulty using your arms	30%	30%	22%	30%
Difficulty using your hands and fingers	44%	31%	26%	21%
Difficulty walking or climbing stairs	37%	28%	17%	22%
Difficulty with fatigue / limited stamina	40%	30%	23%	26%
ALL RESPONDENTS	40%	27%	17%	20%

Respondents with difficulty thinking/frequent worry/anxiety reported using fitness apps at rates much higher than the average. For these respondents and those with difficulty seeing, the gap in use rates between fitness apps and all other apps was the greatest. Notably, those with difficulty speaking used diet/nutrition and lifestyle apps at the highest rates (41% and 29%, respectively) among the several functional disability types.

Satisfaction and Ease of Finding Usable and Effective mHealth Apps

To understand the current experiences of consumers with disabilities when using or searching for mHealth apps, respondents were asked to rate their:

- Satisfaction levels with the use of health/wellness apps
- Ease/difficulty in finding usable and effective health/wellness apps

Using a scale of 1-5, with 5 being very satisfied, respondents primarily reported neutral levels of satisfaction with the use of mHealth apps. Only respondents with 1) frequent worry/anxiety and 2) difficulty speaking reported being satisfied or very satisfied with the functioning of their mHealth apps. For all other disability groups respondents reported either being neutral or dissatisfied with respect to the use of mHealth apps.

The satisfaction levels for each disability type were aggregated to produce overall satisfaction indices (Table 2), which ranged from 3.12 to 4.00; a satisfaction score of 5.00 would indicate that all respondents rated their satisfaction as “very satisfied.” The average score for the entire sample including all disability types was 3.46. It is important to note that this score includes a high percentage of respondents rating their satisfaction as neutral (a score of 3), indicating widespread lack of enthusiasm for existing mHealth apps.

Table 2. Satisfaction with mHealth apps and ease of finding mHealth apps that work for me.

Disability type	**Satisfaction index**	**Ease of finding index**
Difficulty concentrating, remembering, making decisions	3.51	3.38
Frequent worrying, nervousness, anxiety	3.68	3.70
Difficulty seeing	3.31	2.98
Difficulty hearing	3.57	3.23
Difficulty speaking so people can understand you	4.00	3.43
Difficulty using your arms	3.19	2.99
Difficulty using your hands and fingers	3.24	3.05
Difficulty walking or climbing stairs	3.29	2.97
Difficulty with fatigue / limited stamina	3.12	2.95
ALL RESPONDENTS	3.46	3.25

Additional findings revealed that most respondents reported neutral or negative feelings regarding the ease of finding mHealth apps that worked well for them. Many more respondents reported that their search was difficult/very difficult (31%), compared to the percentage of those who reported being dissatisfied/very dissatisfied with the use of their mHealth apps (10%). This was also reflected in the overall index score 3.25 for ease of finding an effective mHealth app as compared to the 3.46 score for satisfaction.

Most respondents with 3 types of disability (difficulty concentrating/ remembering, frequent worry/nervousness, and difficulty speaking) reported that their search for mHealth apps that work for them was either easy/very easy. However, respondents in the other 6 disability categories reported substantially greater difficulty an mHealth app that worked for them.

The low-to-moderate percentage of respondents reporting being satisfied/very satisfied with their mHealth apps or feeling that their search for mHealth apps was easy/very easy suggests that additional tools for reviewing and recommending mHealth apps would be useful. As shown in Table 3, 86% of respondents indicated they would use a website that provided information and recommendations about mHealth apps specifically for people with disabilities. More than 90% of respondents with motor-function disabilities (walking and using arms, hands and fingers) and difficulty speaking reported interest in a website for reviews of mHealth apps.

Table 3. If it existed, would you use a website that provides information and recommendations for mHealth apps specifically for people with disabilities?

Disability Type	**No**	**Yes**
Difficulty concentrating, remembering, or making decisions	18%	82%
Frequent worrying, nervousness, or anxiety	21%	79%
Difficulty seeing	27%	73%
Difficulty hearing	16%	84%
Difficulty speaking so people can understand you	7%	93%
Difficulty using your arms	4%	96%
Difficulty using your hands and fingers	3%	97%
Difficulty walking or climbing stairs	8%	92%
Difficulty with fatigue / limited stamina	14%	86%
ALL RESPONDENTS	14%	86%

Respondents also overwhelmingly supported the idea of including reviews and feedback about mHealth apps by peers with similar conditions on such a website (Table 4). Almost 9 out of 10 respondents (89%) supported the idea of peer reviews; there was little variability in support for this across disability types.

Table 4. Would it be helpful to have a website that provides reviews or feedback about apps from users with conditions like your own?

Disability Type	**No**	**Yes**
Difficulty concentrating, remembering, or making decisions	9%	91%
Frequent worrying, nervousness, or anxiety	11%	89%
Difficulty seeing	16%	84%
Difficulty hearing	11%	89%
Difficulty speaking so people can understand you	14%	86%
Difficulty using your arms	12%	88%
Difficulty using your hands and fingers	11%	89%
Difficulty walking or climbing stairs	10%	90%
Difficulty with fatigue / limited stamina	15%	85%
ALL RESPONDENTS	11%	89%

User Needs for mHealth Apps

We also asked respondents to identify specific problems using apps as well as their "wish list" features or functionality for mHealth apps. The survey provided a variety of responses that included the following:

- need for greater accessibility of mHealth apps, such as improved readability of the output; multimodal output such as sound, vibration and text; and integration with Apple's VoiceOver audible screen navigation by touch; integration with JAWS screen reader; screen magnification; and captioning;

- need for low battery drain of mHealth apps, which is critical for people with disabilities who often regard their mobile devices as personal safety tools;
- broader integration with other apps and biosensors (blood pressure cuffs, thermometers, etc.) or types of devices (like personal computers); customized versions of apps that suited specific personal disability or situation – a calorie counter/activity monitor for sedentary people who consume and use far fewer calories than the general population, an app that captures distance and calories for wheelchair users, an activity tracker that takes into account their severely uneven gait;
- specific app solutions – an app that reads the air quality (pollen count, barometric pressure) in the immediate vicinity, or an exercise app for people with multiple sclerosis or rheumatoid arthritis.

Conclusions

The ongoing evolution of consumer technologies across a wide array of devices, software and services holds enormous promise for supporting the development of mHealth solutions for people with disabilities. The technology development landscape includes continuing enhancements to established technologies like smartphones and tablets, emerging new platforms like wearable fitness trackers and smartwatches, home-based smart speakers and intelligent personal assistants, and cloud services supported by natural voice recognition and artificial intelligence.

At the same time, the rapid pace at which these technologies continue to evolve poses substantial risk of leaving people with disabilities behind. Consumer technology firms generally have made great efforts in recent years to engage people with disabilities. But, basic usability challenges continue to be evident in new technologies and new versions of existing technology devices, software and services. Furthermore, the exigencies of business survival often mean that products must be engineered initially with the widest possible user base in mind, leaving people with disabilities to wait for subsequent updates that are accessible and useful.

The survey research data presented here indicate that people with disabilities have substantial unmet needs for mHealth apps and related technology. Overall, few respondents reported moderate-to-high levels of satisfaction with their existing mHealth apps, and even fewer reported that finding effective mHealth apps was easy or very easy. Respondents overwhelmingly indicated that they would use an online resource with information and recommendations for mHealth apps, and that they would find it helpful if such a resource offered reviews by peers with disabilities like their own.

The number and variety of needs and wishes for mHealth apps identified by respondents also indicates that this is an area where there are substantial unmet needs. As mHealth technologies and mobile app solutions proliferate, researchers and developers must make sure that the needs of people with disabilities are addressed.

Acknowledgement

This research was conducted by the Rehabilitation Engineering Research Center for Community Living, Health and Function (LiveWell RERC), which is funded by the National Institute on Disability, Independent Living and Rehabilitation Research (NIDILRR) of the U.S. Department of Health and Human Services, grant number 90RE5023. The opinions contained in this document are those of the grantee and do not necessarily reflect those of HHS or NIDILRR.

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Development of a Serious Gaming App for Individuals with Spinal Cord Injury

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Abstract

In this paper we describe the development of SCI Hard, a serious game designed to promote self-management skills among adolescents and young adults with spinal cord injury and dysfunction (SCI/D). With assistance and input from individuals with SCI/D and healthcare providers, SCI Hard was designed as a mobile gaming app that allowed for game play by individuals with high levels of tetraplegia. It takes approximately five hours to complete and consists of four levels that require the player's character to figure out how to get around with SCI, manage their health, and engage in activities so they can save the world. Evaluation of the game by fourteen individuals with SCI/D found that while reactions varied regarding the music and plot, in general, participants had a positive experience with the game and felt that playing it could benefit those with new SCI as well as a general audience. In conclusion, electronic games — if thoughtfully designed with input from the target population — appear to offer a potential avenue for engaging adolescents and young adults with SCI/D in the self-management process. The medium is familiar and allows a safe place to learn rules, test boundaries, and experiment with the connection between outcomes and actions/inactions.

Keywords

Spinal cord injury/dysfunction, adolescents, serious game, health management, intervention

Introduction

A serious game is “a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, public policy, and strategic communication objectives (Zyda 26)” (Charlier et al. 230). Serious games based on development of self-management skills have been created for asthma, diabetes, safe sex negotiation, and promoting nutrition and physical activities (Baranowski et al; Stinson et al; Thomas et al). They have been effective in improving self-care, increasing self-efficacy, reducing symptoms, minimizing secondary conditions, reducing emergency room visits, and decreasing health care costs (Lieberman).

Many of the individuals who sustain traumatic spinal cord injury (SCI) are from the millennial generation (adults born in 1981 to 1997; ages 18-37 in 2015; Fry). While the mean age for individuals with SCI is 42 years old (National Spinal Cord Injury Statistical Center; NSCISC), over half are in the 16 to 30 age range at the time of injury (SCI-Info-Pages). Younger patients with traumatic SCI are overwhelmingly male (NSCISC), many of whom need medical care for the first time in their lives. They have a high school education or less, with lower literacy levels and fewer resources; in addition, many come from ethnic and racial minority backgrounds (Burnett et al.). Millennials and younger generations, though, tend to have a high degree of technical sophistication (Dede; Litten and Lindsay), which can be leveraged to promote the transfer of knowledge and self-management skills. In particular, games that can be downloaded and played on a mobile platform such as a smartphone are likely to be accessed and played by adolescents and young adults. Importantly, data from a recent survey conducted by Meade and colleagues confirm similar patterns of use of this technology by individuals with SCI (Mayman and Meade; Mayman et al.).

Intervention Development

SCI Hard is a serious gaming application that was developed to tailor *Health Mechanics* (Meade), a self-management program created to facilitate management of spinal cord injury or dysfunction (SCI/D), into a format consistent with preferences and learning styles of the target population of adolescents and young adults. The *Health Mechanics* program is an evidence-based intervention that teaches or reviews the skills of attitude, self-monitoring, problem solving, communication, organization, and stress management.

Game development was shaped by current theories of health behavior and standard practices. In particular, we used the Model of Internet Interventions by Ritterband and colleagues (Ritterband et al.) to frame development; this model acknowledges a wide variety of mechanisms for changing behavior and leading to symptom improvement but articulates the importance of user characteristics and their influence on website (application/intervention) use as precursors that allow for behavior change. That is, an individual must access and use the Web, Internet, or game application in order for it to influence behavior change and the extent of use can influence the degree of behavior change, at least within certain limits. In particular, members of the millennial generation expect a high degree of interactivity, technological sophistication, and visual impact (Oblinger and Oblinger), and the degree to which these expectations are met will directly influence the individual's engagement, enjoyment, and ultimate use of the program. This model influenced design choices such that we attempted to prioritize characteristics that would be fun and engaging for the target population.

In addition, multiple theoretical and evidence-based approaches to learning and self-management were adopted throughout the development of SCI Hard to promote positive changes. These included modeling expectations for health behaviors, providing the opportunity to develop skills through feedback mechanisms relating actions to consequences, reinforcing the impact of behavior and the importance of continued management practice (Meade and Cronin).

Multiple industry-proven tools and development platforms were used in creating SCI Hard to ensure a consistent and interactive experience. Art assets were modeled and animated in 3D Studio MAX (Autodesk, Vers. 2015, 2016), while the model's textures and colors were created in Adobe Photoshop (CS6) and Pixologic's ZBrush (Pixologic R4). Cut scenes for the game were assembled in Adobe After Effects (CS6), a common motion graphics tool, and then exported to the game using custom scripts so the game's logic could interpret artist-defined animations. The assembly of assets and introduction of game logic and mechanics relied on the Unity 3D game engine (Unity Technologies, Vers 3.5.6-Vers. 2017), which allowed for rapid iterations during development and cross-platform support. While the Unity3D platform provided many standard options for simulating lighting and materials, due to the unique visual style and "rolling horizon" effect found in the game, many custom tools and methods were developed.

Mobile platforms were targeted when developing SCI Hard in order to leverage their natural accessibility and mobility. The mobile device market represents hundreds of devices with many requiring special considerations for each combination of device and operating system (OS). Due to Apple's strict standards placed on iOS devices, initially only Apple iOS devices were supported to minimize potential variables that could impede the team's ability to respond to feedback from the advisory group. Additionally, a decision was made early on to support second-generation mobile devices to their present release due to minimum memory and computation requirements. Even with a limited number of potential devices and OS, it was discovered throughout the development process that undocumented limitations of the various devices introduced additional challenges. One such example was the precision with which a finger is tracked across the surface of the screen. Many devices do not report a straight, equally spaced collection of contact points as one would expect if a consistent straight line was dragged with a finger. Thus, additional effort was required to smooth and anticipate inputs to ensure an effortless experience. During the beta release phase, support was added for the Android platform.

A primary concern with creating this game was to ensure that it was both engaging and accessible to individuals with SCI from the target population, including individuals with tetraplegia. An advisory panel consisting of healthcare providers and individuals with SCI from the target group was an essential part of the development process, as they provided feedback about game accessibility, content, dialogue, style, and pace. Based on this feedback, gameplay mechanics were crafted to ensure that the varying levels of physical and mental ability did not impede the gaming experience. The player uses simple finger or mouth-stick movements, focusing on a single action at any given time, such as moving through a scene, shooting, or interacting with a person or object.

In navigating through the game, players are required to monitor factors such as health, stress, and energy and are encouraged to optimize each of those factors through specific behaviors. In particular, health is a composite of managing skin integrity, bowels, and bladder as well as balancing diet and exercise. Players have to conduct pressure reliefs, organize and execute a catheterization (“cathing”) schedule, and monitor bowel-related functioning throughout the game in order to stay healthy and be able to engage in other activities. Health and energy can be improved through visits and engagement with in-game healthcare professionals, including a physiatrist, and engaging in continued rehabilitation (occupational therapy [OT], physical therapy [PT], and rehabilitation engineering). In addition, failure to perform needed positive health behaviors is met with consequences within the game environment. For example, players who do not cath will see a reduction in points/abilities while leaving a stink trail behind them, which will additionally impact the mood and reactions of non-player characters (NPCs). Table 1 provides a more comprehensive review of the health behaviors required and how these are conceptualized within the game.

Table 1. Health Mechanics and Required Health Behaviors

Issue to Manage	How to Manage and Monitor	For Planning	Consequence
Skin	Pressure reliefs -every 30 minutes monitored via timer	Recognize need for pressure reliefs at regular intervals	Skin breakdown and decreased health
Bowel	Bowel program - once every 1-2 days monitored via timer	Need bathroom	Bowel accident, Stink cloud, Decreased health, Embarrassment/increased stress, Impaired communication
Bladder	Cathing - once every 4-6 hours monitored via timer	Need correct supplies (“cath kit”) or need bathroom	Bladder accident, Stink cloud, Decreased health, Impaired communication
Stress	Monitor stress levels, make time for stress-relieving activities, and enhance cognitive flexibility- monitored via POS	Monitor regularly, notice relationship between stress, health and communication, and take time for stress-relieving exercise	Decreases health, communication, cognitive flexibility and ability to navigate
Cognitive Flexibility; Resilience	Enhances problem-solving, attention, and memory- monitored via POS	Manage Stress, play memory mini-game/Dr. Shrync’s cognitive test	Impacts health, impacts resistance to Chillax 3000
Health	Perform all health behaviors, improve fitness, manage stress, and increase cognitive resilience -monitored via POS	Optimize all behaviors and carry needed items in backpack (including food and cath kit)	Impacts stress, impacts energy / fatigue, and impacts ability to accomplish tasks
Energy/ Fatigue	Improve fitness, manage stress, and perform all health behaviors - monitored via POS	Optimize all behaviors and pacing of behaviors	Impacts navigation, influences ability to accomplish tasks
Fitness*	Eat healthy food, avoid unhealthy food, drink water, exercise/ engage in physical therapy - monitored via POS	Purchase / Pack healthy food in backpack, and go to PT[c] to exercise	Impacts energy and health

SCI Hard focuses on enhancing skills, encouraging positive health behaviors, and empowering people within their own environments, recognizing that people have different resources and abilities. By teaching skills to better manage health, it was hypothesized that this serious game should not only reduce the occurrence of complications but also promote higher levels of social integration and quality of life. In particular, playing the game should allow players to recognize the consequences of their behaviors, as actions and inactions are tied to visible results and substantial changes in statistics.

The Game and Story

While early on players are engaged in learning game dynamics, monitoring health, and adjusting activities to optimize performance, as they gain skill and increase in level they are asked to participate in a larger quest, more reminiscent of adventure and role-playing games (RPGs). In this world, Dr. Shrync, the psychologist they encounter in inpatient rehabilitation, is determined to control the population through his mind-controlling device, the Chillax 3000, and take over the world. Individuals with SCI, because of their increased awareness of their surroundings and heightened problem-solving abilities, are a threat to him and his plans. Because of this, Dr. Shrync crafts a plan to use the everyday animals of the town to do his bidding and hinder or even harm the character and those close to him or her. After defeating several such minions and achieving a specific ability level in task management, players are invited to join an underground resistance of healthcare professionals who are working to thwart Dr. Shrync's evil plans. If the player accepts, they are sent on a secret mission that will allow them to save the world, which they will be able to complete only if they continue to perform the health behaviors required to maintain their health.

The game consists of four levels and more than thirty mini-games that focus on the development of particular skills. At the start of each new game, players have the opportunity to customize their character to suit them, including changes to their sex, outfit, and skin tone (figure 1). Additional information about the story for the game and its various levels can be found in table 2.

Fig. 1. Screen shots from SCI Hard. *Upper left:* Title screen. *Upper right:* Customizing the character. *Lower left:* Basketball mini-game. *Lower right:* Health metrics screen.

Table 2: Storyline and Skills Reinforced at Each Level of SCI Hard

Level	Story/Plot line	Self-management Skills Reinforced
1	Players wake up in a rehabilitation hospital and discover that they have a SCI.[a] They must learn the basics of navigating and managing their health before they can leave the hospital.	Self-monitoring Organization
2	Players work with their rehabilitation team to manage their health and communicate effectively, as well as manage a complex social situation.	Communication Problem solving
3	Players have the opportunity to learn to drive and purchase an accessible van while trying to get to a local club to see their friend perform, while navigating motor skills and social interactions.	Integration of skills to increase independence
4	Players must unravel Dr. Shrync's complex plot to rule the world and defeat him in a final high-energy showdown that requires the use of skills learned so far while managing their health.	Multitasking Self-monitoring

Discussion

Methodology for Evaluation

Two separate evaluations were part of the development of SCI Hard, assessing first the beta version and then the final version of the game; feedback from the beta version was used to refine the game prior to the final version. While SCI Hard was initially developed for individuals with traumatic SCI between the ages of 16 and 24, the decision was made to allow individuals from the ages of 14 to 29 and those with spinal cord dysfunction (including spina bifida) to participate in the second evaluation phase in order to assess its applicability to a broader audience.

Participants and Procedures

This study was approved and monitored by the Institutional Review Board at the University of Michigan and took place between May 2015 and March 2016. Participants were eligible to participation in the study to evaluate SCI Hard if they were between the ages of 14 and 29 and had traumatic SCI or a spinal cord dysfunction. Exclusion criteria included having significant cognitive impairment, undergoing current hospitalization or rehabilitation, or experiencing significant emotional distress or suicidal ideation at the time of the screening or assessment.

All participants were instructed to play the game as often as possible over the following two weeks but, at a minimum, to try to complete all levels at least once. Individuals who participated in the first evaluation did so from a borrowed device with the game already uploaded onto it; individuals who played the final version did so after downloading it onto their own mobile device. During the two-week period for game play, participants were reminded to play the game via email or phone calls. Follow-up assessments occurred approximately two weeks later and were conducted either in person or through online surveys with technical assistance available through telephone support if needed. Participants received a $50 incentive for completing the study or a prorated payment for partial completion.

Feedback About the Game

All participants were asked specific questions about how often they used the game, what level they achieved, and specific game-related challenges, and then were asked to provide feedback about their experience. They were also questioned about the extent to which they viewed the game as relevant to individuals with SCI and potentially useful in learning to manage their condition.

Results

Eighteen individuals 16 to 29 years old enrolled the study. However, three did not complete the follow-up assessment and one was not able to access the game; for this reason, the data of only fourteen individuals are included in the section. Of these fourteen participants, eight played the beta version of the game and six played and evaluated the final version. Participants who completed the study ranged from 18 to 29 years of age (mean age = 24.43; sd =4.20), were evenly split between males and females, and were primarily non-Hispanic White (84.6%). Most participants had traumatic SCI (n=11), though two had spina bifida and one had another type of impairment. The level of injury ranged from high-level tetraplegia to low-level paraplegia with most (92.9%; n=13) reporting some ability to use their arms and hands.

In describing their game-playing habits, most reported playing electronic games on a hand-held gaming device (including a smartphone) either every day or a few times a week (71%). In contrast, a majority said they never played games on a computer (57%) or a tablet (57%), while only 29% reported regular use of a game console. Participants were most likely to indicate that they played shooter games, racing games, sports games, puzzle games, and computer board or card games (all 42.9% or n=6). Few participants endorsed playing music games, arcade games, RPGs, or Massively Multiplayer Online (MMO) games.

Subjective evaluations about SCI Hard were sought from all participants. Table 3 provides a summary of this information. Overall, players liked the game and found the story line relatable and/or educational, though this was not universal. When asked their opinions about specific game elements, most participants gave positive feedback about the graphics and art, the dialogue, the characters, and the mini-games. Reactions to the music and plot were a little more varied. Six of the fourteen participants felt that the game changed the way they thought about their SCI or managing their health; however, thirteen felt that the game would be beneficial to individuals with a new SCI, particularly within the first two or three years after SCI (four responses) and newly injured kids, teens, and young adults. Other groups that were identified included “Anyone. People that don't have SCI could get a better understanding of what it's like to have it.”

Table 3: Subjective Evaluation Responses of Participants for Each Version

Question	Response: Beta (n[a] = 8)	Response: Final Version (n = 6)
How often did you play the game?	Ranged from a couple times a week to almost every day.	Ranged from a few times a week to every day.
What kept you from playing it more?	Glitches within the game or other activities.	Busy schedules, disinterest, health issues, and technological problems.
How far did you get in the game?	Non-completion (62.5%) and game completion (37.5%).	Non-completion (66.67%) and game completion (33.33%).
Did you play the game through more than once?	Yes (25%) No (75%)	No (83%) Yes (17%)
What did you like about the game?	Game relatable and educational.	Characters, mini-games, and health management devices.
What did you not like about the game?	Dialogue, technological problems, lack of guidance within the game, and tasks related to chores.	Some of the characters or sequences within the game, parts of the game difficult to figure out.
What did you think of the graphics/art?	Ranged from “Good” to “Love it.”	Ranged from “Good” to “Love it.”
What did you think of the dialogue?	Ranged from “Okay” to “Amusing” to “Goofy.”	Ranged from “Good” to “Comical” to “Could be improved.”
What did you think of the characters?	Responses ranged from “Good” to “Funny” to “Cheesy.”	Responses ranged from “Good” to “Colorful” to “Cheesy.”
What did you think of the mini-games?	Ranged from “Fun” to “Frustrating.”	Ranged from “Fun” to “Frustrating.”
What did you think of the music?	Ranged from “Good” to “Annoying.”	Ranged from “Good” to “Annoying.”
What did you think of the plot?	Ranges from “Liked it” to “Did not understand it.”	Ranged from “Liked” to “Disliked.”

Question	Response: Beta (n[a] = 8)	Response: Final Version (n = 6)
Do you think that the game changed the way you thought about your SCI or managing your health?	Yes (12.5%) Somewhat (50%) No (37.5%)	Yes (33.3%) Somewhat (33.3%) No (33.3%)
Who do you think could benefit most from playing the game?	Adolescent SCI patients, newly injured individuals, non-SCI population who want to learn about the experience of individuals with SCI.	Adolescent SCI patients and newly injured individuals.
Did you have any other comments or concerns?	Technological problems, need for additional guidance, and desire to see more positive message.	Technological problems, need for additional guidance (less frequency than the beta version).

Conclusions

SCI Hard was developed using an iterative, community participatory approach to facilitate or reinforce the application of self-management skills in a format tailored to the preferences, learning styles, and skills of adolescents and young adults with SCI/D. Results provide preliminary evidence that this serious game was feasible to implement — even at a distance — and acceptable to the target population. In addition, while the game was evaluated only with individuals with SCI/D of varying lengths and severity, responses from this group identified others who may potentially benefit from playing. While most agreed that the game would likely be most helpful to adolescents and young adults with relatively new spinal cord injuries, it was also noted that playing SCI Hard could provide anyone with new insights into the complicated health behaviors and other challenges associated with managing a SCI.

However, the results also made it clear that SCI Hard was not universally liked. Some participants found particular aspects — or even the entire game — annoying. Similarly, some healthcare providers may not care for the way particular characters or disciplines are represented.

While personal preferences are always going to influence how free time is spent, it may be that for some individuals with SCI, playing SCI Hard may need to be assigned or prescribed in the manner described for other educational games. At a minimum, having the opportunity to discuss the game and gameplay elements with rehabilitation providers may allow for expectations and stereotypes to be better articulated.

The evaluation contained in this paper focused on describing its usability, enjoyment, and relevance. The next step is to evaluate its short-term impact, including the extent to which playing the game results in improved knowledge, problem solving, and adjustment to disability and/or increased self-efficacy. The final and most important step, though, will be to determine the game's long-term influence on improving health behaviors, reducing secondary conditions and healthcare costs, and improving community integration.

Importantly, though, this study describes an innovative way that we can leverage technology to supplement existing practices and to enhance outcomes. Health care is changing and rehabilitation also needs to change and adapt. Technology can allow for scalable solutions that can be tailored to particular groups and issues.

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Designing Human-Centered Services For Visually Impaired Seniors

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Abstract

This human-centered, ethnographic research discloses the foundational knowledge on behaviors, attitudes, and unmet needs of visually impaired seniors gained throughout a pilot project.

Keywords

Blind and visually impaired seniors, service design, ethnographic research, mobility, assistive technology, independence

Introduction

Seniors comprise an increasing percentage of individuals who have no or low vision in the United States. According to the 2015 disability statistics by Cornell University, in New Hampshire more than 26,000 individuals live with vision loss, with some estimates that two-thirds are seniors over 65. This trend is accelerating as baby boomers age and seniors live longer. ‘Future In Sight’ is a New Hampshire-based non-profit that provides a range of education, rehabilitation, and training services to children and adults living with profound vision loss. Recently, ‘Future In Sight’ decided to expand its services to include a larger portion of this population, particularly seniors who live in rural areas at or below the poverty line and have limited access to rehabilitation and medical services.

In an effort to better understand the emerging needs of this target group, ‘Future In Sight’ reached out to Essential to craft a pilot research project. The study employed Design Thinking principles to provide foundational knowledge on senior clients’ behaviors, attitudes, and unmet needs, and to learn about future design and innovation opportunities.

In this pilot project, five individuals in different stages of their vision-loss journey were given a chance to be an advocate for more tailored and informed services. The results of this pilot project will be used as evidence to support future grants, enabling ‘Future In Sight’ to serve a larger population with improved and expanded service offerings.

Founded on systems thinking, Service Design identifies goals and outcomes that a customer must achieve to feel satisfied in all phases of their journey with an organization. Through this systematic approach, service designers align organizations’ capabilities and business opportunities with customer needs and experiences, exploring front-stage and back-stage activities from all stakeholders’ perspectives (Reason, and et al. 2016).

This paper reviews the process and the results of the aforementioned qualitative study, which used the service design approach to offer insights and opportunities for improving ‘Future In Sight’ services.

Methodology

Service Design and Design Thinking often rely on ethnographic research that has roots in sociology and anthropology. With direct involvement of research target groups, Design Thinking provides contextual and in-depth knowledge about people’s thoughts, feelings and actions. Direct involvement of visually impaired people in research validates their experiences and empowers them to have a voice in designing services that can meet their needs (Bühler, 2001). The team conducted five 120-minute sessions in the form of an exploratory, co-creative, and semi-structured interviews at the participants’ homes using a combination of qualitative methods inspired by Hanington and Martin: in-depth interviews, home walk-throughs, a “day in the life" and journey mapping (Hanington and Martin, 2011).

The process of protocol and activity development was challenging due to lack of previously conducted research projects and the prevalence of visual-driven methodologies and activities in Design Thinking. Considering the sensitivity of the subject, the goal was to create a rapport and to provide comfort and ease where participants would be inspired to openly share their experiences and emotions. The team was looking for an approach that allowed for a deeper connection as well as access to tacit knowledge of visually-impaired seniors. Studies by J. Berbrier in 2002, U. Herrmann in 1995, J. Michael in 1981, and E. Inman in 2016 shed light on the power of the art therapy practice in eliciting these emotions and building empathy. Using the the art therapy strategies put forth by aforementioned studies as inspiration, the created research stimuli were tactile-driven with the goal to trigger memories and emotions, to offer a space where visually impaired seniors could describe their dreams and to better communicate and to engage with the sighted world. The methodology and stimuli, shown in Figure 1, were also adjusted to accommodate an individual's sensory abilities and comfort level (Michael, 1981, Berbrier, 2002, Herman, 1995, and E. Inman, 2016).

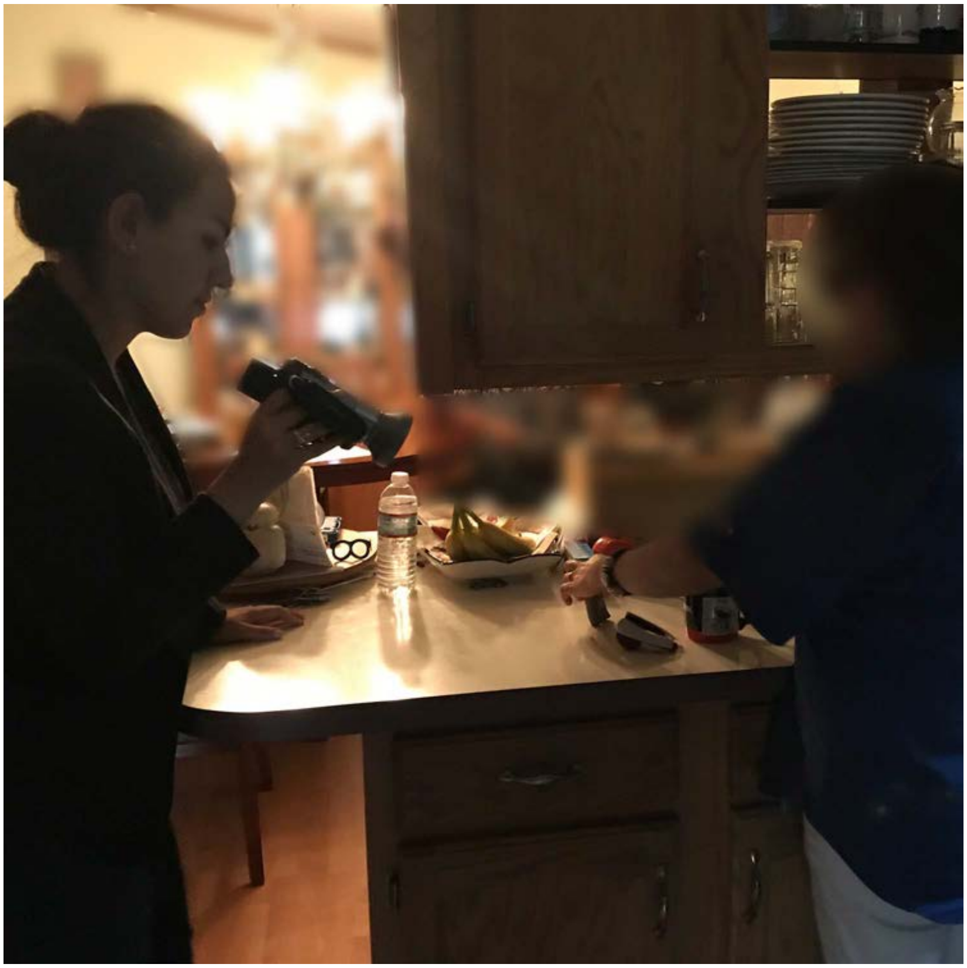

Fig.1. The sample of the methodology and stimuli that were adjusted to accommodate individual's sensory abilities and comfort level – from the left to right journey mapping, home tour, and helpers and hurdles.

The topics were arranged in a sequence to cover three areas: warm-up and building a foundation, dive into life with low vision and its consequences from different perspectives, and reflecting on the past to design a better future:

- The warm-up introductory questions were followed by mapping each participant's journey after being diagnosed with low vision
- The deep conversation part started with identity and life with low vision, followed by daily life experiences both indoor and outdoor, helpers and hurdles and their relevant influence, and feedback about 'Future In Sight'
- The opportunity section covered the role of technology, positive moments, and aspirations.

In the journey mapping activity, participants shared their experiences from the time they began noticing a loss of vision until now, with prompts, such as *"Let's start with when you first noticed your vision loss. Could you share your experience with me? How was the situation? Where were you? How did you feel?"* As a way for participants to better indicate their emotional state and how these emotions changed throughout their journeys, an abacus was designed with a bead attached to each column, Figure 1, Right Image, which stood for a stage of a journey. Participants used the location of the bead to communicate their emotional state at that time; top for positive, bottom for negative, and neutral if in the middle.

In the home tour exercise, participants shared areas of their homes where they perform their daily activities while pointing out their favorite areas, tasks and objects as well as the ones they struggle with and frustrate them.

In the helpers and hurdles activity, participants were offered two groups of models: circles on the right for helpers and squares on the left for hurdles. They were prompted that these helpers or hurdles could be anything: people, places, things/objects, behaviors, needs, inside their home or outside and were asked to describe how they were affecting their lives. After making a pile of helpers and hurdles, they were given a bar, Figure 1, Left Image, and asked to show how the scale tilts– weighing their helpers and hurdles.

In the opportunity section, participants were presented with a list of potential opportunities, such as personal grooming, support for families, peer advice, awareness services from healthcare providers about existing services and organizations, and public education and volunteer services. They were asked to pick the items they may want ‘Future In Sight’ to pursue or cover more strongly.

In the second part, the discussion focused on the role of technology in meeting each individual main needs and desires. To enhance the engagement and support from less vocal participants, a list of potential solutions/benefit statements was presented, covering daily needs such as:

- A VoiceOver technology that gives you auditory descriptions of what is on the screen of your device, reads text aloud and provides suggestions.
- A smartphone app that uses vibration to guide you through routes in your home, which are marked by colored tape on the ground.
- A smart cane that vibrates at different levels depending on how close you are to objects and hazards.
- A scanning device that reads and announces the color of anything around you.

Results

Analysis Process

The gathered data were analyzed through an iterative, sense-making process with the aim of framing the problem from different perspectives and understanding the hidden connections – as L. Kimbel put it “what goes on in a context from inside it.” The analysis process requires creativity and openness to what surfaces from the data including unexpected findings and surprises (Kimbel, 2014). Accordingly, the team drew relationships among many data points, such as what people do, say, feel and know, in meaningful ways both from a bird's-eye and detailed views – using sticky notes and large excel sheet posters. As a result of this rigorous process, more than 40 insights emerged and clustered into topics comprising of: participants' needs, goals, attitudes, thoughts, emotions, and actions during four stages which include 1) Pre-Diagnosis, 2) Diagnosis and Progression, 3) Engagement, and 4) Future. These topics yielded nine core themes: disconnection from surroundings; many mobility barriers; power of small changes; independence is a rare golden feeling; irreplaceable role of family, friends, and peers as key supporters; awareness and preparation; fear of unknown; aspirations; and the pivotal role of technology.

One of the first realities of vision loss is the disconnection with the physical world and loss of control over surroundings. Consequently, people slow down, create ad-hoc solutions, and adopt new skills and behaviors. From the mobility perspective, replacing abandoned activities with new achievable activities increases hope and redirects energy. Low/no vision is just one of many obstacles individuals face when trying to remain or become mobile: these can include a negative self-image, fear of strangers' inappropriate behaviors, and the protective impulses of family members. Mobility (or lack thereof) is also a self-reinforcing process. People with low/no vision often become homebound and isolated due to a lack of mobility services. If they do go outside, they don't encounter many limited-vision peers, which further discourages them from going outside and also makes the need for improved mobility services more visible. As a result, opportunities and solutions that enhance mobility and provide independence were widely appreciated.

Independence is a rare, golden feeling, where as losing one's driver's license and the ability to help others or asking for help are felt to be signs of dependency and are the lowest moments of an individual's journey. Family, friends, and peers are key supporters in individuals' journeys; lack of support from any of these groups extensively impacts individuals' lives. Interactions with peers, both one-on-one and in a group, assists individuals and their families in coping with their condition, inspiring them to take action and build community.

Looking at each participant's journey, awareness of where one is on their journey and preparation for what is to come can benefit individuals in coping with their condition. However, people don't know about available resources and are hesitant to ask unless they are innately extremely proactive. Confronting this new reality and its limitations is a hard but necessary step for adopting a positive attitude toward their present and future life with vision loss. Fear of the unknown can be so overwhelming that people opt to remain in denial as long as they can.

Finally considering the role of technology, losing vision does not negatively impact tech-savvy individuals' interest in supportive technologies. They are actively looking for new resources and mastering new skills. However, losing vision could have negative impacts on the technological interest and skills of less tech-savvy people. They may avoid technology because they feel unable to understand it, feel overwhelmed with the other adjustments vision loss requires, or aren't interested in utilizing their resources.

Experience Frameworks

To share the process that yielded these insights and bring them to life for the audience, various frameworks were used, such as User Profiles, Experience Maps, Maslow Hierarchy of Needs, and Five Human Factors.

A User Profile framework depicts a thorough picture of each participant using various data points, such as needs, goals, attitude toward condition and technology, feedback on 'Future In Sight', and aspirations. For example, Figure 2 shows PL's Profile– one of the female participants. She started her journey with 'Future In Sight' a year ago. She had to quit her job a couple of months after being diagnosed with Retinitis Pigmentosa.

Her main hobby was writing, but she does not write that often anymore: *"I don't write as much as I used to because it's harder for me to do it...sometimes it's just so hard to see. It wasn't like I was a typer. It wasn't like I was on the computer."* She finds her hurdles, such as lack of support from her family and not being comfortable to go out, a little bit heavier than helpers since they do not change. She is relatively happy with her services and found her visitors from 'Future In Sight' very encouraging, but believes there is a need for more tailored services, where individuals get more time with staff. *"They need more time with people…if there were a little more time and stuff...when you come into this you don't know what to expect."*

An Experience Map captured end-to-end participants' experiences with a holistic view of individual's daily life or life chapters, providing a foundational knowledge that illuminates how 'Future In Sight' fits into a broader context. The experience maps uncovered actions, expectations, emotional goals and triggers, and contextual pain points. PL's lowest journey moments, shown in Figure 3, are being diagnosed with Retinitis Pigmentosa and giving up driving: *"When the doctor told me I shouldn't have been driving for four years and shouldn't be driving anymore I became unglued. I cried and wanted to rip everything in the place. It took away my ability to be myself. It feels like you're losing your identity. Because I used to travel for my job and was always driving."*

The second circle on the map depicts her current situation, where she feels despair and loneliness that are being balanced by 'seeking online resources to learn new adjusting skills' and 'continuing emotional and physical support by 'Future In Sight's' peer group and volunteers.' The experience map also shows her emotions, as well as experience with 'Future In Sight,' e.g., her primary pain point, was 'the on-boarding process from different services' and her positive moment 'meeting with peers.'

The Maslow's Hierarchy of Needs framework, illustrated in Figure 4, was used to showcase different levels of participants' needs and to start a conversation around opportunities with the 'Future In Sight' team members. Firstly, people would like to maintain their routine and health; then, they aspire to be more active and social, and finally, want to adopt new solutions and skills to improve their lives. The latter two proposed a new line of opportunities for 'Future In Sight.' Looking at PA's goals and aspirations, she would like to gain the support of her family and friends, be more mobile, attend a writing class and finish her book, and finally, perform public speaking – advocating for people with low or no sight.

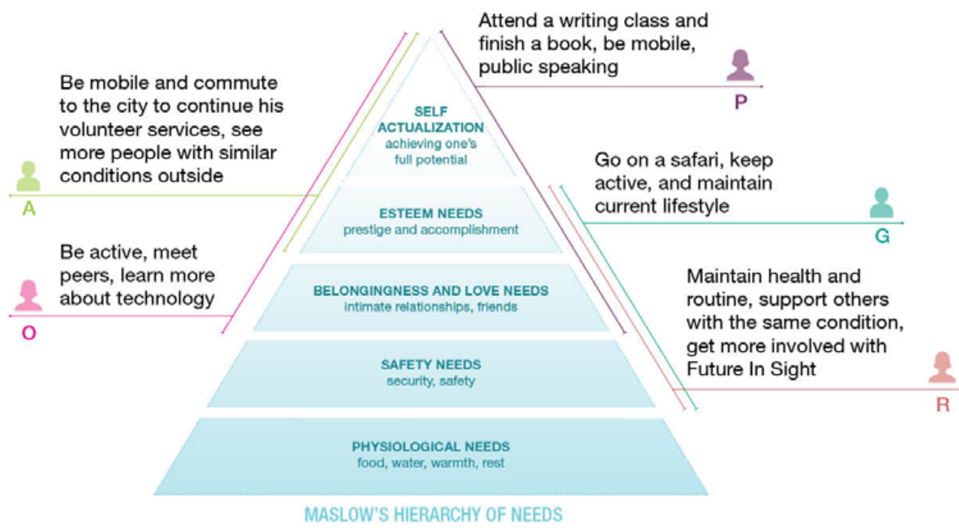

Fig. 2. Maslow Hierarchy of Needs was among the various frameworks that captured the study's process and insights.

The Five Human Factors, captured in Figure 5, was among the frameworks used to structure data gathering and analysis, illuminating participants' needs and desires. Besides people being the chief entity, each factor also includes content referring to activities, environments, interactions, and objects. Kumar introduced social and emotional needs as two aspects of the Five Human Factor framework (Kumar, 2012), where some of the fundamental insights correlated closely to these two aspects. Physical, cognitive, cultural are the other three aspects.

From the emotional needs perspective, feeling insecure is a source of fear and frustration for no/low vision individuals and their families. Some participants had built coping mechanisms around self-talks and meditations. A study by Marquès-Brocksopp (2014) showed that promoting this positive behavior and mindfulness enhances individuals' spiritual well-being, as well as their emotional, social, and physical health. Another emotional need insight echoes the fact that confronting the new reality and its limitations is a difficult but necessary step to adopt a positive and proactive attitude towards vision loss. From the social needs' perspective, mobility and social integration are connected and symbiotic: the lack of one can result in isolation, which is the most common negative emotion among the participants. The helpers and hurdles model, illustrated in Figure 5, confirms these needs. In order of significance, family and friends, being mobile and independent, and support from 'Future In Sight' play positive roles in an individual's journey.

HELPERS	FAMILY & FRIENDS	FUTURE IN SIGHT + PEERS	OBJECTS/TECH	CURRENT JOYS	PETS
	Spouse Grandchildren Living close by all the family Friends & Family Family having adjusted to her and not asking too many questions Neighbors	Future In Sight Volunteers from Future In Sight Interactions with peers	Magnifiers Computers Audiobooks Personal hacks: the order and shape of his medication Coffee Mug	Looking forward to getting to know NH Spending time in the garden Being stable Being able to live here independently	Her dog Spending time with her neighbor's cat

HURDLES	FAMILY & FRIENDS	DRIVING & BEING MOBILE	DAILY TASKS	LOSING TEMPER
	Lack of support from her family Decision not to live with his children, did not want to be a burden A friend, who makes her aware of what it is like to start losing her mind	The thought of not being able to drive Not being able to drive Uncomfortable to go out, goes only once a week usually with the help a volunteer Cannot exercise Cannot exercise Not being mobile & not being able to go outside Not knowing where he is at any given moment in his home	Makeup and doing her hair Cannot read magazines Not being able to write that often Cannot see the food on his plate House chore, e.g., cleaning and cooking Identifying his clothes and putting them on, on the correct side	Losing her temper Loss of her patience

Fig. 3. The Helpers and Hurdles Model illuminates the significant role of family, friends, and 'Future In Sight' services.

Journey with Future In Sight

The participants' experiences with 'Future In Sight' were mapped using the five-stage Customer Journey model (Entice, Enter, Engage, Exist, and Extend). A Customer Journey communicates a rich understanding of customers' behaviors and how they interact with a company– covering their end-to-end experiences. It offers a strategic direction for an ideal journey by supporting a team to generate ideas for the before, during and after interactions. This model, illustrated in Figure 6, highlights the critical moments that can make or break the service experience in green and orange. The figure on the left displays channels that individuals encounter on their journey with 'Future In Sight'.

Often, doctors recommend 'Future In Sight, ' and alternatively and rarely if people are proactive, they find out about the organization through research. After this first encounter, there is usually a period of denial since people still have some vision, which ranges between a couple of months to years. Then, a social worker visits individuals who will assess the situation and introduce 'Future In Sight' services for further engagements.

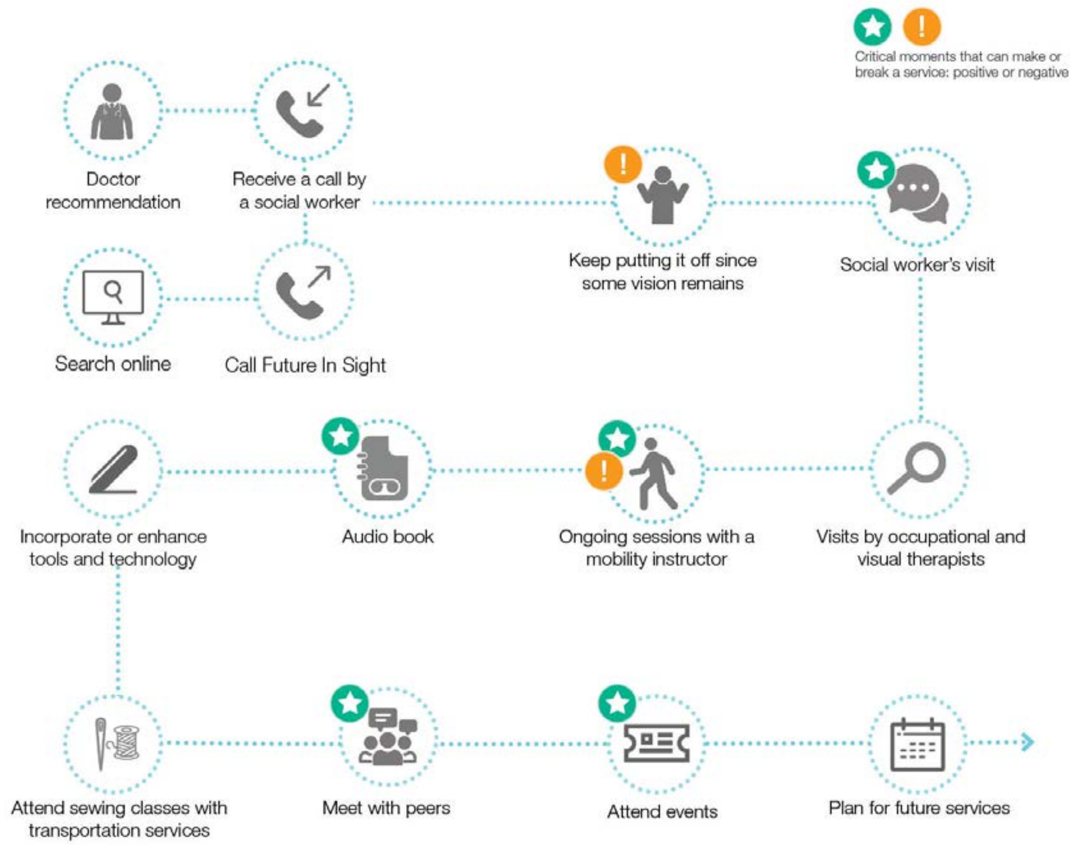

Fig. 4. The participants' experiences with 'Future In Sight' were mapped using the customer journey model.

The goal of the Entice stage is creating awareness and curiosity. In this stage, ophthalmologists have a fundamental role in engaging and re-engaging individuals with 'Future In Sight'. As one of the shared resources for seniors, they should actively provide information about available resources and services. Coping with vision loss and its consequences is overwhelming, authorities and other resources should reach out to individuals instead of the other way around. One of the hypothesis formed in this stage was around stigma: people treat vision loss like Alzheimer's, and unlike cancer they avoid talking about it. This results in there not being enough familiarity and awareness about different phases, emotions and strategies of vision loss.

In the Enter stage, with the goal of designing the first experiences, awareness of where individuals are in the journey, and preparation for what is coming next, can help them to cope more easily with their condition. The challenge is that people are usually unaware of their available resources and are hesitant to inquire. The only exceptions are the extreme, proactive participants. In response, one of the principal strategies is offering a reassuring, positive outlook to raise awareness and influence an individual's acceptance of their condition, and its present and future consequences. A model by S. Hugo and et al. in 2011 also found self-awareness, associated with individual's first contact with their loss, and self-identification as two chief milestones of the adaptation process.

The findings of the Engage stage stem mainly from onboarding and personalized services. Onboarding needs time and attention and is substantial in incorporating solutions into an individual's lifestyle. The other key strategy is designing customized services based on triggers, personality, and journey of an individual. This strategy highlights the value of the service design's co-creative approach in developing, delivering, and augmenting the clients' experiences. The emphasis of service design on this participatory, individualistic approach is a part of a broader philosophy of the inclusion and empowerment of people with impairment in more aspects of their lives – in consultative positions and decision-making processes (Luck, 2003).

Finally, in the Exit & Extend stages, the goals are to design remarkable end-of-journey experiences and to enrich connections with customers. The study revealed that people strongly value the opportunity of volunteering for 'Future In Sight'; playing an ambassador role brings joy and purpose, and helps them accept assistance from 'Future In Sight'. Furthermore, successful experiences with one organization motivate and encourage individuals to reach out to similar services and organizations in new places. As a result, efforts from one organization like 'Future In Sight' has direct influences on perception around similar organizations and attitude of individuals and their network in reaching out for help.

Findings on the role of technology were focused on the level of interest, attachment to current solutions, and the desire for being mobile. Overall, people expressed interest in technology support and enhancement. Younger participants were more open to technology and more eager to adopt new solutions for coping strategies, being independent and setting life goals. They have currently incorporated technology into their lives and expressed the highest level of enthusiasm toward the provided list of opportunities.

Access to technology has major effects in increasing the role of technology in people's lives. For example, online research will lead to learning about and seeking new resources while not being able to use a basic house phone with voice recorder can disconnect individuals and decrease their interest in adopting new resources. Playing "phone tag" can also make people give up on reaching out. Similarly, as mentioned in one of the core themes, losing vision can negatively impact the interest and skill-development of less tech-savvy people. Moreover, mobility is one of the major concerns among the participants; opportunities offered by technology to enhance mobility and provide independence are strongly valued.

From adopting a new solution perspective, besides low vision, an individual's attitude toward technology is another important factor influencing whether or not someone will use technology for support. People also in any stage would like to stick to their current solutions and may resist change, even though that change could make their life easier. They will adopt new resources and technologies that work best with their existing ones. For example, WA, our oldest participant, has access to many resources, such as a laptop, smart TV, Kindle and Alexa, but he is not interested in using them to their full potential. He already embraced reading on a Kindle and did not want to try an audio player, but he is open to trying better magnifiers as his current ones are not working well.

Raw Data Workshop and Opportunities

After the analysis process, Essential organized a raw data workshop with the ‘Future In Sight’ team members to share the results and discuss the next steps. At the end of the workshop, a list of opportunities using the “How might we” expressions were introduced to facilitate conversations identifying future services. For instance, how might we:

- show seniors they need services even though they still have some eyesight?
- encourage a proactive attitude without making people feel negative about their future?
- use technology to help people with way finding and with meditation?
- fight societal stigmas, catalyzing a change in perceptions of living with low/no vision?

Following the workshop, Essential created a graph, Figure 7, illustrating future approaches and opportunities to design more inclusive services, including topics such as: ‘enriching initial contacts and curiosity’, ‘improving socializing and mobility services’, ‘fostering emotional support and peer communities’, and ‘reducing stigma in the society’.

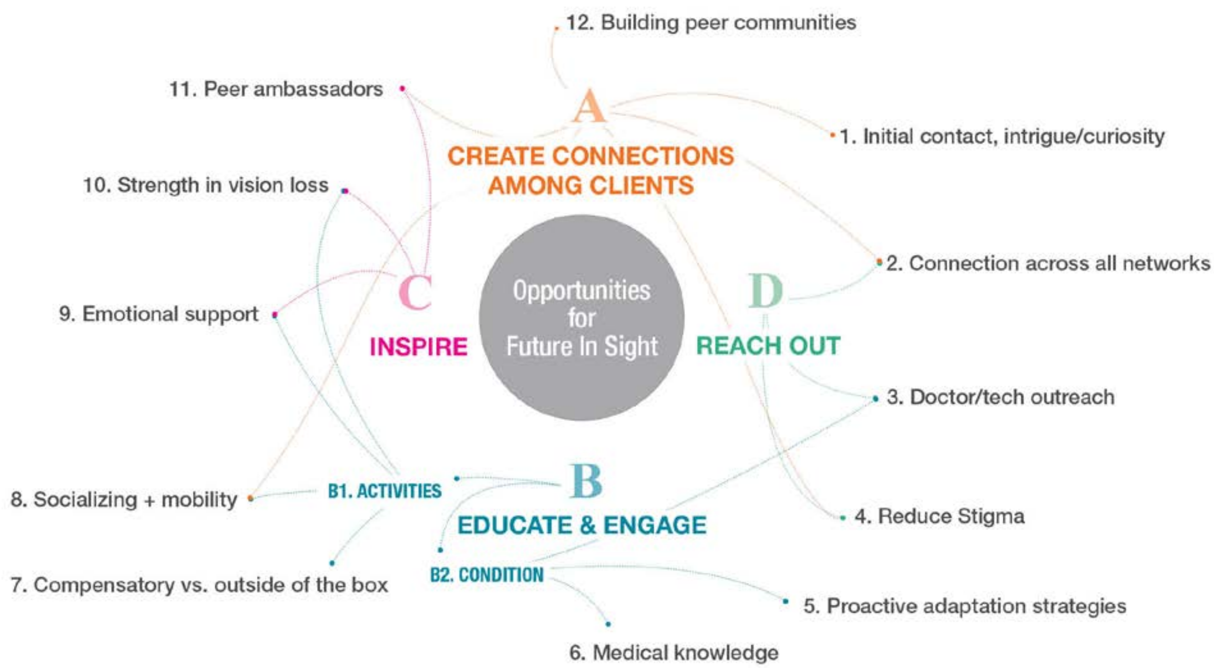

Fig. 5. Future approaches and opportunities for ‘Future In Sight’

Conclusion and Future Studies

This exploratory study was a pilot project with the goal of introducing the value of Design Thinking and the Service Design approach to the ‘Future In Sight’ team. That value was recognized by identifying core themes like the pivotal roles of independence, awareness, and technology when creating services for visually impaired seniors. Accordingly, the findings of this study call for further research into these core themes and their emergent hypotheses. For example, stigma about vision loss often leads to lack of awareness and isolation which causes seniors in early stages of the vision loss journey to feel less secure and/or confident.

Vision loss is not the end of a journey but the beginning of a new chapter in an individual’s life. In other words, new challenges create opportunities for self-actualization. Negligence has wide-reaching consequences where vision loss becomes the cause for many other losses such as reading, driving (mobility), careers/livelihoods, socialization, and ultimately, independence. However, coping with vision loss and its consequences is so overwhelming, that it is up to society at large and advocates like ‘Future In Sight’ to reach out to individuals (instead of the other way around), supporting their need to overcome fears and frustrations to meet their full potential.

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Supporting Simulation Use for Students with Intellectual and Developmental Disabilities

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Abstract

In this study, we explore how enhancing interactive science simulations with sonifications can scaffold interaction and learning for students with intellectual and developmental disabilities (I/DD). We added auditory cues to three PhET Interactive Simulations as additional feedback to highlight important concepts and relationships. Working with seventeen students who have I/DD, we evaluated the success of these cues in emphasizing science concepts, explored what additional help may be necessary to support successful inquiry-based learning for these students, and collected feedback on the auditory cues and the students' overall user experience.

Keywords

Sonification, intellectual and developmental disabilities, science education, simulations

Introduction

More than 800,000 K-12 students in the US have an intellectual or developmental disability (I/DD) (Snyder et al, Table 204.30). Students with I/DD are commonly taught in inclusive, general education classrooms (Snyder et al, Table 204.60). To support the inclusion of students with I/DD in science learning, the Georgia Tech Sonification Lab is working with PhET Interactive Simulations (phet.colorado.edu) to make their award-winning educational simulations (sims) more accessible. PhET sims provide interactive learning environments designed to support exploration and experimentation, and are frequently used for guided-inquiry activities in K-12 and college science classrooms (Moore, et al.).

Effective approaches to support understanding of science concepts for students with I/DD is an active area of research (Stavroussi, et al.). In this work, we seek to investigate the use of highly interactive and exploratory science learning simulations by students with I/DD and the benefits of sonification to support learning. Sonifications can provide additional presentation modalities beyond the visual for complex concepts, giving users the opportunity to learn in different ways (Low & Sweller), some of which may be particularly beneficial to students with I/DD. For example, sound can be used to draw additional attention to the most important representations on-screen or provide recognizable auditory cues that remind students of relevant contexts.

Sonified PhET Simulations

We enhanced three PhET simulations with prototype sonifications consisting of a combination of auditory cues (Table 1). The sounds were customized for each sim based on past research, pedagogical content, and structure and interactivity of each sim. Many of the sound design choices were informed by past auditory display research (e.g., Walker & Nees), and used to highlight important state changes or relationships. We briefly describe each sim and the most pedagogically relevant sounds below. See Tables 2-4 for a complete list of sound descriptions, mappings, and rationale.

Table 1. Auditory Description Categories.

Auditory Display Type	**Description**	**Example**
Auditory Icons	Brief realistic representations of an action	An object being rubbed on a sweater
Earcons	Musical, learned auditory representations	A sound which plays after a reset button press
Mapped Sonifications	Modulated representations which vary based on the parameter changing	Increasing pitch as more electrons are transferred to a balloon

Table 2. Sound Design Table: John Travoltage.

Concept or Action	**Visual Representation**	**Auditory Representation**	**Mapping**	**Reasoning for design**
Foot Movement	Foot moves across carpet	Filtered noise, sounds like rubbing on clothing	Increasing speed = faster carpet rub, slower drag = louder	Auditory icon mimicking real-world sound
Transfer of charge	Blue electrons build up in his body	Short “popping” sounds, one for each electron grabbed	Pitch increases as the number of charges on him increase	His body is “filling up” with charge, following same auditory pattern a bottle has as its filled with water
Accumulated charge	Electrons move around body and distribute themselves	“Clanking” sound	Any amount of electrons cause volume > 0	Earcon evoking the feeling of particles moving
Hand Movement	Hand moves towards or away from doorknob	Short melodic tones	Pitch increases as hand approached doorknob, decreases as moved away	Parallels localization task, pitch represents closeness to the target
Being shocked	A bolt of electricity travels from hand to doorknob, electrons leave body and enter doorknob	“Bzzzt ouch!” followed by short melodic tones of electrons leaving	Pitch decreases as electrons discharge	Using auditory icon to evoke the feeling of being zapped; pitch decreases as electrons are ‘draining’ out (inverse of charge accumulation)

Table 3. Sound Design Table: Balloons and Static Electricity.

Concept or Action	**Visual Representation**	**Auditory Representation**	**Mapping**	**Reasoning for design**
User-controlled balloon movement	Location in the play area	"Buzzing" musical loop when negatively charged	Increasing volume as it's moved further away from the sweater	Polarity mapping between distance from the sweater, changes based on number of charges on it.
Non-controlled balloon movement	Velocity of Balloon movement	Filtered noise, sounds like "whoosh"	Increased volume as the balloon velocity increases	Sonification paralleling realistic drifting sounds
Induced Charge	Electrons in wall are repelled	"Buzzing" musical loop	Playback rate increases (higher pitch = more deflection of electrons in the wall)	Sonification from polarity mapping research, objects with more energy have increasing tempo (and higher pitch from playback rate)
Balloon pick up/drop	N/A	Two tones in succession	Ascending tones for pickup, descending for drop off	Earcon representing z spatial position (selected is 'higher' than dropped)
Hitting Wall	Balloon touches wall	"Bumping" sound	N/A	Auditory icon mimicking real-world sound
Rubbing on sweater	Balloon moving back and forth along sweater	Filtered noise, sounds like rubbing on clothing	Volume increases with faster & longer rubs, plays during any movement on the sweater	Auditory icon mimicking real-world sound

Table 4. Sound Design Table: Build an Atom.

Concept or Action	Visual Representation	Auditory Representation	Mapping	Reasoning for design
Pick up/drop particles	Particle is removed/added from bin	Two tones in succession	Ascending tones for pickup, descending for drop off	Earcon representing z spatial position (selected is 'higher' than dropped)
New element type built	Proton added to center of the atom, element name shown, element abbreviation updated in table	Two note chord plays after proton drop sound	Higher pitch for lighter elements, lower pitch for heavier (more massive) elements	Earcon from polarity mapping 'mass' or 'weight'
Neutral/ion	Label shows: + Ion, - Ion, or Neutral Atom	Three note glissando	Rising pitch for positive ion, descending pitch for negative ion, no sound for neutral	Earcon from auditory graph research (pitch change in direction of positive or negative)
Stable/Unstable	Label shows unstable or unstable; atom nucleus vibrates when unstable, static when stable	Pulsing constant tone when unstable	Sine and triangle wave with a low frequency oscillator at 10 Hz	Earcon, informed by alert and warning research

John Travoltage

The *John Travoltage* sim can be used to support exploration of static electricity. It opens with a man, John, standing on a carpet next to a doorknob. Students can move John's leg to accumulate negative charges, and move his arm towards or away from a doorknob to discharge the charges - resulting in a "zap." The farther John's hand is away from the doorknob, the more charge must be accumulated on his body before a discharge occurs (Figure 1). John's hand movements are mapped to the pitch of a sound: pitch increases as his hand approaches the doorknob. When his foot is rubbed on the carpet, an auditory icon plays a realistic "rubbing" sound; the appearance of each negative charge on John's body results in a short tone with ascending pitches to represent the accumulation of electrical charge. A gentle "clanking" sound represents the movement of accumulated charges on John's body.

Fig. 1. Screenshot of PhET sim John Travoltage. Left panel: Hand away from doorknob, many electrons discharging. Right panel: Hand near doorknob, a few electrons discharging.

Balloons and Static Electricity

The *Balloons and Static Electricity* sim can also be used to support exploration of static electricity. The sim consists of a balloon, a sweater, and a wall; all three of these start with a net neutral charge. The balloon can be moved around the play area, and can collect negative charges when rubbed on the sweater. If the balloon has a net negative charge, upon release it will move to and stick to the (positively-charged) sweater. Moving the negatively-charged balloon near the wall results in an induced charge effect. Negative charges in the wall are repelled by the negative charges on the balloon resulting in a slight induced positive charge of the wall near the balloon.

The more negatively charged the balloon, the greater the induced charge that occurs along the wall (Figure 2).

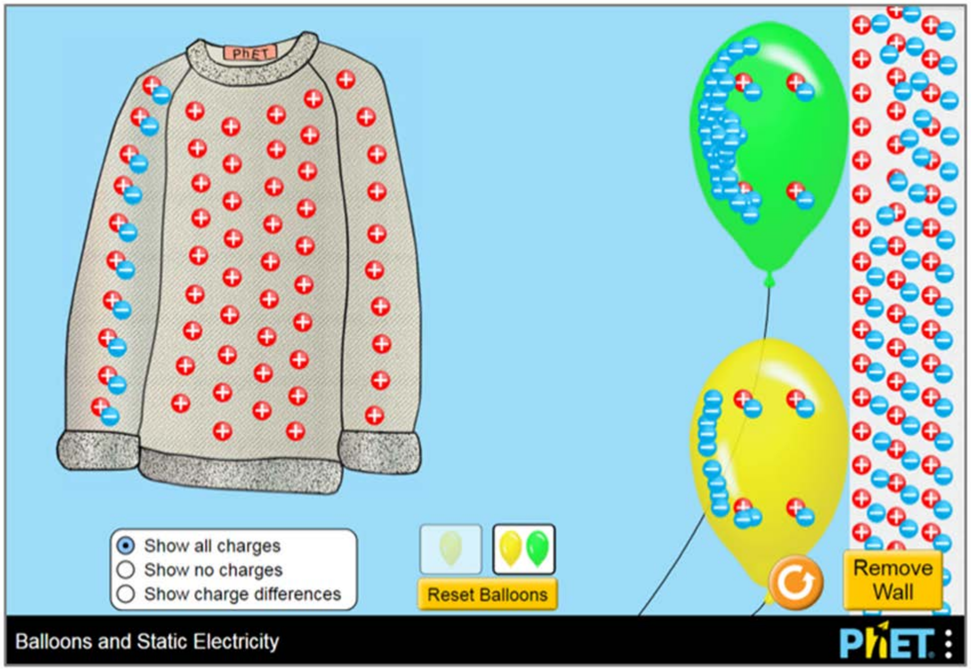

Fig. 2. Screenshot of the PhET sim Balloons and Static Electricity. Upper balloon has a large number of negative charges and results in a large induced charge along the wall. Lower balloon has fewer negative charges and results in a smaller induced charge along the wall.

Ascending and descending tones represent selecting and releasing the balloon. The volume of a pulsing tone represents the charge on the balloon (more charge results in a louder volume). Another short tone increases in frequency as more charges are transferred. The balloon's movement when released is represented by a consistently increasing tone, played at a speed determined by the amount of charge on the balloon.

Build an Atom

Build an Atom is a chemistry sim that allows exploration of a model of an atom, represented by a nucleus with two electron orbits, with buckets of protons, neutrons, and electrons. Students can drag the protons, neutrons, and electrons into the atom model and receive feedback indicating what atom they have built, its overall charge, and its location in the periodic table. Some of the feedback is provided as text labels on the atom model, and other feedback is provided in boxes beside the atom model (Figure 3). Ascending and descending tones represent selecting and releasing protons, neutrons, or electrons. The most notable sonification was the representation for element type: when a new element type is built, two tones play together; decreasing pitch of the pair represents heavier elements.

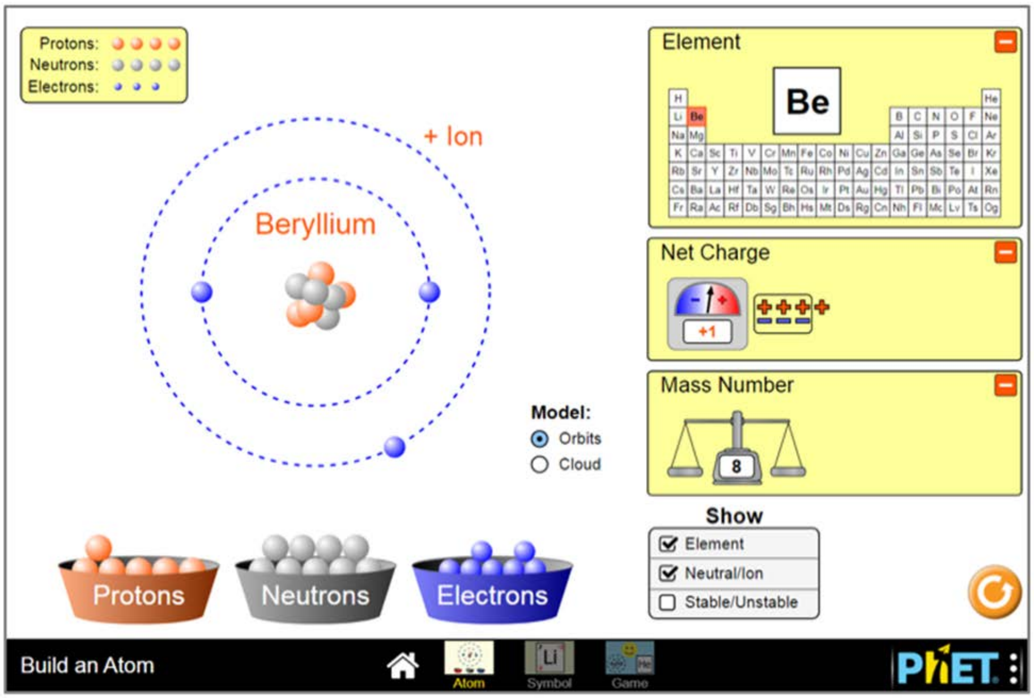

Fig. 3. Screenshot of the PhET sim Build an Atom. Atom model shows Beryllium with four protons, four neutrons, and three electrons. Readouts along the side indicating element, location in the periodic table, net charge, and mass number.

Methods

Participants included 17 students from the summer component of the EXCEL Program at the Georgia Institute of Technology. The EXCEL Program is a four-year college program for students with intellectual and developmental disabilities, and the summer component includes both current high school students and recent high school graduates. Students reported daily use and familiarity with smartphones, tablets, and computers. Five students reported that they play video games on consoles, computers, or handheld devices. Multiple students stated they had trouble reading familiar and unfamiliar words, remembering content from lessons, and focusing on school or schoolwork.

Of the 17 students, twelve used *John Travoltage*, eight used *Balloons and Static Electricity*, and four used *Build an Atom*. Each student had up to five minutes of free exploration time where they could play with the sim to gain familiarity. Next, students answered sim-specific task questions to explore whether or not they were understanding the audio and visual representations. Students were encouraged to use the sim to answer the task questions. Total time spent using the sims ranged from 5-12 minutes (*John Travoltage*), 7-18 minutes (*Balloons and Static Electricity*), and 11-25 minutes (*Build an Atom*). After sim use, we collected survey responses on general user experience (Finstad; Watson, Clark & Tellegen) and asked for open-ended feedback about the sonifications. A complete list of task and survey questions can be found at bit.ly/csun2018-methods. Screen capture recordings and verbalizations were analyzed for trends in successful and unsuccessful student interactions with the sims in conjunction with their survey responses.

Results

Student Exploration

These interactive simulations are designed to support student exploration as a part of an inquiry learning process. During the free exploration portion of the interviews, all of the students explored the sims on their own, though some students (five with *John Travoltage*, three with *Balloons and Static Electricity*, and two with *Build an Atom*) needed additional encouragement to start. Some of the students consistently continued to use the sim (without prompting) to answer the questions (seven using *John Travoltage* and *Balloons and Static Electricity*, four using *Build an Atom*), while the rest attempted to respond from memory of their free-exploration experience. With prompting from the researcher, these students would utilize the sim to respond more thoroughly to questions.

Student Use of the Sonified PhET Simulations

All of the students interacted, engaged in successful exploration, and also encountered challenges while using the sims. Here we describe student interpretations of the sound and visuals, and common challenges.

John Travoltage Simulation

Eleven of the twelve students who used *John Travoltage* correctly interpreted what happened when they rubbed John's foot on the carpet; all of them referenced seeing the charges appear, and two mentioned hearing the sonification representing transfer of charge from the carpet to his foot. After adding electrons to John's body, six students correctly interpreted the resulting "clanking" sound, representing the electrons dispersing throughout John's body. Nine students correctly interpreted the "zap" sound and described (when asked) that the spark moved from John's hand to the doorknob.

During sim use, we asked what happened to John in the sim when they moved his hand towards the doorknob. Four students responded correctly that John had to have a certain amount of charge on his body to be shocked, and five other students thought he would be shocked all the time. As a follow-up, we asked the students to generate 4, 6, 10, and more than 12 electrons, and then tell us what happened; nine students correctly described the overall phenomenon, and three referred to the "zap" sound later in the interview. When asked to provide additional feedback about the sounds, students indicated they liked the discharge “zap” sound, the “clanking” charge sound, and the sound when moving John’s arm.

Two common challenges were encountered with this sim. Three students had difficulty during initial exploration getting John’s leg to move, which is required to begin picking up negative charges. Students would use the mouse to ‘click’ on the leg (which does not result in leg motion) rather than using a ‘click and drag’ interaction. With prompting from the interviewer, students encountering this issue were able to successfully move the leg. A second common challenge, encountered by seven students, starts with the successful collection of charges on John’s body, and successfully moving John’s arm to result in a discharge event; however, then some students did not move John’s arm again without prompting, resulting in a narrowing of the exploration students engaged in. Leaving John’s hand near the doorknob results in repetitive discharge events when rubbing the foot on the carpet, and does not allow for exploration of how the amount of charge on John’s body relates to the distance John’s hand needs to be from the doorknob to discharge.

Balloons and Static Electricity Simulation

All eight students who used *Balloons and Static Electricity* correctly described what happens to the balloon when it has charges and is released away from the sweater (i.e., it drifts towards the sweater), and all correctly described that the negative charges in the wall move away from a negatively charged balloon. Five students later referred to hearing the sound that represented this induced charge on the wall. In the user experience questions, four students mentioned their favorite sounds related to the behavior of the balloon, for example, the “thunk” sound of the balloon hitting the wall, or the “swooshing” sound of the balloon being attracted to the sweater.

A common challenge, encountered by six of eight students, involved the successful transfer of all of the available negative charges from the sweater onto the balloon. Transferring all of the charges is a useful exploration, and allows students to set up scenarios to observe the most extreme behaviors in the sim. For example, when all of the available negative charges are on the balloon, moving the balloon to the wall results in the largest induced charge, and releasing the balloon results in the balloon moving to the sweater with its highest velocity. Once this has been accomplished, students need to use one of the two reset buttons ('reset' the full sim, or 'reset balloon') to remove the charges from the balloon. Without resetting the balloon, students cannot contrast the large induced charge and the high balloon velocity with other cases, narrowing the available opportunities for making comparisons with the sim.

Build an Atom Simulation

All four of the students who used *Build an Atom* recognized that adding particles to the atom model resulted in changes to the atom labels for element name, stability, and atom properties such as atomic mass, but three of the students struggled to read and understand these label changes. Labels included discipline specific terms, such as element names (e.g., "Helium," "Lithium," or "Oxygen") and state information (e.g, "Ion" and "Neutral Atom"). The only student who did not have difficulty interpreting the label changes had previously taken a chemistry class. Three students reported their favorite sounds were the earcons representing selecting and dropping particles, and the decreasing pitch sound representing increasing mass.

In addition to challenges reading and interpreting the sim's labels, students had difficulty relating the changes that occur in the atom model at the center of the screen and the readout boxes along the right side of the screen. For example, one student, with the 'Mass Number' box open, did not notice the update in the mass number on the scale while adding neutrons, and thought that “neutrons don’t do anything.” Another student used the stable/unstable checkbox during the free explore portion, but did not refer to it again even when directly asked which particles affect stability. Similarly, none of the students referred to the net charge box when describing what makes an atom neutral or an ion, although two students opened it during the free explore time.

Discussion

Accessing Unique Exploration Pathways and Supporting Comparisons

Consistently across all sims, we observed a trend in students initiating effective sim use by setting up scenarios which would help them explore different ideas in the sim. However, many students limited the number of comparisons between scenarios (e.g., not resetting the amount of charge on the balloon in *Balloons and Static Electricity* to compare scenarios with a few, a few more, and many negative charges), and needed encouragement to try more comprehensive different interactions. Cueing for students to choose a specific new interaction pathway could be provided by a teacher facilitator, peer, activity prompt, or by a learning environment that the sim is embedded within.

Supporting Exploration and Interpretation of Peripheral Simulation Features

Students tended to focus directly on the content in the center of the screen, where the majority of their interactions were, posing a challenge for sims which provide additional details through peripheral displays (e.g., expandable boxes) or interface controls (e.g., reset buttons or radio buttons to change views). Auditory or visual cues that highlight relationships between central and peripheral representations may help address this challenge. Prompting further exploration of these details, through built-in scaffolding or additional instructional support, can also be used to help direct attention to these peripheral displays and controls when needed, and encourage more comprehensive exploration for students.

Conclusion

In these interviews, students explored the sims, and enjoyed and made use of the sound representations. Many students indicated understanding some of the primary learning goals of the sims, particularly after completing the prompted tasks. Modifications of the tasks used in this work could be utilized by teachers to support students with I/DD in the classroom.

To address the apparent print disabilities observed, we are investigating the addition of text-to-speech to support students with interpretation of on-screen text. We have also begun including description content into multiple PhET sims, to support students with visual impairments, and noted that providing this content to students with I/DD could be beneficial. We are also investigating the use of visual cues, in the form of arrows, to support ‘click and drag’ interactions. Increased visual and auditory support to highlight coordinated changes across the whole screen, including relevant peripheral features, could better support and scaffold self-driven exploration and understanding.

Overall, the sonifications supported understanding for students with I/DD, and the students referenced these sounds while answering questions in the interviews. Future work will explore how text description and sonifications could work together to support diverse learner needs and scaffold sim exploration.

Acknowledgements

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Virtual Reality based Scalable Framework for Travel Planning and Training

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Abstract

The problem we are addressing is to provide greater travel independence through utilization of immersive technologies to navigate spaces utilizing VR and modern day mobile devices. We have focused on specific issues of travel training and fixed route services such as navigating through public transportation hubs. Immersive exploration of travel routes well in advance of attempting the travel reduces anxiety and builds confidence in wayfinding.

We explore the technology stack, working methodology, and outcomes.

Keywords

Assistive Technology, Travel Training, Travel Independence, Virtual Reality

Introduction

A key goal in the use of assistive technology is to help level the landscape so that individuals with disabilities can partake in the benefits (whether utilitarian or optional) that other members in society regularly get to enjoy and take for granted.

Enabling travel independence addresses a big part of this goal. There may be services such as paratransit that's available. However, over reliance on such services can result in ineffective benefits; travel independence is not achieved when it becomes necessary to book such services a day or two in advance, service schedules are not reliable, and the sense of agency (the ability to spontaneously adjust travel plans due to last minute change of circumstances) is all but nonexistent. Additionally, services like paratransit are costly and generally are hard to sustain a reliable quality of service as its usage grows.

Much of this problem can be addressed using effective fixed route (“FR”) services such as subways and transportation hubs. These services already have accessibility features like elevators, wheelchair ramps and the like. Uncertainties encountered during travel can hamper FR services; most specifically, wayfinding in a complex transportation hub.

The approach introduced in this paper is to outline the framework we developed that incorporates the use of Virtual Reality (“VR”) and other immersive technologies that allow individuals with disabilities to conveniently explore environments they will need to travel ahead of attempting the route; practice the route, help eliminate uncertainties and anxieties, obtain useful information and engender a sense of confidence, before taking one step out of their home.

We explain the technology stack, key decisions for our choices, the workflow methodology for recording immersive 360 images and embedded video clips, images, voice overs, ambient sounds, text content, and other curated media elements.

We explain our approach to the user interface.

We outline the framework for cost effective and scalable deployment based on ubiquitous, readily affordable hardware, and ability to distribute content.

Discussion

Virtual Reality (“VR”) and other immersive technologies allow individuals with disabilities to conveniently explore environments and venues. We view this technology as a resource that can be harnessed to facilitate travel training and encourage travel independence. We discuss the approach we developed, key decision criteria for our implementation, preliminary results and basic next steps.

In recent years 360-degree camera technology has become a cost-effective way to record immersive images and videos. This combined with ready availability of smartphones and inexpensive VR viewing devices opens the door to achieving virtual exploration as a potent tool in travel training and travel independence.

The recording technology of 360 cameras addresses one set of needs, but does not provide a built-in solution for wayfinding or navigating a large public space such as a transportation hub. The key feature that we developed is to create a virtual map that allows an individual in VR to interactively “teleport” along line of sight through multiple 360 images as they actually would be doing in a wheelchair.

We enable simple gaze activated navigation so that dexterity and movement of hands is not an issue. Where appropriate we can embed useful information in the form of visual hot spots, informative video clips, voice overs, and instructional information. We include the use of spatial ambient sounds. We also have a framework to automatically collect and analyze user activity and patterns such as identifying hotspots the user is viewing, and establish metrics on learning improvements. These overall features are outlined in Table 1.

Table 1. Basic Features & Capabilities

Feature/Capability	**Detail**	**Comments**
Map of Venue	Accurate floorplan or map of venue is needed	This must be available ahead of 360-image capture.
Image Capture: 360-degree capture	Can be either monoscopic or stereoscopic	• Collection of images should be sufficient to enable line of sight navigation • Location on map needs to be recorded. • Orientation of images need to be consistently aligned.
Embedded Interactive Content	• Pop-up images & video clips • Voice overs • Text-to-speech • Captions	Content can be bundled into a self-contained application or can be delivered at runtime over the Internet.
Ambient Sounds	Separate audio recording of ambient sound for each 360-image	Because individual recordings are paired with the corresponding 360-image, you get spatial sound “for free”; the collection of sounds and their arrangement in the virtual environment enable this capability.
VR Hardware	Inexpensive & readily available hardware – basically: Smartphones with Gear VR or Daydream (and additionally in Tablets such as iPads)	Additionally, for travel training settings, a separate computer can be used for providing a special Coach Mode and/or collecting/analyzing user data.
Data Analytics	Smartphones can record session data	Session data can include event driven information such as actions like which hotspot was gazed at, at what time, and where the user was in the virtual scene. This collected data is available for analysis in either spreadsheets or databases.
Coach Mode	Wireless connection between smartphone & PC	• Connection is in real time so that travel trainer can see what the user is looking at as it happens. • Connection is bi-directional so that travel trainer can directly provide visual cues to the user during the session.

It is important to note subtleties in our implementation. Virtual objects like teleport icons appear with sizes corresponding to their virtual distance from the user (see Fig.1), thus, providing better information. Of course, the teleport icon size automatically changes size as the user moves through the virtual scene.

Fig. 1. Sample VR based navigation entirely through gaze control.

Workflow

Enabling this wayfinding capability with embedded useful supplementary content involves a four-step process of planning for a given site, mapping the facility, integrating/curating the content, and deploying/publishing so the venue is explorable to a broad base audience (see Fig. 2).

Planning a site after selecting it from a list of candidate locations typically involves a physical visit, identifying specific routes, building a floor plan, noting items of interest, scheduling a date and time for the recording, and of course, securing necessary permissions/permits. It is during this planning stage/site visit that we have the opportunity to take note of things like peculiar features in the fixed route service, such as an excessive gap between the train and the station platform.

Fig. 2. Workflow for each site/venue.

Capture is handled with 360 cameras, noting physical location of all photos. It is a requirement that every 360 image recorded must have coverage by line of sight so that wayfinding paths can always match actual physical path traversal with a wheelchair.

The curation process is most labor intensive. The 360 images need to be placed into a virtual map that corresponds to the real physical spaces and orientation of 360 images needs to be preserved so that “teleporting” through the various places feels natural. We create and position occlusion walls are so that teleporting only happens through direct line of sight of what is visible within each 360 image. Where appropriate, we embed visual hot spots that have interactive features, that can for instance, play an instructional video. After this there is lots of testing for verification of accuracy, completeness, and usability.

Application Structure

The application is designed to be simple and intuitive. The first step is to select a suitable train or subway station. Fig. 3 shows one of the main menus as we program it in the Unity environment. All the user needs to do is gaze at any one of these stations for a brief period to be teleported to that virtual station.

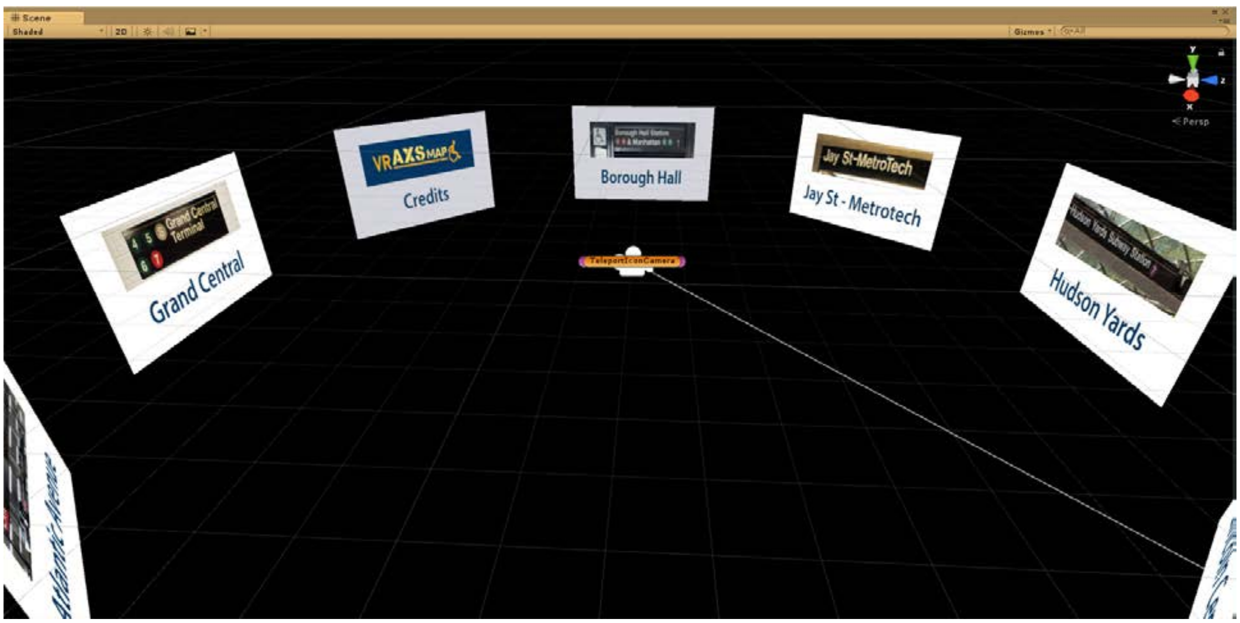


Fig. 3. 3D Menu for selecting a Station

From there the user can navigate through the virtual station (as depicted in Fig. 1) by gazing at the various icons like those shown in Fig. 4.

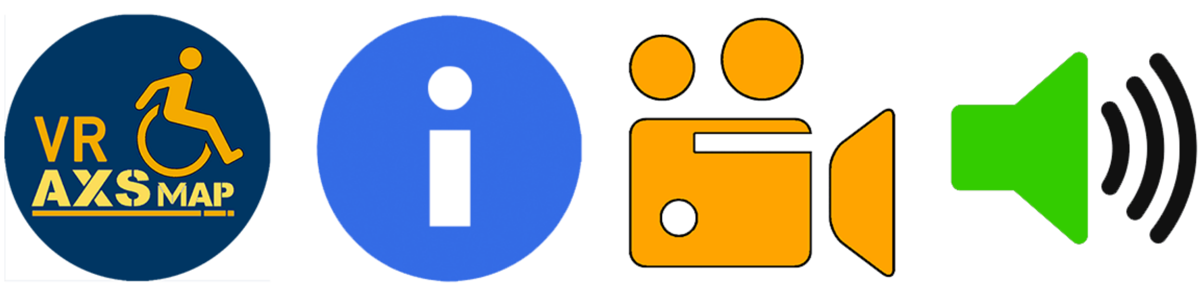
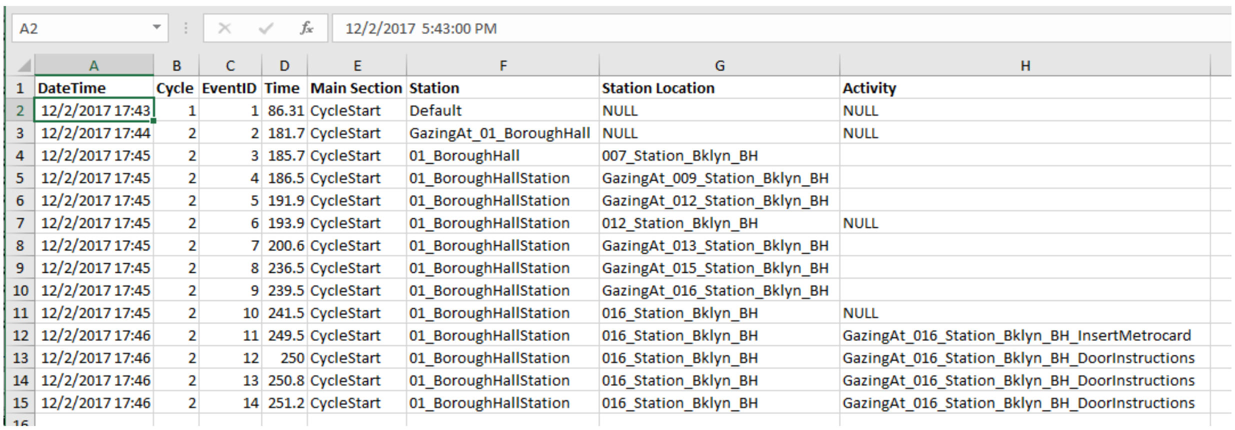


Fig. 4. Representative Interaction ICONS

Data Analytics

One of the exciting developments in our implementation is the ability to capture data on user activities to assist in facilitating user improvement using metrics. Fig. 5 shows a screenshot of data exported to Excel. We currently can only export the data in CSV format, but are exploring other options.



A2 | 12/2/2017 5:43:00 PM

	A	B	C	D	E	F	G	H
1	DateTime	Cycle	EventID	Time	Main Section	Station	Station Location	Activity
2	12/2/2017 17:43	1	1	86.31	CycleStart	Default	NULL	NULL
3	12/2/2017 17:44	2	2	181.7	CycleStart	GazingAt_01_BoroughHall	NULL	NULL
4	12/2/2017 17:45	2	3	185.7	CycleStart	01_BoroughHall	007_Station_Bklyn_BH	
5	12/2/2017 17:45	2	4	186.5	CycleStart	01_BoroughHallStation	GazingAt_009_Station_Bklyn_BH	
6	12/2/2017 17:45	2	5	191.9	CycleStart	01_BoroughHallStation	GazingAt_012_Station_Bklyn_BH	
7	12/2/2017 17:45	2	6	193.9	CycleStart	01_BoroughHallStation	012_Station_Bklyn_BH	NULL
8	12/2/2017 17:45	2	7	200.6	CycleStart	01_BoroughHallStation	GazingAt_013_Station_Bklyn_BH	
9	12/2/2017 17:45	2	8	236.5	CycleStart	01_BoroughHallStation	GazingAt_015_Station_Bklyn_BH	
10	12/2/2017 17:45	2	9	239.5	CycleStart	01_BoroughHallStation	GazingAt_016_Station_Bklyn_BH	
11	12/2/2017 17:45	2	10	241.5	CycleStart	01_BoroughHallStation	016_Station_Bklyn_BH	NULL
12	12/2/2017 17:46	2	11	249.5	CycleStart	01_BoroughHallStation	016_Station_Bklyn_BH	GazingAt_016_Station_Bklyn_BH_InsertMetrocard
13	12/2/2017 17:46	2	12	250	CycleStart	01_BoroughHallStation	016_Station_Bklyn_BH	GazingAt_016_Station_Bklyn_BH_DoorInstructions
14	12/2/2017 17:46	2	13	250.8	CycleStart	01_BoroughHallStation	016_Station_Bklyn_BH	GazingAt_016_Station_Bklyn_BH_DoorInstructions
15	12/2/2017 17:46	2	14	251.2	CycleStart	01_BoroughHallStation	016_Station_Bklyn_BH	GazingAt_016_Station_Bklyn_BH_DoorInstructions

Fig. 5. Sample Data Capture in a Session.

Deployment

All of this is built with Unity and XpressVR (a Unity based toolset developed by one of the authors), so it is relatively straight forward to deploy to a variety of standard VR, smartphone, desktop and tablet devices, which are outlined in Table 2.

Table 2. Deployment Modalities

Feature/Capability	Detail	Comments
Smartphone	• Gear VR (implemented) • Google Daydream (in development)	• Android based. • Navigation and interactivity accomplished through gaze control • Optional hand controller can be used • Suitable for data analytics (data can be captured on device and transferred after session).
Immersive Non-VR Device	iPad or smartphone	• Android or IOS. • Requires holding device in hand to face in a desired direction. • Navigation and interactivity accomplish orienting device to face “target” (effective equivalent of gaze control) and also through touch input.
PC System	Travel training & Data Analytics usage	• Tested on Windows but should work with MacOS. • Wireless connection between PC & smartphone. • In Coach Mode smartphone can be monitored in real time. • Event and monitoring data can be transferred from smartphone and analyzed on PC using standard spreadsheet of database software.

Our expectation is that the Apps will be placed onto online Stores with media content served from the cloud.

There are several important features we are bringing into this delivery platform:

- We can accommodate multiple types of disabilities from a single code base. Specifically, in addition to dealing with the wayfinding features, we can vary imagery better suited to low vision (through selective magnification). We are also devising a framework to throttle up or down to match different cognitive abilities.

- Individualized customization is a standard feature so that each individual can have the App tuned to his/her specific need.
- Cloud services facilitate passive updating of application content.

Conclusions

Travel independence is a specific kind of challenge. Technology brings in all sorts of solutions for adaptive devices. It can be as simple as a curb cut, or as elaborate as a custom-built input device. ADA and other compliance based directives can bring institutions, organizations, and companies to incorporate adaptive accommodations, but when it comes to helping individuals to achieve travel independence there remain some significant gaps. Fortunately, technologies like the kind we developed and are reporting on here rebalances this inequity. We can now harness VR and related immersive technologies to greatly enhance the utility (and freedoms) available through fixed route services.

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Survey of User Needs for ICT – Community Living by People with Disabilities

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Abstract

This report summarizes data from the Survey of User Needs for Information and Communication Technology (SUN-ICT) conducted by the Rehabilitation Engineering Research Center for Community Living, Health and Function (LiveWell RERC). This survey is part of the authors' long-standing research program to track the use, usability and user needs of people with disabilities for mainstream consumer information and communication technologies. This survey is also the cornerstone of a larger research undertaking based on the Concerns Report Method (CRM), which assesses the relative importance of functional activities by people across disabilities (Fawcett et al. 1987). The CRM has been used extensively with different consumer groups to identify strengths and specific needs in various community contexts. We present two related lines of analysis: 1) an inventory of current technology used by people with disabilities; and 2) an exploration of the types of daily activities that people with disabilities would like to engage in, but experience some difficulty. This analysis provides: 1) a snapshot of where people with disabilities are in terms of ICT adoption, and 2) the challenges to independence and community participation they continue to face which ICT may be able to ameliorate.

Keywords

Information and communication technology, smartphones, tablets, wearable technology, disability, survey research.

Introduction

Assessment and identification of the technology needs of consumers with disabilities trails behind innovation in information and communication technology (ICT). The accelerating development and proliferation of ICT devices in a variety of form factors (mobile phone handsets, tablets, wearable devices and home automation and control), the emerging Internet of Things (IoT), and the ubiquity of the “cloud,” means that people with disabilities might be at even greater risk of having their needs overlooked than ever before.

The challenge for rehabilitation researchers is to identify and articulate to technology developers in an actionable way the priority needs and access issues of disabled ICT users. ICT industry professionals and researchers alike acknowledge the importance of engaging customers with disabilities, but find this difficult within the constraints of time, budget, and intense competition. This problem is exacerbated by the rapidly accelerating pace of technology development, which poses continuing challenges to ensure that hard-won accessibility gains are not lost in new generations of technology.

The current era’s emerging technology ecosystems of wearable technology and home automation and control (wearables and smart homes) is like preceding eras when cellphones and later smartphones were first proliferating in the marketplace. Then as now, mainstream consumers were the original target users of the new platforms and associated peripheral gear, apps, etc. These platforms and technologies hold enormous promise to facilitate independence and community participation by people with disabilities. But, uncertainty remains about how readily individuals will adapt to these technologies due to concerns regarding privacy, ease of use, reliability, accuracy and impact on people’s lives.

People with disabilities and the general population report similar rates of adoption of mature platforms, including cellphones, smartphones and tablets (Morris 2016, 2014). But, historically adoption rates by people with disabilities has lagged those of the general population. Furthermore, there has been a continuing challenge of ensuring access and leveraging the underlying capabilities of consumer ICT to serve the needs and interests of people with disabilities. Hard won gains in accessibility can be and are often undone by the release of new versions and new generations of consumer technology (Wentz and Lazar 2016); (Schroeder and Burton 2010).

At the same time, the proliferation of these technologies almost requires that people have access to them or risk being left out of the conversation, literally and figuratively. Disconnecting may not be an option (Rainie and Anderson 2017). Access and use of consumer information and communications technology by all members of society is both imperative and uncertain.

This report summarizes data from the Survey of User Needs for Information and Communication Technology (SUN-ICT) conducted by the Rehabilitation Engineering Research Center for Community Living, Health and Function (LiveWell RERC). This survey is part of the authors' long-standing research program to track the use, usability and user needs of people with disabilities for mainstream information and communication technologies. This survey is also the cornerstone of a larger research undertaking based on the Concerns Report Method (CRM), which seeks to assess the relative importance of functional activities by people across disabilities (Fawcett et al. 1987). The CRM has been used extensively with different consumer groups to identify strengths and specific needs in various community contexts (Schriner and Fawcett 1988; Conducting Concerns Surveys).

We present two related lines of analysis: 1) an inventory of current technology use by people with disabilities; and 2) an exploration of the types of daily activities that people with disabilities would like to engage in, but experience some difficulty. This analysis provides: 1) a snapshot of where people with disabilities are in terms of ICT adoption, and 2) the challenges to independence and community participation they continue to face which ICT may be able to ameliorate.

Discussion

The survey questionnaire comprises 5 sections listed below. Part 3 is an inventory of ICT device ownership, providing the data to understand where people with disabilities are currently in terms of technology use. Part 5 comprises paired questions on the importance and satisfaction with the ability to engage in 75 distinct activities grouped in 8 domains of daily living.

Part 1 – About you (demographics)

Part 2 – About your abilities

Part 3 – About your use of ICT devices

Part 4 – Problems or issues using ICT

Part 5 – Activities that might benefit from use of ICT

Data for the survey reported here were collected from November 2016 through August 2017 using convenience sampling. The total number of respondents who reported a disability is 265. The mean age of respondents with a disability was 56.6 with a standard deviation of 15.1 years. Females constituted 60.8 percent of respondents and non-whites were 13.8 percent of respondents (Table 1). Two-thirds of the sample had a college degree and slightly more than half (58.5%) reported annual household incomes below $50,000. The median household income in the United States in 2016 was $57,617 (Guzman 2017).

Table 1. Demographics: All respondents with disability

Demographic variable	**Percent**
Female	60.8
Non-White/Caucasian	13.8
Bachelor degree or higher	67.8
Annual household income below $50,000	58.5

Respondents were asked to identify whether they had difficulties in any of 11 general functional categories (Table 2). Respondents were asked to indicate all that apply, and as such reported having on average 2 functional limitations or difficulties, the most common being difficulty hearing and difficulty walking, standing or climbing stairs. The rest of the survey questionnaire comprises several sections, including an inventory of respondent technology profiles – ownership and use of cellphones, tables, wearable technology, home automation, etc.

Table 2. Functional difficulties of respondents

(percentage of respondents with each type of disability)

Disability Type	**Percent**
Difficulty concentrating, remembering, or making decisions	14.2
Frequent worrying, nervousness, or anxiety	18.9
Difficulty seeing - Low vision/Blind	25.6
Difficulty hearing - Hard of hearing/ Deaf	47.6
Difficulty speaking so people can understand you	10.2
Difficulty using your arms	17.3
Difficulty using your hands and fingers	26.8
Difficulty walking, standing or climbing stairs	45.7
Difficulty with fatigue/limited stamina	28.0

What ICT devices people with disabilities currently have

Regarding ownership of ICT devices and other technology (Table 3), the most commonly owned devices were smartphones (81.5% of respondents), laptop computers (68.9%), tablets (64.2%) and desktop computers (57.5%). Rates of ownership of all other devices were far lower, ranging from 4.3% for sleep monitors and home activity sensors, to 18.1% for home security systems. Notably, respondents reported owning fitness trackers - the most common of the newer generation of consumer ICT devices – at a relatively low rate of 13.4%. Smartwatches (many of which include fitness tracking functionality) were owned by 11.4% of respondents. Fewer than 10% of respondents reported owning home automation devices.

Table 3. Ownership of information and communication technology devices (percentage of all respondents with a disability)

Information and Communication Technology Devices	**Percent**
Smartphone	81.5
Laptop computer	68.9
Tablet computer (iPad, Kindle Fire, Galaxy Tab, Microsoft Surface)	64.2
Desktop computer	57.5
Home security system	18.1
Fitness tracker or sensor (Fitbit, Garmin)	13.4
Smartwatch (Apple Watch, LG Watch)	11.4
Basic mobile phone	9.4
Specialized assistive technology	9.1
Home automation or control system	8.7
Other wearable technology (rings, pendants, glasses)	5.1
Home activity sensor system	4.3
Sleep monitor	4.3

Ownership of ICT devices is not uniform in the sample of people with disabilities. Demographic characteristics, including age and income are variably associated with device ownership. Generally, the effects of age and income are less for established technology devices like smartphones and tablets (Tables 4 and 6), and greater for emerging platforms such as fitness trackers, smartwatches and home automation (Tables 5 and 7). Table 4 shows relatively consistent ownership rates of smartphones across the first 5 age groups spanning 18 to 70 years, with rates ranging from 79% to 91%. Only for the over-70 age group does ownership drop to 61%. Tablet ownership rates are more consistent across the 6 age groups.

Table 4. Ownership of information and communication technology devices (percentage of all respondents with a disability)

Age	Basic cellphone	Smartphone	Tablet
18-30 (n=12)	17%	83%	67%
31-40 (n=34)	6%	91%	74%
41-50 (n=34)	18%	79%	74%
51-60 (n=65)	12%	85%	52%
61-70 (n=71)	4%	85%	69%
Over 70 years old (n=36)	8%	61%	61%

Age-ownership patterns are also evident for other emerging platforms/devices.. For fitness tracker, which are generally lower cost and offer simpler functionality than smartwatches, ownership rates rise steadily from the youngest age group (18-30) to the third youngest group (41-50) and then decline for the oldest 3 age groups. For smartwatches and home automation, a more distinct negative linear relationship between age and ownership rate is evident. These results are consistent with expectations of technology adoption by which younger people tend to be earlier adopters of new technology.

Table 5. Ownership of information and communication technology devices (percentage of all respondents with a disability)

Age	Fitness tracker	Smartwatch	Home automation
18-30 (n=12)	8%	25%	33%
31-40 (n=34)	15%	18%	18%
41-50 (n=34)	21%	15%	15%
51-60 (n=65)	17%	11%	5%
61-70 (n=71)	11%	7%	3%
Over 70 years old (n=36)	6%	8%	6%

Annual household income also affects ownership of both established and emerging technologies, although in variable ways. For basic cellphones (“feature phones”, in industry parlance) there is a strong inverse relationship between income and ownership rates – higher income individuals with disabilities own these less expensive mobile phones at lower rates than lower income individuals. However, for smartphones, tablets and fitness trackers the relationship is reversed: as household income rises, ownership rates also rise. A slightly different pattern is evident for smartwatches and home automation: ownership rates generally rise with household income, except that those in the lowest income groups have slightly higher ownership rates than those in the middle-income groups.

Table 6. Ownership of information and communication technology devices

(percentage of all respondents with a disability)

Annual household income	**Basic cellphone**	**Smartphone**	**Tablet**
Less than $10,000 (n=22)	18%	68%	64%
$10,000-$14,999 (n=19)	21%	74%	53%
$15,000-$24,999 (n=37)	14%	76%	54%
$25,000-$34,999 (n=25)	12%	80%	56%
$35,000-$49,999 (n=34)	6%	74%	65%
$50,000-$74,999 (n=37)	8%	84%	65%
$75,000-$99,999 (n=21)	5%	86%	81%
$100,000 or more (n=39)	3%	97%	85%

Table 7. Ownership of information and communication technology devices

(percentage of all respondents with a disability)

Annual household income	**Fitness tracker**	**Smartwatch**	**Home automation**
Less than $10,000 (n=22)	5%	14%	9%
$10,000-$14,999 (n=19)	5%	11%	5%
$15,000-$24,999 (n=37)	3%	5%	5%
$25,000-$34,999 (n=25)	8%	4%	0%
$35,000-$49,999 (n=34)	15%	9%	9%
$50,000-$74,999 (n=37)	19%	14%	11%
$75,000-$99,999 (n=21)	33%	14%	10%
$100,000 or more (n=39)	23%	26%	21%

What people with disabilities want to do

Review of response data on ICT device ownership helps to document where people with disabilities currently are in terms of technology access and use. The second part of our analysis provides an initial description of where people with disabilities wish to be in terms of independent living and community participation.

For this part of the research we used the Concerns Report Method (CRM) to ask respondents to rate issues of concern in their community. Issues were selected from a larger pool of items by a panel of consumers and advocates with specific knowledge of their community. Using a five-point Likert-type rating scale, survey respondents rated each issue on two dimensions: Importance and Satisfaction. For example, a survey item may pertain to the availability of affordable and accessible housing. The respondent would rate how important it is to him or her that there is accessible and affordable housing available in the community and how satisfied he or she is with the availability of accessible/affordable housing in the community. We asked survey respondents to rate the importance to them of specific activities, and then asked them to rate their satisfaction with their ability to perform those activities, both on a 1-5 scale. The aim of this approach is: 1) to identify the things (in this case, common activities) that are most important, and 2) to identify the important activities with the lowest satisfaction. Results will help structure further inquiry with the objective of identifying and building use-cases for technology designers and developers to address the unmet needs of people with disabilities.

The 1-5 rating scales range from not important/not satisfied to very important/very satisfied. In analyzing survey responses, issues rated high in both importance and satisfaction are considered strengths. Issues rated high in importance but low in satisfaction are considered concerns or needs. The list of functional activities to be rated for importance and satisfaction in the SUN-ICT was developed by the research team in collaboration with our stakeholder group of people with disabilities. This Research Partners Panel includes people with vision, mobility, dexterity, cognitive and speech limitations.

The section in the survey questionnaire that uses the CRM methodology includes 8 sets of questions relating to domains of activity related to independent living and community participation. These domains are listed below.

1. Getting and using information
2. Communicating and networking
3. Leisure and social activities
4. Thinking and remembering
5. Community mobility and travel
6. Managing and controlling your environment
7. Managing money and finances
8. Maintaining health, wellness, and safety

Respondents provided importance-satisfaction ratings for 75 specific activities across the eight domains. Of the 75 specific activities listed in the questionnaire, 19 (or 25%) were given an average rating of at least 3.80 on the 5.00 scale, which used as the threshold for activities of high importance. Differences between importance and satisfaction for 19 activities were calculated. Activities with a difference or 0.40 or greater were identified as "concerns", while the others were treated as "strengths", or at least less concerning. This analysis identified 10 concerns (Table 8) and 9 strengths (Table 9).

The list of "concerns" in Table 8 offers important insights into the needs of people with disabilities. The activities with the greatest difference between importance and satisfaction were in the Managing money and finances domain – shopping, comparing prices and goods, and using credit/debit cards. Other domains of high concern were community mobility and travel (finding safe routes and recognizing traffic conditions) and thinking and remembering (remembering people, managing time, and recording notes and reminders). Respondents also indicated a need to be better able to communicate using voice calling and email.

Table 8. Activities with HIGH IMPORTANCE and LOWER SATISFACTION, all respondents with a disability

Domain	Activity	Importance	Satisfaction	Difference
Managing money/finances	Shopping for goods or services (comparing, purchasing)	4.33	3.78	0.55
Managing money/finances	Using credit or debit cards	4.50	3.95	0.54
Community mobility/travel	Recognizing traffic conditions	4.06	3.56	0.50
Getting/using information	Getting information on the internet (news, sports)	4.41	3.92	0.49
Communicating and networking	Voice Calling	3.96	3.47	0.49
Thinking and remembering	Remembering names of people, places, things	3.97	3.50	0.47
Communicating and networking	Sending and receiving emails	4.74	4.28	0.46
Community mobility/travel	Planning a safe and easy route	4.14	3.68	0.46
Thinking and remembering	Recording notes, reminders, and to-do lists	4.07	3.61	0.46
Thinking and remembering	Managing time (calendars, alarms, alerts)	4.30	3.86	0.44

Activities of greatest strength (those that have high importance but relatively high satisfaction) include social networking, getting weather updates, managing medications, budgeting/tracking expenses, and getting public safety alerts (Table 9).

Table 9. Activities with HIGH IMPORTANCE and HIGH SATISFACTION, all respondents with a disability

Domain	Activity	Importance	Satisfaction	Difference
Communicating and networking	Text messaging and instant messaging	4.41	4.05	0.37
Getting/using information	Getting directions and instructions (YouTube videos, recipes, tutorials)	4.13	3.76	0.37
Community mobility/travel	Knowing your community layout (location of stores, houses)	4.11	3.78	0.33
Managing money/finances	Using online banking (transfers, deposits, checking balance)	4.38	4.08	0.30
Getting/using information	Getting public safety alerts (emergency alerts, amber alerts)	3.97	3.72	0.26
Managing money/finances	Budgeting, tracking expenses, managing receipts	3.87	3.61	0.26
Health/wellness/ safety	Managing medications	3.98	3.74	0.25
Getting/using information	Getting weather updates	4.13	3.97	0.16
Leisure and social activities	Social networking (Facebook, LinkedIn, Snapchat, Instagram)	3.80	3.67	0.12

Conclusions

These survey research results provide key insights into the current ICT device ownership profile of people with disabilities and the lifestyle activities that are most salient to them. They show that the pattern of ownership of established ICT devices like smart phones and tablets and ownership of emerging ICT devices is generally similar for both people with disabilities and the general population. Rates of smartphone and tablet ownership are high, while fitness trackers, smartwatches and home automation systems are low.

Smartphone and tablet ownership rates by people with disabilities matches or even exceeds those of the general population. The Pew Research Center tracking survey measured smartphone and tablet ownership by the general population in 2016 at 77% and 51%, respectively (2017). This compares to 81.5% and 64.2%, respectively, for the SUN-ICT survey results reported here. For fitness trackers, ownership rates are much lower for people with disabilities than the general population: 13.4% versus 12% for the general population according to Gartner (2016). Gartner's data for smartwatch ownership shows a similar rate (12 percent) as the SUN-ICT data for people with disabilities (11.4%).

More research and analysis is needed to track technology adoption trends by people with disabilities. Generally, it is expected that technology adoption rates of people with disabilities taken all together (i.e., all disability types) tend to lag the general population. This is likely the result of accessibility issues needing time to be resolved and the underdeveloped capabilities (and consequently, the use cases) insufficiently developed in early generations of new technology devices.

The survey results also point to a list of key activities in which people with disabilities want to participate, but for which they have substantially less satisfaction in their ability to engage. At the top of the list are activities related to managing money and finances, specifically 1) shopping for goods/services and 2) using credit/debit cards. Activities related to community mobility and travel (recognizing traffic conditions and planning a safe and easy route) also rank high on the list of "concerns". Taking these results together can help researchers, designers and engineers prioritize the types of solutions they undertake. Activities related to thinking and remembering was also prominent on the list of concerns.

The analysis presented here represents an initial review of the data. Further analysis by disability type might provide sharper relief to patterns of device ownership and priority needs of people with specific functional limitations. For instance, people with cognitive difficulties might assign even higher importance and lower satisfaction scores to activities related to thinking and remembering than the rest of the sample. Limitations of this study include the need to analyze the data according to disability type and the relatively small sample size for doing so. Segmenting the sample by disability type will produce smaller subsample sizes that might further limit analytical reliability.

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A Pilot Study of Computer Auto-Personalization at American Job Centers

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Abstract

The Global Public Inclusive Infrastructure auto-personalization project aims to create a system that allows people to easily discover and set up assistive technology and other computer accommodations and features to meet their individual needs and preferences. As a first trial, a prototype of the auto-personalization system was tested with 11 participants at an American Job Center (AJC). Participants were all customers at the AJC. They used near-field communication cards to set up the system in different ways and tried job search-related tasks of their own choosing. Participants were all positive about their use of the auto-personalization system—all reported they would like to use the system again at the AJC and most listed other places they would like to be able to use it. Following this study, two computers with the auto-personalization system installed were placed at the AJC for continued customer use.

Keywords

Automatic personalization, assistive technology, access feature, computer, settings

Introduction

Information and communications technology (ICT) is becoming more and more integral to daily life: at home, at school, at work, and in the community. However, not everyone is able to use these technologies and access to ICT has not kept up with the proliferation of platforms. It used to be possible to avoid using technology in daily life, but technology use is quickly becoming essential to participation in most activities (Vanderheiden et al. 108).

As a result, many people are falling behind or at risk of being excluded because they cannot access the technology they encounter. There are about 56.7 million people with disabilities in the U.S., and the number of people with disabilities is increasing as the population is aging (Brault 5). There are also many people who do not consider themselves as having disabilities, but who have difficulty using technology due to challenges related to literacy, digital literacy, or aging.

There are some tools and strategies available today to help people facing barriers using ICT, but solutions are not currently available for all. Even for those for whom solutions do exist, many do not know that a solution exists or how to search for them (Ding et al. 161). Also, access solutions are often available only on some devices but not others (e.g., PC but not Android or macOS), and they are often difficult to configure and set up (Vanderheiden et al. 507-508).

The Global Public Inclusive Infrastructure (GPII) has been established to work on these and related issues to ensure that people with disabilities can all access the ICT that is becoming ubiquitous and they are increasingly encountering in their daily lives.

Auto-Personalization

Auto-personalization is one of the three pillars of the GPII. With GPII auto-personalization as envisioned, a person could have an interface they can use and understand on any computer (and eventually any technology) they encounter. The person would present a personal key (e.g., a USB device, NFC card, fingerprint, etc.) that is used to fetch and apply the user's setting preferences to the computer, launching and configuring any assistive technologies and access features that the person needs. In this manner people can have computers instantly set up for them without even having to know how to do it manually.

American Job Centers

American Job Centers (AJCs) are the first, real-world test of the GPII auto-personalization system. American Job Centers are a federally funded network of more than 2500 career centers located across the country. Along with providing free access to computers and the Internet, job centers offer their customers an array of no-cost services that can include assistance in exploring careers, finding a job, building a resume, researching training options, and learning about federal, state and local support services available.

As reported by AJC staff and observed on site visits, AJC customers include individuals with limited or no previous experience in using computers, as well as those with extensive experience. Staff reported that some customers are very tech savvy, but that many others are uncomfortable or even fearful of technology. Despite efforts to improve outreach and services for people with disabilities, AJC staff also reported continued challenges in enrolling people with disabilities and encouraging individuals to self-identify as having a disability, in order to receive more information and services.

The U.S. 2014 Workforce Innovation and Opportunity Act (WIOA) has increased emphasis for American Job Centers to be both physically and programmatically accessible to people with disabilities. However, many centers are currently not well equipped to provide programmatic access. In a report funded by the U.S. Department of Labor, only 44% of AJCs were determined to be fully accessible in the programmatic domain compared to 92% in the physical domain (Chamberlain et al. vii). Because the GPII auto-personalization system may be a potential solution to help improve the programmatic accessibility of AJC computing resources, we wanted to test its use by AJC customers.

Methods

The purpose of the study was to get feedback from people using initial implementations of the GPII auto-personalization system to do their own computing tasks. The researchers wanted to know how people felt about the system and to see if there were additional features and uses that people might identify. In the study, researchers used both interviews and direct observation.

Participants were recruited with posters and information sheets in a southern California job center and by on site recruitment to fill open study timeslots. Potential participants answered a short screening questionnaire. No participants were screened out of the study. In total, 11 job center customers (4 female, 7 male) took part in the observations and interviews. Three additional individuals were scheduled but did not show up for their respective sessions. Sessions were approximately 1 hour long. Participants were given $25 for participating in the study.

When participants arrived for their study session, they went through a consent process. Participants were informed that the auto-personalization project was part of a federal grant that involved developing a new system to help make computers easier to use—for people with disabilities and also for mainstream users. Participants were told that they could carry out any computer tasks of their choice that were typically conducted at job centers, but they would be using the auto-personalization tools and instructions while doing so. They were also informed that they would be asked to provide feedback during and at the end of the session.

Participants sat at an all-in-one computer (Sony VAIO Tap 21) with a built-in near-field communication (NFC) card reader. The computer ran Windows 10 with a prototype version of the GPII auto-personalization software on it. The software would make changes to system settings in response to NFC cards. Next to the computer was a sign with instructions on using the NFC cards to enact the changes. Figure 1 shows a picture of the experimental setup.

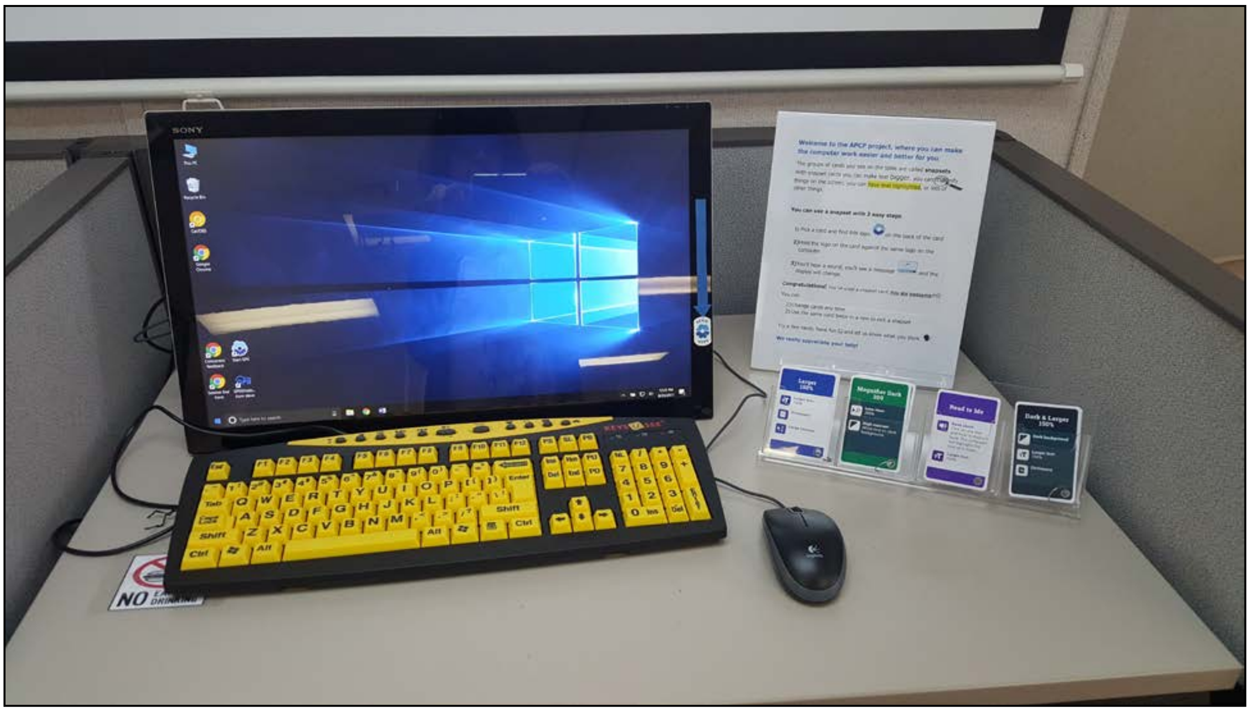

Fig. 1. The experimental setup of an all-in-one computer with NFC cards and instructions on using the auto-personalization system nearby.

Also, next to the computer was a rack of 11 NFC cards in four logical groupings. In each group, cards had coordinating color schemes and were joined together in the lower right corner with a ring through a hole in each card. Participants could thus fan out the cards in a group to look them over. Each NFC card was labeled with a name and the major features that the card enabled or changed. The NFC cards and access features used in the study are listed in Table 1.

Table 1. NFC cards in the study and the features that each enabled.

Name	Logical Group Color	Screen Scaling (DPI) settings	Windows high-contrast theme settings	Windows Magnifier settings	Enabled Chrome extensions
Larger 125%	Blue	125%	None	None	Google Dictionary
Larger 150%	Blue	150%	None	None	Google Dictionary
Larger 175%	Blue	175%	None	None	Google Dictionary
Dark & Larger 125%	Black	125%	White on black	None	Google Dictionary & High Contrast
Dark & Larger 150%	Black	150%	White on black	None	Google Dictionary & High Contrast
Dark & Larger 175%	Black	175%	White on black	None	Google Dictionary & High Contrast
Read to Me	Purple	150%	None	None	click2speech
Magnifier 200	Green	None (100%)	None	Lens view, 200%	Google Dictionary
Magnifier 400	Green	None (100%)	None	Lens view, 400%	Google Dictionary
Magnifier Dark 200	Green	None (100%)	White on black	Lens view, 200%	Google Dictionary & High Contrast
Larger + Magnifier 200	Green	175%	None	Lens view, 200%	Google Dictionary

During the sessions, all of the applicable Chrome web browser extensions were introduced to the user the first time that an NFC card with the feature was used:

- Google Dictionary (by Google), which provides definitions and pronunciations for words.
- High Contrast (by Google Accessibility), which offers contrast settings for web pages.
- click2speech (by Zsolt Nagy), which allows users to click web pages to have parts highlighted and read to them through text-to-speech.

Additionally, researchers introduced the Mercury Reader Chrome browser extension (by https://www.postlight.com) to participants during each session. Mercury Reader provides a customizable article view by removing ads and other distractions from web page articles.

Once participants were ready to begin their session, they were encouraged to undertake job search-related computer tasks of their choosing. Verbal instruction was kept to a minimum, with the researcher referring participants to the instructions near the computer.

After a participant had tried a feature and explored the computer with it, the researcher asked for feedback on how participants felt about the settings. User ratings were entered on a tablet or desktop computer, outside of the researcher's view.

At the end of the study session, participants were asked a few questions about the usefulness of the system and what additional features they might like to see.

Results

During the screening, four participants self-identified as having disabilities. Two of them mentioned difficulty seeing—the other two mentioned disabilities that would not ordinarily affect use of a computer. Three additional participants, who did not identify as having a disability, volunteered that they would need to bring glasses or potentially use a magnifier during their sessions because they might otherwise have difficulty using a computer. During the screening, participants answered a few questions about some difficulties that people might have with computers. The results are in Table 2.

Table 2. Participant (n = 11) responses to the three survey items about computer use.

Difficulties with computers	Never	Sometimes	Often	Always
I find it hard to see print on the screen	2	7	2	0
I find it hard to read English	11	0	0	0
I find web sites are too busy/complex	2	5	1	3

During the study sessions, participants were not required to try every NFC card. However, to encourage participants to try more types of cards, the researcher cued participants to, "perhaps try another set of cards," if participants had only tried one group initially. On average during a session, participants tried 5.8 of the NFC cards (S.D. = 1.33) out of the 11 that were available. Ten of the 11 participants tried at least one card from all four groups. All participants also tried the Google Dictionary and Mercury Reader browser extensions.

After trying out settings from an NFC card or other feature, participants answered a short two-question survey. The first question was, "How much do you like using the last display setting?" on a 5-point scale with anchors "I don't like it" (1) and "I would use it often" (5). Most of the time, participants answered the short survey just once for each feature or group of NFC cards. However, participants would sometimes try an NFC card or feature and dismiss it immediately without taking the survey. Figure 2 shows the responses from the job center customer participants to the question. Every participant was able to find at least one NFC card with settings that they gave a maximum rating of 5. Participants tended to give favorable ratings with an average rating per NFC card or feature of 4.2 (S.D. = 2.17).

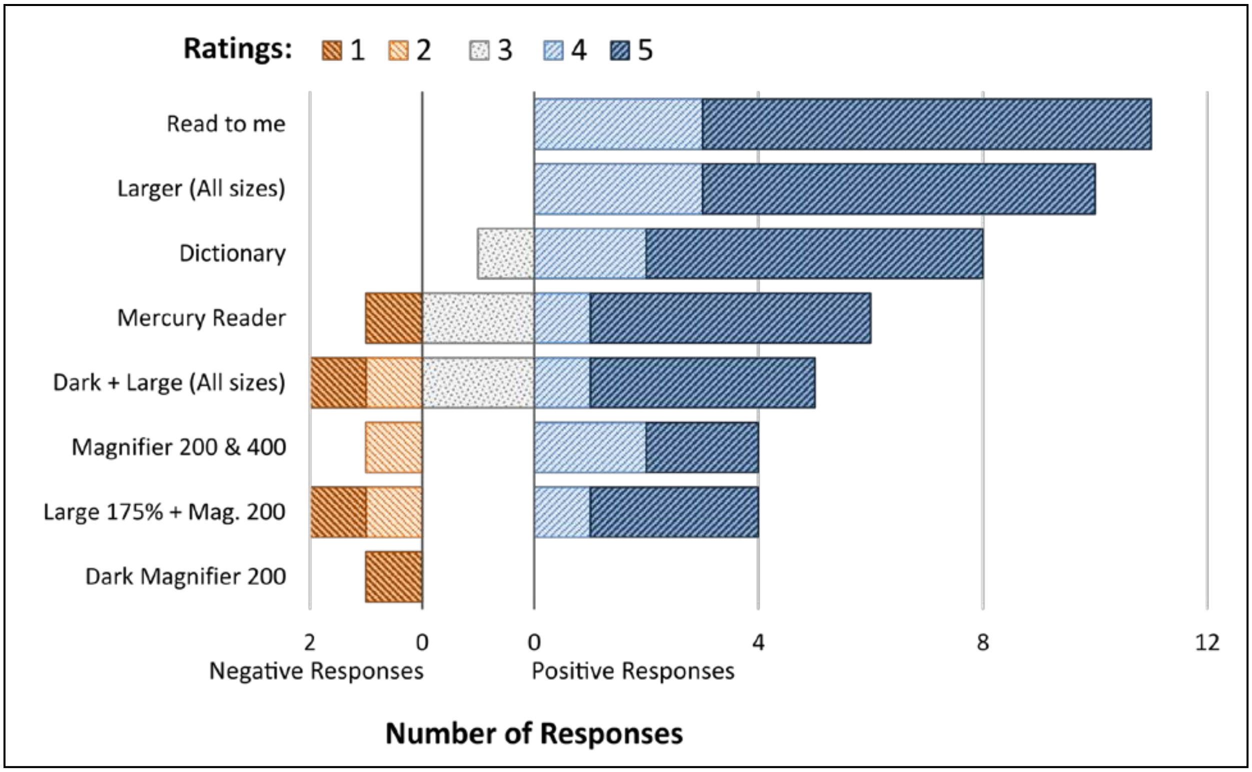

Fig. 2. A diverging stacked bar chart showing the number of responses (n = 11) to the question: "How much do you like using the last display setting?" for the tested NFC cards and features. Participants neither tried every card nor answered the survey for every card that was tried.

The second question of the short survey about particular NFC cards or features was, "Does your last setting make it easier or harder to use this computer?" There were three potential responses: "It makes it harder to use," "It doesn't make a difference," and "It makes it easier to use." The two questions of the survey were strongly correlated (Pearson R = 0.758).

At the end of each session, participants were asked several questions about how useful the system was to them. All participants said that they would want to use the system again at the job center. Ten of the eleven participants also listed other places where they might want to use. Places frequently mentioned by participants in their comments were home (mentioned by 64% of the participants), work (45%), and libraries (27%). Other locations mentioned included schools, airports, public kiosks, and everywhere. When asked what parts of the system participants found useful, two features were mentioned by 5 or more study participants: (1) text-to-speech with highlighting and (2) enlarging or magnifying the text on the screen. One participant, after learning that the system was going to be available at the job center in the future remarked, “There’s going to be a line to use this.” Another participant said, “This is so much fun!”

There were three participants who specifically mentioned during the screening or session start that they felt they had very limited computer skills or found computers to be confusing. These three individuals were able to use the NFC cards with minimal cueing after reading the instruction sheet, and successfully used the computer for basic job-search related tasks.

Staff also had some interesting insights regarding the system after they tried it. Two staff members who had regular customer contact estimated that at least half of their customers required their assistance in using computers in general. These two staff members said that they felt it would be easy for them to demonstrate the auto-personalization features to those customers. One of the staff members took a researcher behind the AJC registration desk and pointed out that many of the customers then seated at computers in the AJC were squinting and leaning forward. “This is going to help a lot of people,” remarked the staff member.

Discussion

The initial feedback of the GPII auto-personalization prototype has been positive, with all participants responding that they would like to use the system again at the AJC. Participants liked that the settings were easy to apply. Many of the participants were not previously aware of the many features and extensions that could be applied to the operating system and web content. Nearly all of the participants thought of different places at work and in the community where they would like to use the GPII auto-personalization system.

The AJC was an interesting place for a first pilot. It provided a good venue for people without disabilities and with mild disabilities. With its constant turnover, it was also a good place to test and improve our introduction and awareness measures. However, there were limitations on the range of users, and the duration of their interaction with the system. Customers at AJCs are not typically users of assistive technologies, and many who have challenges using technology for various reasons do not self-identify as having a disability. The favorite features of AJC customers (larger text and text-to-speech with highlighting) are not representative of the breadth of assistive technology features and settings that must be available for others who wish to use GPII auto-personalization. Because sessions were focused on participants' first encounters with the system, we do not yet know how usage might change with time and experience.

The auto-personalization system has the potential to address the primary challenges or disabilities characteristic of AJC customers when trying to use computers as described by AJC staff and affiliates: low literacy, low digital literacy, cognitive, learning, or intellectual disabilities, mental health disorders, and English as a second language. Other potential benefits of an auto-personalization system include:

- Improving accessibility for AJC customers on all GPII-enabled computers (including those at home, work, or in the community).
- Enabling portability so preferences set up at any one location can easily appear on any GPII-enabled computer.
    - Customers are not limited to the few accessible workstations that sites may have.
    - Customers do not have to manually change settings on each computer they encounter.
- Reducing staff time needed to assist customers making computers work better for them.

- Helping AJCs to accommodate a wide variety of customers without the need for staff to individually learn about, install, and support all the different assistive technologies.
- Promoting independence, confidence and a sense of agency for individuals who may otherwise have difficulty using computers.

Since concluding the observational study, the researchers have placed two GPII-enabled computers at the AJC. These placements have the same setup as in the experiment: an all-in-one computer with a rack of NFC cards and instructions nearby. From these placements, we would like to learn about continued and organic usage of the GPII auto-personalization system.

American Job Centers offer just one view of the efficacy of an auto-personalization system. There are also plans for future pilots of the GPII auto-personalization system across the country in a community college, select high schools, in several libraries, and additional AJCs. Through these pilots, we hope to learn more about the diversity of use of the auto-personalization system. We also hope to gauge the impact of the GPII auto-personalization system on the use of computers in home, school, and community settings.

Features are being added to the GPII auto-personalization system as part of the project. Soon, the system will offer support for personalization—where people can adjust and save their own settings for a one-size-fits-one experience. To this end, the project team is developing software tools that people can use to explore and adjust settings that might be helpful. A capture tool is also being developed that will capture applicable settings that people might already have set up on their personal computers. The captured settings would then be portable and could be applied to other computers with the system installed. These additional features will be implemented in future pilots and will also be introduced in systems already placed.

Conclusions

The GPII auto-personalization system was given positive reviews by AJC customers and staff in this early pilot. With additional pilots at AJCs and other locations, we hope to learn more about auto-personalization to develop a better system. We hope to learn how to better support how people with disabilities learn about assistive technology, features, and settings that would be useful and how to easily apply those settings to computers they use at home, work, and in the community.

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How do We Aid Visually Impaired People Safely Manage Unfamiliar Environments?

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Abstract

It is a challenge for researchers and engineers in the assistive technology (AT) community to provide suitable solutions for visually impaired people (VIPs) for orientation, navigation and mobility (ONM). Our literature review looked at the current state of the art in AT designed to aid VIPs in ONM. Given the spectrum of the AT solutions at the time of our survey, there are several papers in our review which raise the adoptability issue for AT solutions specifically designed for VIPs. We conducted a survey in order to gain insight into how this technology was actually being used by VIPs. We consider the underlying issues and challenges causing current AT solutions to fall short in addressing VIP's ONM needs. We felt that it is critical to re-examine and rethink the approaches that have been taken. It is our belief that we need to take a different and innovative approach to solve this problem while addressing the issues revealed in our survey and subsequent analysis. Motivated by these findings, we propose an integrated cyber-physical system (CPS) framework with "Agents" and "Smart Environments" to address VIP's ONM needs in urban settings.

Keywords

Assistive technology; cyber-physical systems; ONM

Introduction

It is a challenge for researchers and engineers in the assistive technology (AT) community to provide suitable solutions for visually impaired people (VIPs) for orientation, navigation and mobility (ONM). Whereas advancements have been made, affording VIPs improvements in work and study, the problem of being able to go from place to place safely and securely is still to be addressed. Crossing the street is problematic: knowing if it is safe, knowing when to cross, being sure to remain on path and not collide or interfere with objects and people, remain issues dissuading VIPs from a truly independent lifestyle.

Thus, we have arrived at a novel, innovative solution that we perceive will change this situation. We present our cyber-physical framework in which we define a smart environment and an agent, an individual outfitted with a personal internet of things (IoT) made up of sensors and actuators pertinent to the needs of the given subject, which then communicates via a controlling device - known as the personal information hub (PIH) - with the smart environment.

In our prior research (Goldberg 2015), we were interested in the question, if so many technologies are available – including solutions designed to help the visually impaired community with their ONM needs – how many, if any, are being utilized by VIPs?

Results in our survey show that there were not many made-for-the-blind AT solutions being adopted by VIPs for their ONM needs. We analyzed why this might be so and then defined an innovative approach to address the issue through cyber-physical systems (CPS).

Related Work

(Abascal and Civit 2000) suggested that mobile devices, in particular cell phones, helped to ‘untether’ VIPs from their homes by allowing them to carry their devices around with them. In (Kane, et al. 2009), they surveyed how VIPs and individuals confined to wheelchairs used various technologies to help them navigate their surroundings. They showed that VIPs were specifically concerned with not losing their bearings and would carry multiple devices just in case one failed.

Since then much research has gone into seeing what could be done with smartphones. As noted in our survey, smartphones are utilized readily by VIPs; however, it is noteworthy that VIPs use mainly what is generally available and develop their own strategies for what to do with these devices.

With more understanding of alternative technology as in (Abu Doush, et al. 2016), ideas for a more systematic approach to aiding VIPs has evolved. In (Brock, et al. 2014), this becomes more evident as the way to look at AT solutions. (Brock, et al. 2014) and (Abu Doush, et al. 2016) propose an interactive approach although the suggestion is only alluded to as the way forward.

(Ganz, et al. 2015) is noticeable as the population discussed is not the stock 290 million VIPs cited by WHO but rather recent VIPs due to combat (veterans) or complications due to diabetes. This emphasizes a very particular element of the VIP community – i.e. people who may have vocations in which they are now hindered by being a VIP. These VIPs cannot rely on long-learned habits.

We find that these perspectives are inspiring from a technical perspective, but their approaches fall short of providing a truly interactive solution for VIPs with their ONM needs. Our proposed CPS framework goes further to address the issues we have revealed in our survey.

Discussion

A determination was made to substantiate our understanding of the lack of adoption of made-for- the-blind AT for ONM by VIPs. We developed our survey which was sent to as many recipients as possible, through various blind agencies. We were able to get the New York chapter of the National Federation of the Blind, the New York State Commission for the Blind, the Association for Vision Rehabilitation and Employment (AVRE (US)), and the World Blind Union to distribute the link to our online survey. We received 32 responses (Available as an MS-Excel worksheet), mainly from the US, with one respondent who stated that she was in Auckland, New Zealand. This definitely suggests that VIPs do go out and about, and therefore ONM is of interest to them. We collected baseline data (Age, Gender, Degree of Difficulty) and found that we had a decent spread with about 62.5% identifying as female, 84.7% of the respondents were in the working age spectrum of 21 – 65 years old, and of the respondents we had 38.7% identify as totally blind, another 25.8% stating they had light and shapes with the rest having varying levels of low vision.

Current Use of Assistive Technology

We found that by and large, the subjects use white canes (78.6%), with 25% of the population using guide dogs. 96.5% of the respondent's use of smartphone; however, only 50% said they used a phone for ONM. 11 of the respondents told us of the applications they utilized. Of these 54.5% said they use either Apple or Google *Maps* with 18.2% saying they employed *BlindSquare*. When asked what GPS apps they employed, 57.1% stated they used *BlindSquare*, with 35.7% using *Trekker Breeze* or a version thereof. It should be noted that all but one respondent using the latter product are over 45, suggesting that they have been using it since before the apps everyone is using came to market and are still utilizing it.

One totally blind respondent said: *I use GPS apps to research nearby places and to get announcements of nearby streets and places when walking or riding, as well as to get turn-by- turn directions to places. I also use the app of my local public transportation system to find out about the scheduled time for routes, nearby stops, etc. I use [the] app of my local cab company to book taxi cab rides. If I am traveling by air, I use apps such as FlightView, Gate Guru, and Where To Go to find out my flight status, amenities at the airport, and locations of relief areas for my guide dog.*

Another, also totally blind, stated: *Mainly Google Maps. …. Basically, I use it to estimate distances from places (like whether we're approaching my bus stop), for walking directions (often with help from public to figure out new intersections) and for planning a route in the first place as my city (Auckland New Zealand) has a notoriously difficult-to-work-out bus network if you haven't been to any given suburb before. I use Blind Square a little bit to figure out what places are around. …., but most ideal for me would be some form of accessible mode in Google Maps that'd let you know when you need to cross a road when walking, and which side of the road a bus stop is on in the transit mode.*

One respondent with light and shapes said: *My phone serves as the platform on which I run my various ride-hailing and navigation apps. I use Apple Maps to provide GPS directions, and the Uber app to book a ride to my destination of choice.*

A low visual acuity respondent tells us: *I use [my phone] to help me see where I am on the map. I especially do this when I am in buses and can't easily view street signs through my telescope. I rarely took the bus before I got a smartphone.*

Another low visual acuity respondent told us: *GPS apps; help verify where I am, help track back to a specific location.*

Thus we find evidence that a good third of our respondents utilize their smartphone as a mobility aid. The question, though, is in what ways are they using specially made-for-the-blind applications? The application *BlindSquare* is most prominent. As a made-for-the-blind application, it is actually a veneer for a more generally utilized piece of software, *Foursquare*, and used pretty much for the same reasons. The interface is user-friendly for blind users. The *Seeing Eyes GPS* is a new version of *BlindSquare*.

In general, the replies tell the story of adaptation of readily available applications such as *Google* and *Apple Maps*, and *Uber* and *Lyft*.

Gauging Readiness to Use New Technology

We asked if respondents had taken part in clinical studies to which 77.2% of the respondents said “N/A”. We found one had used BrainPort; one, Argus-II; and one had been a subject with Sonic Glasses. Beyond that very few expressed any interest in pursuing this. We questioned them about use of crowd-sourced aids such as *VizWiz* and *TapTapSee*. Only 19.4% responded positively and when asked about electronic travel aids, 18.8% answered positively; one replied that he did use them, but did not like them!

Over all, we found a reluctance to adopt any made-for-the-blind technology other than B*lindSquare* which is a made-for-the-blind interface for a general purpose GPS based application, *Foursquare*. As observed by (Kane, et al. 2009), having GPS is of extreme importance to VIPs who sometimes carry more than one device to be assured of having a working app. Maintaining a sense of ONM is of extreme importance to VIPs.

Possible causes for the lack of adoption of current AT for ONM

We will discuss a few of the issues we see as problematic with current research and justify the need for a different approach. Firstly, we must realize that VIPs are people too. Placing a box on one’s head with a camera and wires all over the place is not something most people would wear, so why expect this of VIPs? But VIPs do need AT. Canes and dogs are limited in how they can help, and in today’s busy world, they are insufficient where safety and security are concerned. The research is often conducted in a controlled environment - as it should be - but when faced with reality, the results are less impressive. Ideas such as crowd-sourced (volunteer based) solutions such as *TapTapSee* are not very reliable if trying to service too many clients with multiple needs at odd hours of the night. Finally, there is the issue of cost. *Argus-II* has gone public and now costs $150,000; who is going to pay for it?

Our proposed CPS framework with an “agent” and a “smart environment” will shift much of the data storage, data processing and communication tasks to the “smart environment". This would in turn reduce the computation power requirement for individual devices. It is possible for a VIP to just use his/her smartphone or a simple personal device, such as Raspberry Pi, to perform the functions of the agent.

Proposed Solution

In our research we propose an innovative approach to the often asked question, "How do we aid a visually impaired individual safely and effectively navigate an unfamiliar environment?" Thus far, assistive technology solutions have concentrated on passive approaches which by and large have not been adopted by the community for which they were created. By 'passive' we refer to the fact that solutions either: Read a situation and attempt to understand what is sensed with minimal information garnered from the environment. For example, a camera captures images and then attempts to 'understand' the given context through vision algorithms. Or, read data provided by the environment through a specially designed reading device and attempting to act upon it. In short, there is no ongoing interaction between the system analyzing the situation and the environment that is being navigated.

We present a cyber-physical solution that would aid an individual in his/her traversal of an environment, enabling the system to facilitate a secure and effective way through the area. The key CPS concepts, as defined in (Zhang 2015), bridge the physical world we live in with the cyber world, utilizing information that comes from the Internet of Things (IoT). People with vision loss or other special needs may have difficulties comprehending or perceiving signals directly from the physical world, but they can make connections in the cyber world. These cyber connections and real-time information exchanges will enable or enhance their interactions in the physical world.

It is natural to view the problem space from two perspectives: The person with special needs; the environment that the person needs to navigate through or around.

Therefore it is natural to design our AT solution with two subsystems:

1. The agent,
2. The smart environment.

The agent is a cyber representation of an individual who is outfitted with a body-worn internet-of-things, controlled primarily through Bluetooth technology by a device we call a Personal Information Hub (PIH). The smart environment is a cyber representation of a physical environmental infrastructure embedded with computer technology that can communicate with a set of agents at any given instance utilizing WiFi and Bluetooth technologies. The individual and the physical environment along with their cyber representations (agent and smart environment) form an integrated cyber-physical system framework.

Who better to know the environment than the environment itself? A major issue with current assistive technology solutions is that the agent has to work out the whereabouts of the individual and deal with the issues that might arise. In our framework, the smart environment would store data about the environment. We envisage a smart environment with a labeled 3D model – coupled with algorithms – built to take in data from an agent and able to give information back to the agent on all matters regarding the environment, such as traffic signals, information about the terrain, etc.

Through the PIH, continuous information could be exchanged with the smart environment via WiFi or Bluetooth. Prior to interaction, a handshake could be established in which the agent transmits a data file. This allows the smart environment to respond according to the needs of the individual represented by the agent. As with the smart environment, the agent is the optimal place to keep information about the individual. This includes which devices are part of the individual's personal IoT that can be utilized by the smart environment.

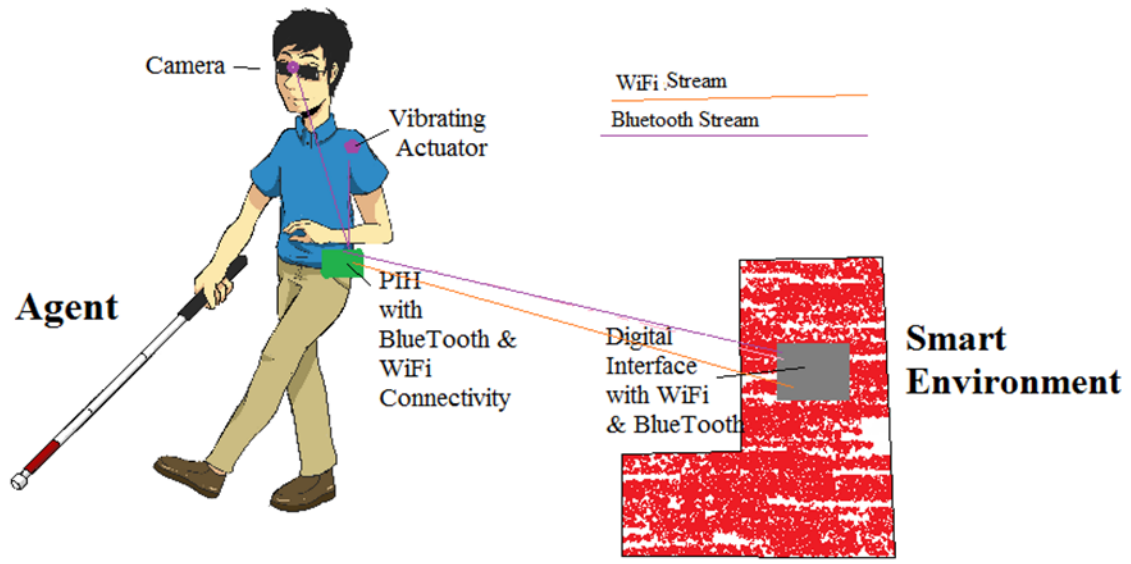

Fig. 1. The architecture of the cyber-physical system showing how the communications would work.

The architecture is described in Figure 1. A camera worn on the glasses could capture an image or video stream that can be processed according to the needs defined by the smart environment's algorithms.

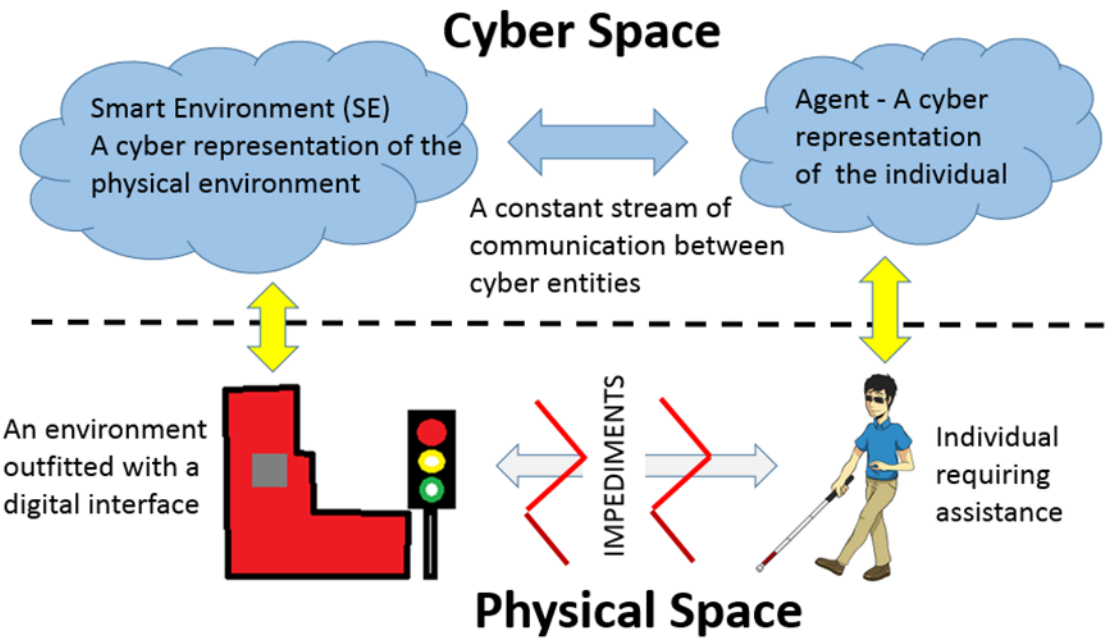

Fig. 2. Concept of the CPS Framework and how it operates

Figure 2 describes the cyber-physical framework concept. The entities in the physical world are represented by the elements in cyber-space. Problems arise in the physical world. The individual experiences certain difficulties in perceiving information from and reacting to his/her physical environment. In this instance, a VIP has a visual impairment that causes this difficulty. Thus, via connectivity in cyber-space, through elements representing the individual (the agent) and the environment (the smart environment), the VIP can mitigate the impediment in the physical world and be able to better interact with his/her surroundings.

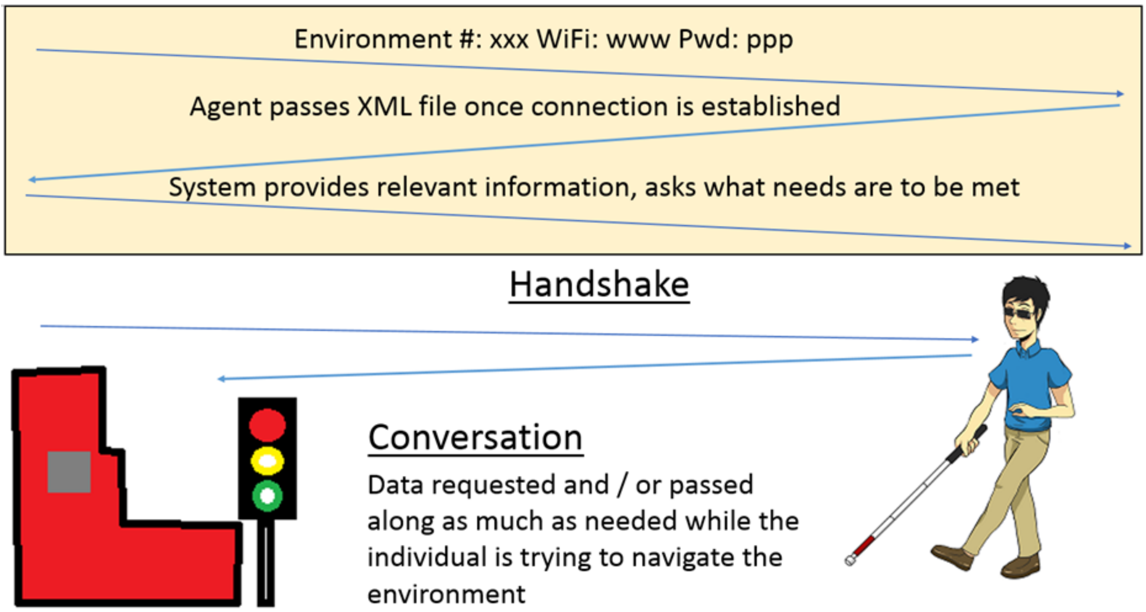

Fig. 3. A process diagram showing the handshake and the conversation.

Figure 3 describes the operation of this system. Through sensors such as cameras in the environment, the CPS would be able to monitor possible problem situations. Consider the following scenarios:

Let us take a cyclist riding irregularly through the environment or a vehicle which is disobeying the traffic rules. In each case, we have an anomaly which the individual is unable to capture but which could put the individual in danger. Here a CPS could be constructed to monitor such anomalies. Through the constant communication between the agents and the smart environment, the system would be able to warn individuals who may be in danger. In this case the message is transmitted to an agent's PIH, which in turn guides the individual in a personalized response that is designed to fit his/her specific needs, such as using customized audio or haptic messages for a VIP.

Even these simple real life examples require a sequence of timely information exchanges between the agent and the smart environment to enable the individual to safely navigate the physical environment. This is supported by integrated computing and communication systems, a CPS framework. Once such a CPS has been constructed and an agent is able to interact with it in the way intended, a chain of smart environments would be able to share data about expectations. An individual has an intended path and specific needs. The agent could relate this to the chain of smart environments. Should an issue arise, a communication down the chain could pass on relevant data that may help direct the individual more efficiently. Furthermore, should situations in a given environment be problematic, this could be shared between environments to better manage situations.

Our project is still in an early research stage. It could be implemented in steps, with currently available technologies, to integrate the CPS framework into the current urban infrastructure. This could be done the system would evolve seamlessly and with minimal interruption to a busy, ever evolving world.

Conclusion

Thus far we have reviewed the AT available for meeting the ONM needs of VIPs. While there is much in the way of research and ideas being proposed, we understand that little, if any AT is actually being adopted for use beyond the basic GPS applications that are readily available to the general public. While we have explained the concept and some key AT components here, it is in our ongoing research that we will design, develop and test the full framework and how it might be applied in urban settings.

Acknowledgements

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A Survey of Visually Impaired Consumers About Self-Driving Vehicles

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Abstract

This study investigated public opinion of persons who are blind or visually impaired related to user acceptance, concerns, and willingness to buy partially and fully automated vehicles; commonly referred to as self-driving vehicles. A 39-question Internet-based survey was distributed in the United States that collected 516 useable responses from persons 18 years and older who self-identified as visually impaired. Respondents generally had an optimistic view of the potential benefits of self-driving vehicles however a majority of respondents expressed concerns regarding the technology. Concerns focused on the possibility of equipment failure, vehicles getting confused by unexpected situations and vehicle interactions with pedestrians and bicycles. A majority of respondents agreed that the needs of individuals who are blind or visually impaired are being considered in the development of self-driving vehicle technology though higher education levels were associated with a decrease in a respondent's belief in this contention.

Keywords

Self-Driving Vehicles; Accessibility; Visual Impairment; Advanced Driver Assistance Systems

Introduction and Background

At present, a significant amount of consumer research is being conducted to understand consumer preferences regarding self-driving vehicle technology to ease consumer adoption. Despite wide-ranging research, it has been suggested that most self-driving vehicle technology being developed is not in fact accessible to individuals with visual impairments (National Federation of the Blind). We purport that this may be at least partially attributable to the scarcity of research that has focused specifically on the opinions and preferences of blind and visually impaired consumers. The present study was designed to contribute to the literature that is specifically focused on furthering the understanding of the opinions and concerns of consumers with visual impairments as it relates to self-driving vehicle technology and related issues.

Method

Online Survey

The present study was conducted as an online survey using the Qualtrics survey platform. The questionnaire was adapted from a public opinion survey regarding self-driving vehicles in the U.S, U.K. and Australia conducted by Schoettle and Sivak with format modifications designed to enable screen reader accessibility, scale adjustments and content modifications intended to address topics related to visual impairment. The survey addressed general opinions about self-driving vehicles, concerns, issues related to visual impairment and willingness to pay for the technology. Responses were gathered from January 4, 2017 through April 12, 2017.

Respondents

Participants were recruited through email notifications distributed by 16 state agencies for the blind and by the American Council of the Blind. Participation was restricted to individuals 18 years of age and older whom self-identified as blind or visually impaired.

Participants were entered into a drawing for a $300 prepaid gift card as compensation. This recruitment strategy resulted in 556 replies from potential respondents with completed surveys received from 516 respondents. The final response rate of the survey was 92.8%. The margin of error at the 95% confidence level for the results is +/- 4.0%. Approximately 54% of respondents were female and approximately 45% were male. More than half of respondents were 45 years of age or older, while those in the 18-44 age range made up 33.45% of those participating in the survey. Nearly sixty percent of respondents held at least a bachelor's degree (58.92%), while fewer than 1% had less than a high school education. Those employed full-time (35.12%) exceeded the combined number of respondents who were full-time students, part-time students and those employed part-time (23.8%). More than half of respondents (55.34%) indicated that they had been blind or visually impaired all of their lives.

Results

General Opinion of Self-Driving Vehicles

A majority of survey respondents had heard of self-driving vehicles prior to the survey (95.96%) with most respondents having a positive impression of the technology (50.18% extremely positive, 30.44% moderately positive and 7.75% slightly positive). Fewer than 10% had a negative impression of the technology with 2.03% of respondents indicating that they held an "extremely negative" impression of self-driving vehicle technology.

Expected Benefits of Self-Driving Vehicles

Respondents were asked eight questions related to the anticipated benefits that might occur through the use of self-driving vehicle technology. With each question they were asked to select "extremely likely", "moderately likely", "slightly likely", "neither likely nor unlikely", "slightly unlikely", "moderately unlikely" or "extremely unlikely". Figure 1 illustrates respondent perception of potential benefits accounting for all variations of “likely” (“extremely”, “moderately” and “slightly”), “neither likely nor unlikely” and all variations of “unlikely” (“extremely”, “moderately” and “slightly”). The majority of respondents felt that each of the expected benefits were likely to occur with self-driving vehicles with respondents expressing the most confidence in the likelihood of fewer automobile crashes (79.96% when all variations of “likely” combined), reduced severity of automobile crashes (79.21%) and better fuel economy (75.76%). Lower insurance rates were viewed as least likely (27.52% when all variations of “unlikely” combined).

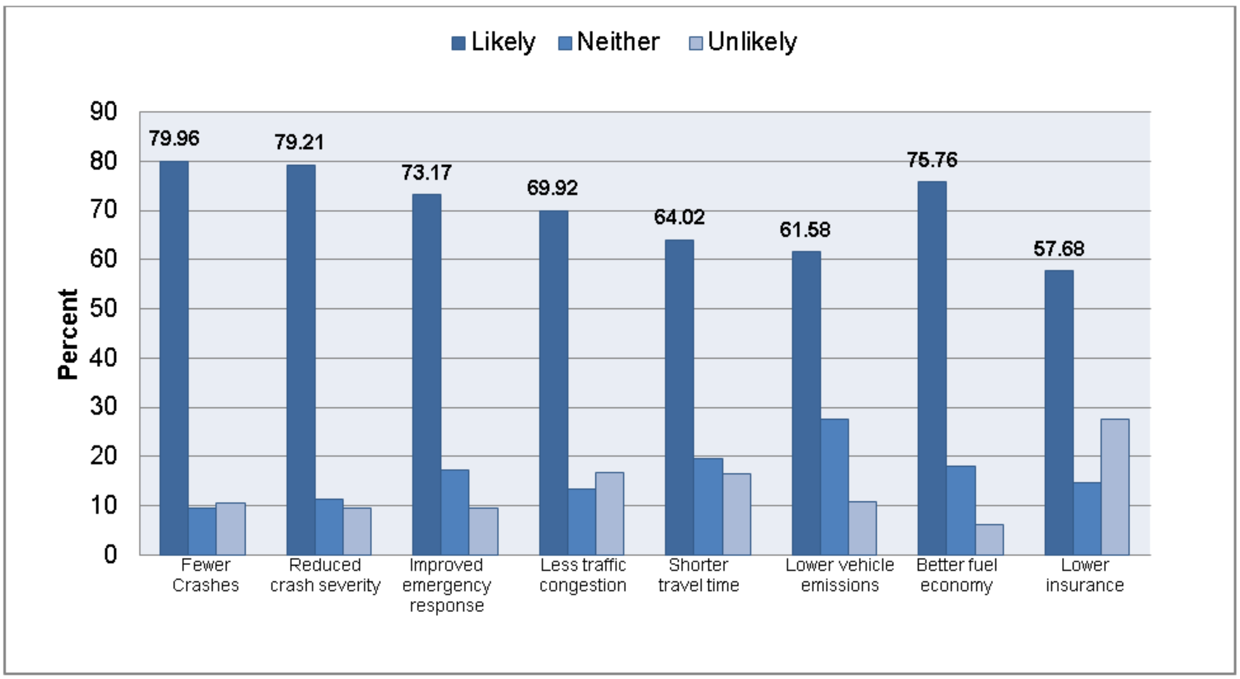

Fig. 1. Summary of responses to Q6-Q13: “*Regarding self-driving vehicles, how likely do you think the following benefits will occur…?*” All variations of “likely” and “unlikely” tallied.

Self-Driving Vehicle Concerns

Operational Concerns

Respondents were asked how concerned they would be about riding in a fully autonomous or self-driving vehicle as the primary operator. A definition describing a fully autonomous or self-driving vehicle accompanied the question. The most frequently selected response was “slightly concerned” (38.96%), followed by “moderately concerned” (22.82%), “very concerned” (16.70%) and “not at all concerned” (21.52%). Subsequently, respondents were asked how concerned they would be about riding in a *partially* autonomous vehicle as the primary operator. A definition describing a partially autonomous vehicle accompanied the question. The most frequently selected response was “slightly concerned” (30.91%), followed by “very concerned” (27.56%), “not at all concerned” (23.84%) and “moderately concerned” (17.69%). A majority of respondents expressed some degree of concern regarding their ability to operate a self-driving vehicle if one was made available to them (32.16% slightly concerned, 15.80% moderately concerned, and 17.66% very concerned). The most frequently selected response however was “not at all concerned” (34.49%).

Issue-Based Concerns

Respondents were asked 10 questions related to self-driving vehicle related issues; Figure 2 provides a summary of their responses. For each question respondents were asked to select “very concerned”, “moderately concerned”, “slightly concerned”, or “not at all concerned”. Respondents expressed the most concern (when all variations of concern are accounted for) about equipment failure or system failure (93.18%), followed by vehicles getting confused in unexpected situations (92.69%) and the interaction between self-driving vehicles and pedestrians and bicycles (87.55%). The least concern was expressed about learning to use self-driving vehicles (44.09%).

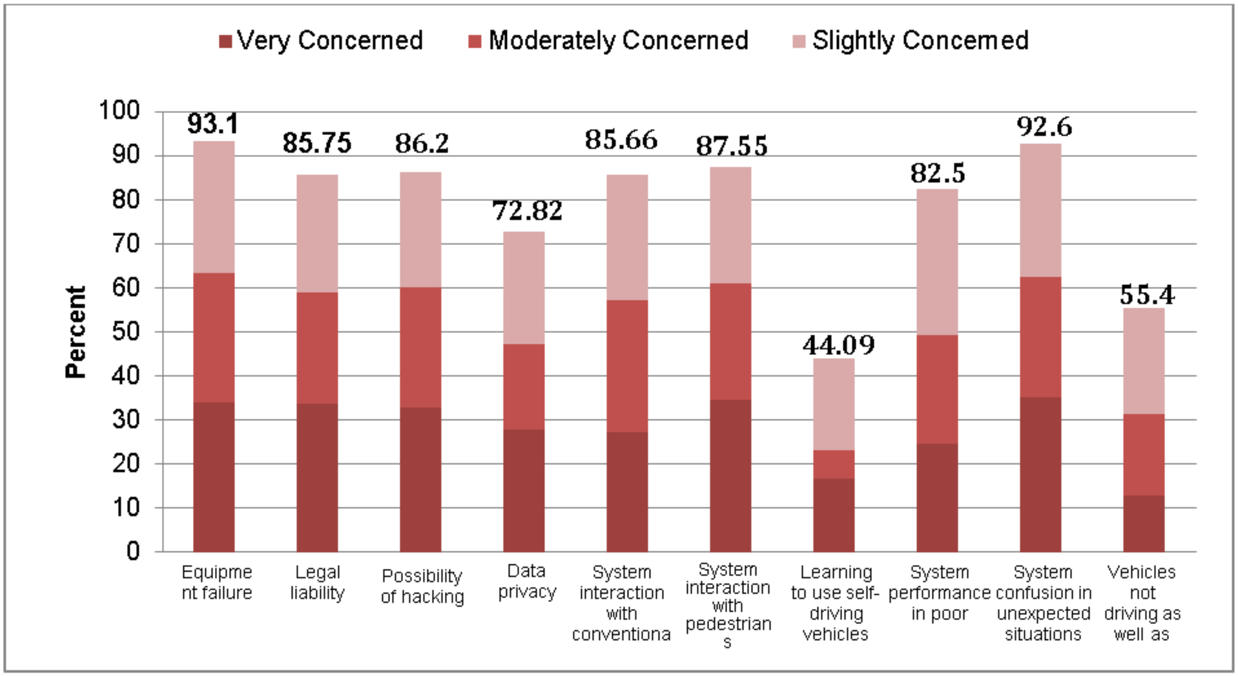

Fig. 2. Summary of responses to Q19-Q28; 'not at all concerned' is not displayed: "*Regarding self-driving vehicles, how concerned are you about…*"

Ownership Interest and Willingness to Pay

More than 90% of respondents expressed some interest in owning self-driving vehicle technology with 93.31% indicating that they were "extremely / very / moderately / slightly interested". Respondents on average indicated that they were willing to pay $6,346 US extra for this technology with those at the 50th percentile indicating that they would pay $1,000 extra and those at the 90th percentile indicating that they would pay $10,000 extra. About a third (n = 171) of respondents (33.11%) indicated that they would not be willing to pay extra for self-driving vehicle technology.

Discussion

Significant concerns were raised regarding all eight of the issues addressed within the study with respondents most concerned about equipment and system failure, self-driving vehicles getting confused by unexpected situations and interactions between self-driving vehicles, bicycles and pedestrians. While these findings are consistent with the literature in that public opinion surveys have generally suggested that consumers have significant concerns regarding self-driving vehicle technology (Daziano, Sarrias, and Leard; Schoettle and Sivak, “A Survey of Public Opinion about Autonomous and Self-Driving Vehicles in the US, the UK, and Australia”; Schoettle and Sivak, “Motorists’ Preferences for Different Levels of Vehicle Automation”) our findings suggest that the concerns of blind and visually impaired consumers may be somewhat different than consumers generally. While concerns regarding legal liability for owners and drivers has been a primary concern of respondents in studies by Howard and Dai and Schoettle and Sivak (Schoettle and Sivak, “A Survey of Public Opinion about Autonomous and Self-Driving Vehicles in the US, the UK, and Australia”), it placed 5th on the list of concerns in the present study. The same is true for concerns regarding self-driving vehicles not driving as well as human drivers, which placed 7th on the list of concerns in the present study but was 3rd in the Schoettle and Sivak study (Schoettle and Sivak, “A Survey of Public Opinion about Autonomous and Self-Driving Vehicles in the US, the UK, and Australia”).

More than 90% of respondents expressed an interest in owning self-driving vehicle technology; high interest in ownership that is consistent with the literature (Kyriakidis, Happee, and de Winter; Schoettle and Sivak, “A Survey of Public Opinion about Autonomous and Self-Driving Vehicles in the US, the UK, and Australia”; Schoettle and Sivak, “Motorists’ Preferences for Different Levels of Vehicle Automation”). A majority of respondents however indicated a willingness to pay extra for self-driving vehicle technology. Much of the literature in this regard, which has presumably focused on sighted consumers, has indicated that consumers generally are unwilling to pay extra for self-driving vehicle technology (Kyriakidis, Happee, and de Winter; Schoettle and Sivak, "A Survey of Public Opinion about Autonomous and Self-Driving Vehicles in the US, the UK, and Australia"; Schoettle and Sivak, "Motorists' Preferences for Different Levels of Vehicle Automation"). Our findings indicate that blind and visually impaired consumers, on average, may be willing to pay more than $6,000 extra for self-driving vehicle technology, a sum higher than the $4900 found by Daziano, Sarria and Leard (Daziano, Sarrias, and Leard), presumably with sighted consumers and approaching the recent findings of Bansai, Kockelman and Sing (Bansal, Kockelman, and Singh) of $7253.

Conclusion

Our findings suggest that while the opinions and concerns of blind and visually impaired consumers may *broadly* parallel the opinions and concerns of consumers generally there are key differences that may impact how these consumers approach and interact with this technology. Awareness of these differences will become increasingly critical if manufacturers are interested in wider consumer adoption of self-driving car technology beyond a core base of sighted users.

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Neil Soiffer, Edgar Lozano, Dan Brown
Pearson Assessments

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Abstract

Over the last 25 years, there has been significant progress towards making math accessible. This progress has come from both research projects and software development. We summarize best practices about what has been learned in those years. We also highlight two current accessible math development projects that build upon those practices about speech, braille, and overcoming limited working memory.

Keywords

STEM Accessibility, Mathematics, MathML, Assistive Technology, Braille

Introduction

Work on making math accessible dates back over 25 years. For references to early work, see Karshmer et.al, 2007. In the last 5-10 years, much of the work has focused on reading and navigating math and the results of that work are embedded in several popular tools including JAWS, NVDA+MathPlayer (Soiffer, 2015), ChromeVox (ChromeVox, 2013), Safari+VoiceOver, TextHELP, and MathJax (Cervone et. al., 2016). With the exception of NVDA+MathPlayer, these systems are limited to working in browsers. MathPlayer+NVDA also works in Word documents and PowerPoint with math created by MathType.

In the following section, we cover key topics in math accessibility. The results of research studies that have led to best practices are summarized for each topic. Following this summary, we highlight two current projects that are pushing the state of the art further along to establish best practices in new areas.

Discussion

Prior work leading to best practice

Math accessibility encompasses input techniques, output techniques, and ways of interacting with the mathematical content. These techniques span different modalities such as keyboards, speech, and braille. Research into these techniques and modalities are discussed below.

Speech output

There are many different ways to speak an expression. Common forms of human speech tend to be ambiguous, relying on the listener either being familiar with the equation or being able to see it. Methods to resolve ambiguity typically involve bracketing words (e.g. “fraction … over … end fraction”), prosody (e.g., ASTOR (Raman, 1994) pauses, rate, and/or pitch changes), sounds/spearcons (Murphy, 2010), and/or conventions (e.g., MathPlayer's SimpleSpeak convention that simple fractions such as x/y speak without bracketing words, but more complex ones will be bracketed). Prosody pauses are particularly important to group subexpressions and produce natural speech. Speed and pitch changes are less important: a ClearSpeak study (Frankel & Brownstein, 2016) found blind and low-vision subjects preferred spoken lexical cues over pitch and rate changes.

Bracketing words help resolve ambiguity when you can't see the expression, but are "verbal noise" to those who can see and may hinder understanding for people with a learning disability (Lewis, Noble & Soiffer, 2010). MathPlayer allows users to specify their disability and will avoid bracketing words for people with a learning disability. In addition to disability, other reasons different speech is needed include terse and verbose forms (experts and learners), subject specific readings (e.g., an x with a line over it would normally be read as "x bar" but if the subject area is known to be a statistics, it would be read as "the mean of x"), and semantic vs syntactic readings (e.g., "x squared" vs. "x superscript 2 baseline" in MathSpeak (Isaacson, Schleppenbach, & Lloyd, 2009)). No studies have been done to evaluate preferences for syntactic and semantic verbal renderings.

Braille output

JAWS, NVDA+MathPlayer, and Safari display braille math codes on a refreshable braille display, although none of them indicate the current focus of navigation with the braille math output, as is done with dots 7 and 8 for textual content. While there is no extensive research on the effectiveness of braille input position indicators for math, having the braille change to reflect the current focus of navigation, or on the use of an outline of the math expression in braille, a small user study conducted by Pearson in October 2015 (Pearson, 2015) noted that participants were confused when dots 7 and 8 were not used to communicate the user's input position. The Pearson Accessible Equation Editor (AEE) has since been updated to indicate the current input position using dots 7 and 8, as well as the current editor selection with dot 8 on the braille display to provide tactile feedback similar to what users expect for textual content.

Display

The use of raster images for math in documents has decreased significantly. On the web, MathML and TeX (often rendered by a polyfill such as MathJax or KaTeX) and SVG is common. These technologies allow the math to scale with the font size so that the math can be enlarged without degrading the quality. Native math in a Google doc and math in Microsoft Word or Apple Pages also scale well. In print, larger math expressions are broken over lines. ASTER supported eliding subexpressions and MathJax has experimented with this technique also.

For people with learning disabilities, synchronized highlighting of speech and text has been shown to be helpful. No studies have been done with math, but the MeTRC study (Lewis, Lee, Noble and Garrett, 2013) found that students with learning disabilities made twice as many errors reading math as they did reading text; it seems very likely that synchronized highlighting is important for math also. TextHELP originally used synchronized highlighting with MathPlayer and IE; it now makes use of MathJax to do that.

Navigation

Navigation of math is now supported by most accessible math software. In the ClearSpeak study (Frankel, Brownstein, & Soiffer 2017), it was the highest rated feature studied. Three forms of navigation were supported: character level, notational (2D structures such as division act like a character when arrowing left/right), and structural (left/right arrow keys move from operand to operator to operand). For the latter two modes of navigation, up/down arrows are used to move into and out of 2D notational structures. Participants liked all three and found the different navigation modes useful in different circumstances. Most other systems only support notational navigation. Although not studied, the ability to navigate up and down a column, such as in a matrix, a system of equations, or in an elementary math problem seems very important.

When moving around, it is sometimes useful to be able to remember a location. MathPlayer's navigation supports user-defined placeholders. Although ClearSpeak study participants liked that feature, it was not widely used and was rated lower than most other features.

Summaries/Outlines/Overviews of larger expression have been tried a number of times in software. Gillan, et. al., (Gillan, Barraza, Karshmer, & Pazuchanics 2004) did a study that showed providing an outline slowed solution time. Nonetheless, they added outlines to their MathGenie solution because they felt it would be useful. As part of a ClearSpeak navigation study, a summary mode was added to MathPlayer; user feedback from studies was that it was not that useful. The authors feel part of this is because the implementation was crude relative to other features.

Input/Editors

Entering and editing math employs all of the above techniques and raises additional issues. One issue is that there are many more math characters and notations than there are keys on a keyboard. TeX and ASCIIMath are two input notations for specifying both characters and layout. Because they are linear and use a standard keyboard, they are inherently accessible. However, they only support character-by-character navigation and speech, and typically must be separately converted to MathML (which screen readers can speak) and braille to verify they were entered correctly. Until recently, these were the only accessible math editor options.

Most direct edit/WYSWYG math editors are not accessible. Two exceptions to this are ChattyInfty (Yamaguchi & Suzuki, 2012) and AEE. Math editors typically use palettes and keyboard shortcuts for all the special characters and notations; for accessibility, palettes must be focusable/keyboard accessible.

There are thousands of mathematical characters and many notations. Organizing this information to make it easy to find and access is a challenge. A study by Dave Schleppenbach (personal communication, 2014) revealed that just 10 operators accounted for 95% of all operators found in standard US algebra textbooks. It is likely that similar findings are true for other subject areas. Additionally, the context of what has been entered can be used to show likely characters and notations for further input. Making common choices easy to access is very helpful to those who are limited to mainly sequential access, such as screen reader users and switch users.

As math is entered and edited, changes to the insertion cursor, selection, and expression need to be communicated to screen readers. Best practices in regard to the amount of information communicated when inserted, selecting, or deleting have yet to be established (e.g., “fraction deleted” vs. saying the contents of a deleted fraction vs. saying nothing). Even best practices for something as common as typing a “backspace” after a fraction has yet to be established. It differs between common editors: AEE, Mathematica, and Desmos’s editor move to the end of the denominator; MathType, WIRIS, and Word select the fraction; and ChattyInfty deletes the fraction.

Braille Input

The most commonly used approach to braille math input is to capture braille cells one-by-one and translate input from braille to other formats, either on user request, or on word or equation boundaries. This approach leads to a user experience where the math markup is not kept up to date with user input, which impedes communication with non-braille users.

AEE uses a transformational approach where each braille input cell directly modifies the underlying content MathML markup (Dooley & Park, 2016). Since this same method is used to process keyboard input, the resulting input behavior remains remarkably similar for braille and keyboard users, and supports immediate interactive feedback between input and output formats.

In braille, a braille character is used to indicate where a fraction starts and another is used for where it ends. Typing a backspace after a fraction raises the question of what should happen with the braille end fraction indicator. In a small Pearson user study conducted in July, 2016 (Pearson, 2016) users preferred having backspace move inside the fraction, although some confusion was noted because the close fraction symbol in braille did not go away (because the fraction still remained).

Speech Input

MathTalk (McClellan, 2005) was an early attempt at speech input using Dragon Dictate (now using Dragon Naturally Speaking), but has had limited success, perhaps because it requires the use of the phonetic alphabet (‘a’ is spoken as ‘alpha’, ‘b’ as ‘bravo’, etc.) and requires slow, clear speech due to the quality of speech recognition when it came out in 1997. Mathifier (Batlouni, et. al., 2011) was another older system. The authors noted that math has a relatively limited lexicon and grammar. They tried to improve speed and accuracy of recognition by limiting recognition to that smaller language. Mathifier was based on CMU’s Sphinx 4 speech recognizer (Lamere, 2001) which relies on Hidden Markov Models to recognize words. They achieved 80% - 85% accuracy with six testers; this is likely too low to be useful. With the advent of machine learning via deep neural networks, speaker-independent speech input on phones, home assistants, and other devices has become popular. These systems work well when given large amounts of data (speech) for training. However, math has not been part of the training and so they are less successful in interpreting math. AEE uses the latest version of Dragon Naturally Speaking, which is based on deep learning. It makes use of grammar rules with a limited lexicon to help improve accuracy with math, but still requires the use of the phonetic alphabet for letters and requires users to learn the grammar. EquatIO, successor to g(Math), uses Google Speech recognition with special filters to correct for common mistakes; it does *not* use the phonetic alphabet. No studies have been run to determine error rates on these two systems.

Handwritten Input

A number of applications such as Windows' Math Input Panel, WIRIS, and MyScript allow handwritten math. The accessibility of such systems has not been studied. Handwriting poses challenges for the physically disabled as well as people who are blind, although those who lost their sight after learning math are often able to write math legibly. Most handwriting systems support conversion to MathML, so the recognized result can be spoken or brailled. This means the result can be checked, but correcting a mistake may be difficult for those who are blind.

Current work -- two examples of best practices

The Logan Project - Process Driven Math

Process driven math (PDM) as an auditory means of interacting with complex math expressions began at Auburn University Montgomery (AUM) in 2015 as an instructional accommodation for a student with a disability profile that included being blind, lacking the physical dexterity to use braille, and being able to speak in at most in a whisper. Over time AUM's implementation of PDM has become a more standardized process suitable for use by students with a variety of print disabilities for whom inaccessibility to college algebra has represented a significant hurdle (Perez, et al, 2017). To date, PDM has involved human tutors. In 2017, AUM received a grant to refine the specifications and develop software to automate the process.

With PDM, students first hear an overview of the expression, such as "rational divided by rational." Students then make choices on what portions or "chunks" of the expression they want to explore and manipulate. Meaningful words are used for each chunk and color coding of those words and symbols is used for those with severe dyslexia. The use of visual chunking has shown promise in previous studies conducted with students having learning disabilities who were struggling with traditional print-based instruction in mathematics classes (Zhang, Dake, et al, 2012). Collapsing big expressions has a long history including Soiffer's work on displaying equations (Soiffer, 1991) and Raman's pioneering work on accessible math (Raman, 1994); it is included in MathJax as "Collapsible Math".

Overviews of expressions go back to the early Mathtalk project -- it attempted to use an "auditory glance" in which a number of recorded musical sounds ("earcons") were associated with mathematical structures (Stevens and Edwards, 1994). While auditory glances have not been used in subsequent software, the ability to hear an overview or summary before exploring the expression more fully was implemented in MathGenie and in MathPlayer 4. For both projects, user-feedback was not enthusiastic as discussed above. For the user groups targeted by PDM and its interactive editing usage in PDM, it seems essential.

The Pearson Accessible Equation Editor (AEE)

AEE uses Content MathML to unambiguously represent a mathematical expression. This notation is inherently neutral with respect to the way math is written, spoken, displayed, or encoded in braille (Dooley, Brown & Lozano, 2016). As a result, the AEE supports multiple forms of math input, including computer keyboard input, braille terminal input, and spoken math input, all of which are used to create the exact same content markup. Once this markup is created, downstream processing tools are unable to determine the input mechanism used to create the expression, which provides a level of confidence that one input format cannot be preferred over another. The AEE also supports multiple simultaneous forms of math output, including computer display math, braille terminal output, and spoken math output, all driven from the same content markup. As a result, several users can interact in real-time with the underlying markup using their preferred input and output formats, enabling instant communication and feedback between, for example, a sighted math teacher and a blind math student.

Conclusions

Prior research has shown that accessible digital mathematics can support increased learning outcomes for students who are blind or who have learning disabilities—especially in more complex subjects like algebra (Edwards, et al, 2006; Lewis, et al, 2010). There are now a number of established best practices for spoken math output, and increasingly, for braille math output. There are however, many, many areas where user studies and more research are needed to establish what works best not just for students with low or no vision, but also for students with learning and physical disabilities. The two projects mentioned above are a step in that direction, but are just two steps in a long journey.

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Fitting Simulation Based on Mobile Body Scanning for Wheelchair Users

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Abstract

Clothing of wheelchair users is one of the problems that hinder their social participation and social return. The types of clothes worn by wheelchair users are often limited in number owing to the physical form and limitations of the physical functions of these users. In addition, they also face other problems such as difficulty in wearing clothes owing to their disability. To resolve such problems, we are working on a sustainable research project for manufacturing ideal clothes for wheelchair users while simultaneously improving functionality, design, and economic efficiency.

As a core part of this project, we have developed a virtual fitting application that enables virtual trial fitting in a seated position and that collects body measurement data of wheelchair users. Mobile RGB-D cameras mounted on current smartphones are utilized for measuring body shape without any direct contact. The measured body shape data are sent to a dedicated fitting server. Then, accurate fitting simulations based on the measured body shapes are performed. After completing the fitting calculations, the fitting results can be downloaded by the client. This system is designed for providing a virtual fitting experience to wheelchair users and for collecting body measurement data required for manufacturing their garments.

Keywords

Fitting simulation, garment manufacture, wheelchair users, sitting position, mobile body scanning, RGB-D camera.

Introduction

Fitting simulation for wheelchair users

Clothing is one problem that hinders the social participation of wheelchair users and social return. The types of clothes worn by wheelchair users are often limited in number owing to the physical form and limitations of their physical movements. In addition, wheelchair users face other problems such as difficulty in wearing such clothes.

To resolve such problems, we are working on a research project for sustainable manufacturing of ideal clothes for wheelchair users while simultaneously improving functionality, design, and economic efficiency. The developments made in this project with respect to functionality, design, and economic efficiency are summarized in Figure 1. For functionality improvement, we have developed a special material and pattern for wheelchair users, a dummy robot for garment evaluation based on body movement replication and data sensing while wearing garments, and an e-textile garment that exhibits measurement functionality such as extension and clothing pressure. For design improvement, we have endeavored to enrich the quantity of the garments worn by wheelchair users and to share pattern and body shape data to garment manufacturer. For improving economic efficiency, we have developed a sustainable framework to reduce production cost for custom-made garments for wheelchair users.

To achieve development in all aspects, a virtual fitting application has been developed in this study. The objective of this application is to realize simulation garment functionality and its design in the virtual space. By enabling 3D measurement through an RGB-D camera and virtual trial fitting based on measurement data provided by a smartphone, economic efficiency is also improved. The application can also facilitate e-commerce and virtual pre-production of garments.

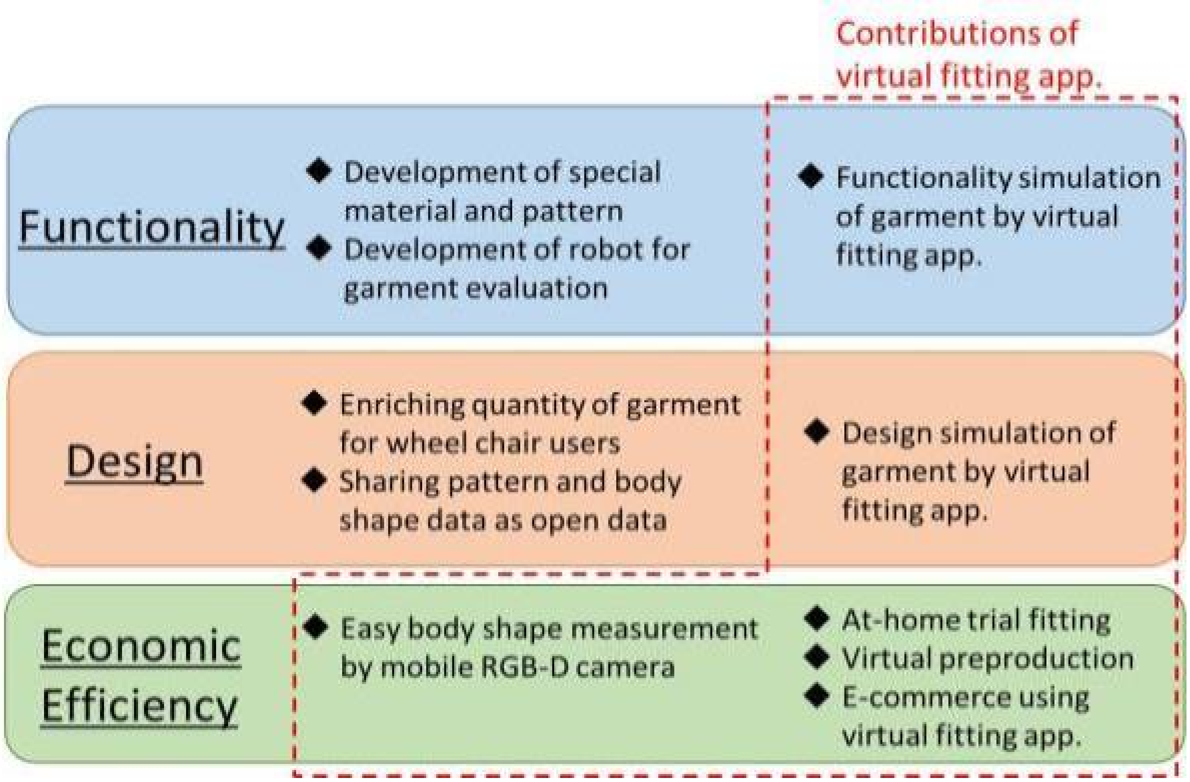


Fig.1. Development aspects in the project.

The virtual fitting application has the following features:

1. Ability to allow wheelchair users to try clothes virtually while they are in a seated position (i.e., in the wheelchair)
2. Ability to realize automated and accurate fitting simulation using examples pre-loaded to a standard model
3. Ability to realize three-dimensional physical measurement function using a common mobile device
4. Ability to verify fitting results by three-dimensional visualization using a common mobile device
5. Ability to develop a form database by collecting the results of three-dimensional measurements on a server

6. Ability to support reliable data required in the garment manufacturing industry (computer-aided design (CAD) data, etc.)

Related Works

While functions for three-dimensional fitting of a two-dimensional pattern by computer graphics are being introduced into more recent CAD software in the apparel industry, most of these functions target a standing position using a pre-defined torso or a standard human body.

Virtual fitting has been studied in the field of computer graphics. (Stefan et al.) performed a fitting simulation by micro-adjusting pre-measured clothing data, while (Igarashi et al.) studied a case in which clothing parts are interactively fitted onto a CG character. Nonetheless, there are no cases that enable automated measurements of the body form and posture when wheelchair users remain in a seated position to realize automated fitting and verify the fitting results.

Virtual fitting experiences have been investigated using augmented reality and mixed reality (MR) in actual points of sales for apparel (Hilsmann et al.) (EON Interactive Mirror). In most cases, these virtual fitting experiences were investigated by utilizing applications for sales promotions that do not actually involve rigorous body measurements. We had proposed a real-time MR fitting situation based on measurement data obtained using an RGB-D camera (Ichikari et. al.). However, that approach emphasized on the simulation of the outward appearance, thus failing to perform strict measurements of the body shape or coordinate with apparel CAD data. The virtual fitting application used in this study does not track the user in real time, but it measures the stationary user carefully in detail in client side and performs accurate fitting calculations at server side. The accurate fitting calculation is based on “Digital Mannequin” which resembles the users’ body form measured by three-dimensional measurement with mobile devices such as smartphone or tablets. The virtual fitting application also enables collecting body form data, which are very important for garment manufacturing

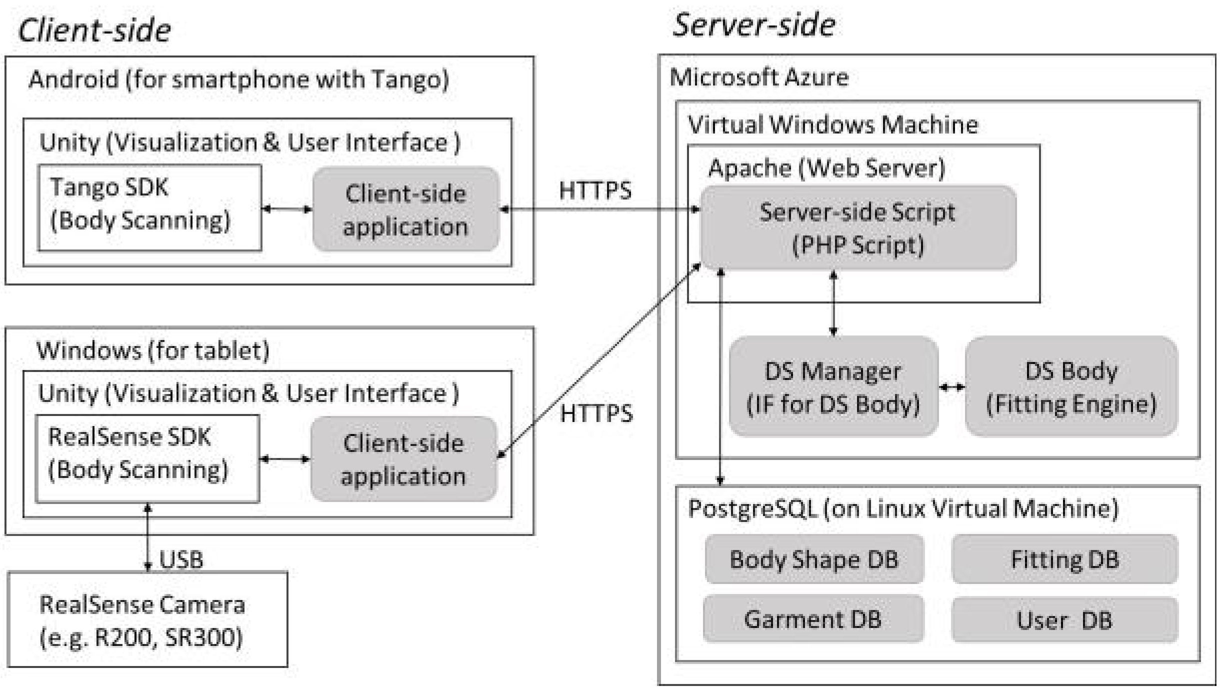


Fig. 2. System configuration

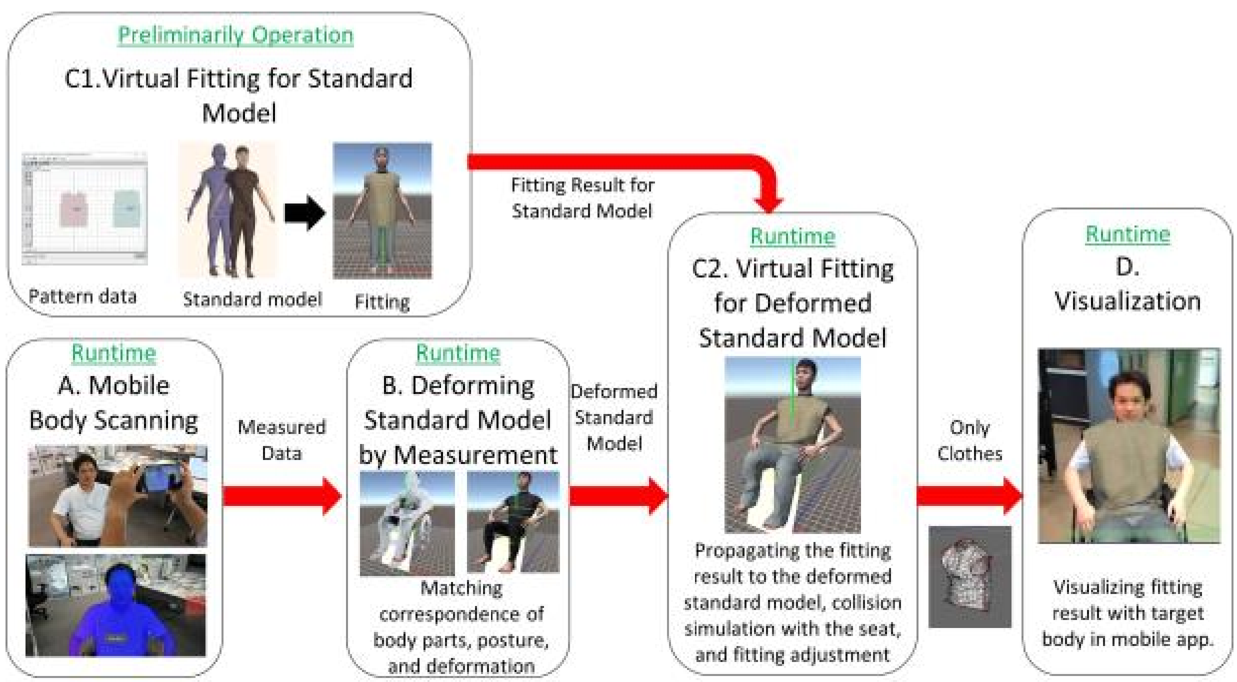


Fig.3. Workflow of the virtual fitting application

Discussion

System Design and Implementation

System overview

The major functions of this virtual fitting application are as follows: realizing body measurement through detailed three-dimensional visualization and providing a physically accurate virtual fitting result based on the measured data. To achieve these objectives, the system comprises a client-side application for performing three-dimensional measurements and visualization on the mobile device and a server-side application for performing the fitting simulation as shown in Fig. 2. The client-side application is installed on mobile platform such as Android or Windows using the Unity game engine. In order to utilize the-dimensional measurement functionality, Tango SDK is used in the case of Google Tango; and RealSenseSDK is used in the case of Windows tablet devices. The server-side application is implemented on a cloud using Microsoft Azure. The server-side application including the simulation engine is running on a virtual Windows machine on the Azure platform. The Apache web server is also running on the virtual machine for exchanging data with the client devices. On the server side, PostgreSQL server is also running on anther virtual machine for managing measurement data, garment data, and client identification data.

A detailed workflow of the virtual fitting application is shown in Fig.3. Each element of the flow is described below.

Mobile scan of the human body

In recent years, three-dimensional measurements on mobile devices such as smartphones and tablets have become possible owing to services such as Tango by Google and RealSense by Intel. This has enabled measurements of the size of a human body in a seated position without any direct contact with the user (via a mobile client). In this approach, seated positions of the wheelchair users are considered as measurement targets. Measurements were taken using the three-dimensional object scanning function that utilizes a distance camera provided by technologies such as Tango and RealSense. To use this function, the user was photographed by capturing the images of the body from various angles. Measurement results were obtained as a point cloud.

A. Correspondence between a standard model and the measured model

The human body shape used in the simulation needs to be combined by a homology model with defined topology and number of vertices and the measured point cloud is converted to a homology model. Through this conversion, the removal of holes and duplications in the measured point cloud and deletion of duplicate data become possible.

For the homology model, a standard human body character model called Dhaiba was used (Mochimaru et al.), which is provided by the Digital Human Research Group at the National Institute of Advanced Industrial Science and Technology (AIST). By using a human evaluation integrated environment that uses a digital human model called DhaibaWorks, Dhaiba models that are adapted to the form and posture of various height, weight, and landmark point sets can be produced.

Posture and form of the models are transformed by specifying rough mapping points in the Dhaiba model and measured scan. Blend shape transformation of several Dhaiba models and local deformation are performed so that the Dhaiba model is transformed to be close to the measured scan. Through this approach, the form of the Dhaiba model is transformed to match the measured model while preserving the homology. Through the alteration of forms, variation in forms among wheelchair users, such as thinning of the lower body, can be modeled. The Dhaiba model transformed by measured form data is delivered to the server-side application for calculating fitting results and collecting form data of the wheelchair users.

B. Fitting of the clothes to a standard model and the measured body

This study employed Dressing Sim Body (DSBody), a fitting simulation engine developed by Digital Fashion Ltd. DSBody can realize rigorous fitting simulation that considers gravity, frictional force, and cloth material characteristics. Human shape model as OBJ format, pattern data as DXF format, and suture line data are provided as inputs to.

Suture results for the human shape model can also be transmitted to another human shape model with homology in DS body. By using this function, simulation results can be automatically reflected onto another human body model with shared homology. First, calculations for the suture of clothes are performed for a standard Dhaiba model in standing position for clothing data at Stage C-1. Next, fitting simulation for the Dhaiba model that is transformed to another posture and form sent by the client can be performed at Stage C-2.

C. Verification of the virtual fitting results

Once the fitting simulation is completed on the server side, the results are sent to the client device as CG data limited to the clothing parts. On the client side, the fitting results of the user can be verified as a three-dimensional visualization.

Because the positions of the cameras at Stage (A) can also be recorded as a byproduct of three-dimensional measurements, the camera position and posture are used to superimpose and synthesize on to the real image from body scans offline. The perception of the user that he has physically tried the clothes is enhanced by the image of the user. By using the same homology model at all stages and by performing fitting calculations against all created clothes data, the user is able to choose from multiple clothing choices and try them when required.

Graphical user interface for garment selection

An example of the graphical user interface (GUI) for selecting garments is shown in Fig.4. Multiple choices of the garments are categorized into types of garments such as pants, skirt, jacket, and t-shirt. If the user selects a category, the choices in that category are visualized as small thumbnail icons with manufacturers' logo. Image of the focused item is enlarged with the attribute information such as the uniform resource locator (URL) of manufacturers' website for reviewing the item in detail. If multiple sizes are provided for the selected item, a size can be specified in this phase. If the user presses the "OK" button, the focused item is displayed in the right column as a selected item. The fitting calculation can be started by pressing "Start dressing" button. The status of progress is shown as the percentage during the calculation.

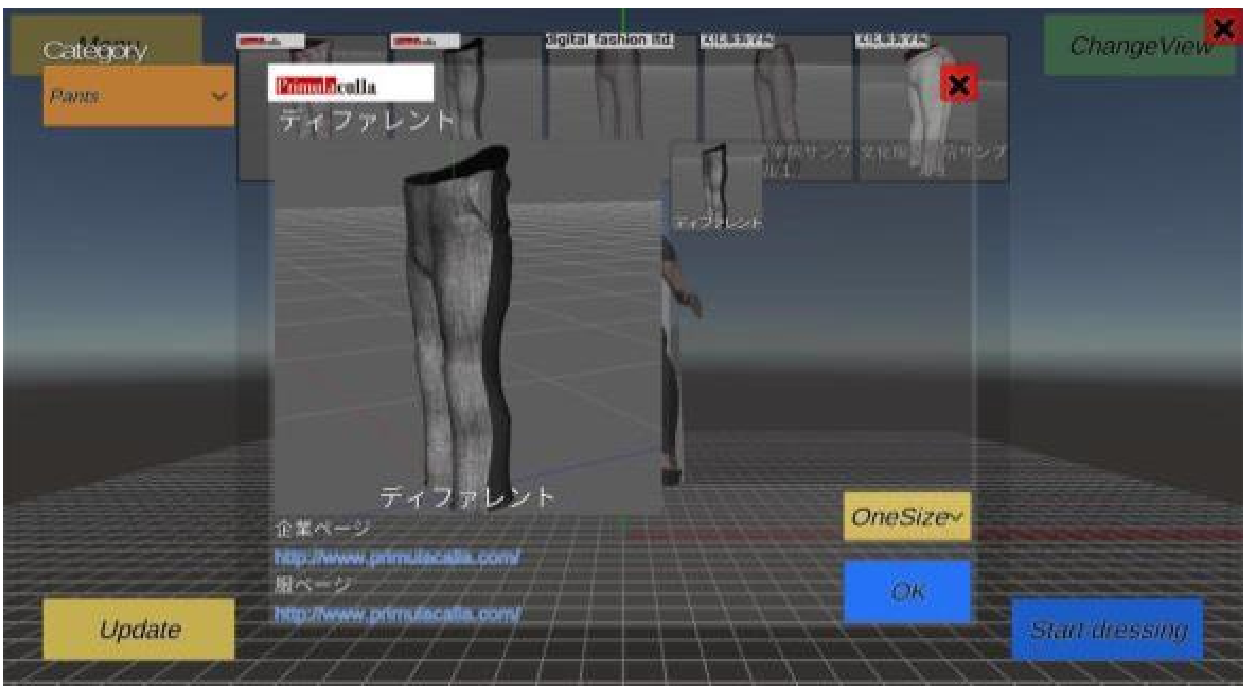
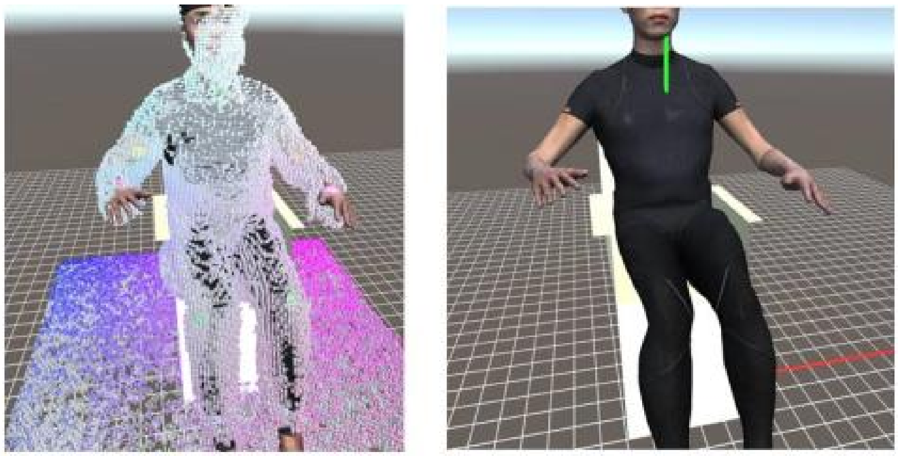


Fig. 4. GUI for choosing clothes from multiple choices

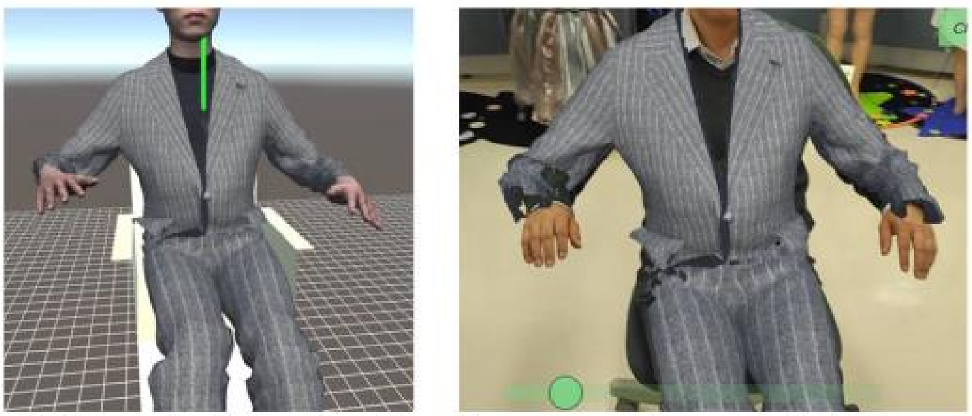
Experimental Evaluation

To test the system operation, the flow of operation from data measurement to simulation calculation and utilization of the simulated results was verified using the prototype system. The flow of the operation to final results was successful in the prototype system (Fig. 5). An example of the values measured at Stage B for chest girth, waist size at seated position, and thigh length is shown in Table 1.

In Fig. 6 and 7, pattern paper data for the clothes used in the simulation are presented. In this study, the authors received pattern paper data for wheelchair users from Bunka Fashion College and Kurashiki School Tiger Clothing Co. Ltd, which engage in clothing development for wheelchair users. Fig. 6. shows the pattern paper data of pants for the normal standing position. Fig.6. shows the pattern paper data of pants for the seated position provided by Bunka Fashion College. As shown in Fig. 6(b), the buttocks of the pants are misaligned, i.e, it appears that the pants are slipping down in the seated position even when they appear to fit in the standing position. Using the dedicated pattern paper data for sitting position, the buttocks are covered appropriately in the seated position as shown in Fig.7.(b). Fig.8. shows another example of fitting result for seated position. This skirt covered buttocks and fitted well during the sitting for avoiding bedsores. Fig 9 shows comparison between results with or without collision simulation with seat. Simulation result can be confirmed in Fig 9(b). By importing actual pattern data for wheelchair users, the effectiveness of the proposed system has been verified.



(a) Transforming the Dhaiba model to be close to the measured scan (b) Transformed Dhaiba model



(c) Fitting result (d) Superimposition of the result onto an image of a wheelchair user

Fig. 5. Example of virtual fitting in the prototype system

Table 1: Error of automated measurement

Measure area	Correct	Estimated
Chest girth	97 cm	98.8 cm
Waist	90 cm	86.3 cm
Thigh length	56 cm	53.3 cm

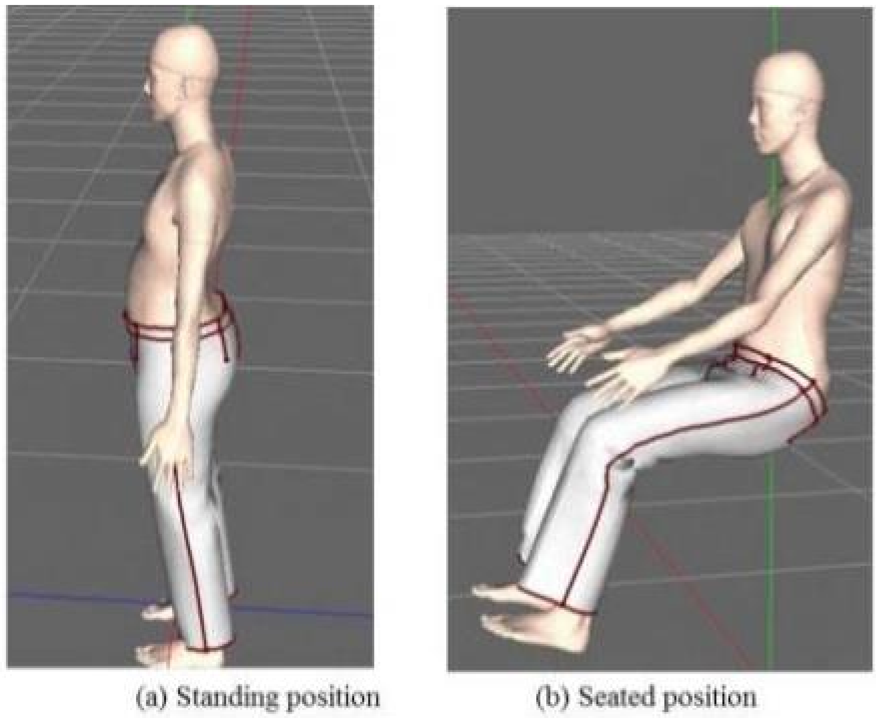


Fig. 6. Simulation results using pattern paper data for jeans for standing position

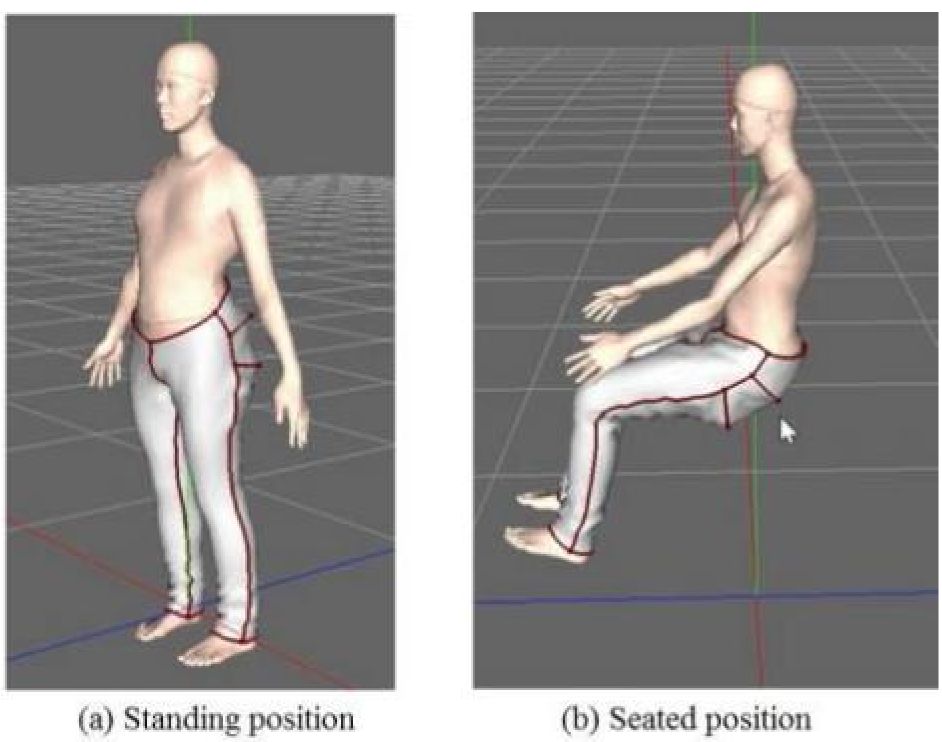


Fig. 7. Simulation results using pattern paper data for seated position

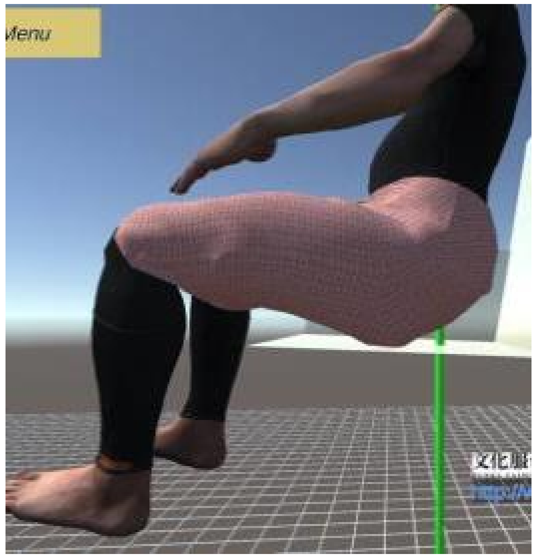
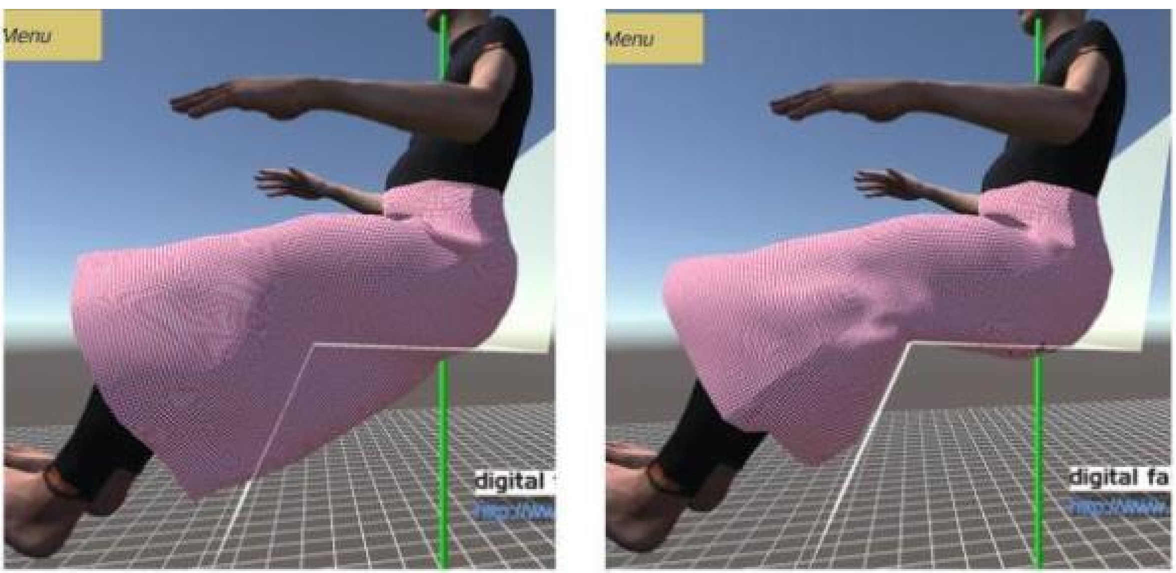


Fig. 8. Fitting result of a skirt designed for seated position



(a) Fitting without collision simulation with the seat (b) Fitting with collision simulation with the seat

Fig. 9. Comparison between results with or without collision simulation with seat

Conclusions

In this study, we propose a virtual fitting application in which wheelchair users can virtually try clothes while they remain in a seated position. The virtual fitting application was developed using a client–server model that comprised an Android device with three-dimensional measuring functionality and a server that realizes a dressing simulation. The users should possess a common mobile device to use this application. By placing a simulation engine on the server side, processing power of the server, which is greater than that of the mobile device, can also be utilized. In addition, there is also a merit in terms of intellectual property since there is no need to distribute a fitting engine to the client side. Therefore, the launch of the proposed application as a service is achievable in real time. Collection of form data necessary for manufacturing clothes has also become possible. Collected data can be utilized as the foundational data for the development of clothing for wheelchair users.

This paper focused on the implementation of the prototype that embodies the proposed concept of a virtual fitting application as well as on the verification of the application's behavior. The final goal is to provide a virtual fitting service by enabling wheelchair users to do trial fitting wherever they want and collecting their form data. Future studies will focus on the enhancement of this service by the automation of the position and posture mapping between measured data and the standard model and on improvements of accuracy of the transformation.

Acknowledgments

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SETT Framework, MODELER, and PODD AAC Intervention in Elementary Grades

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Abstract

We report positive outcomes for a pilot augmentative and alternative communication (AAC) intervention incorporating the Student, Environment, Tasks, and Tools Framework (SETT), Pragmatic Organization Dynamic Display (PODD) Communication Books, and the Model, Encourage, Respond (MODELER) strategy to support the communication development of elementary school-aged students. Communication is a vital tool for humans in moving through their world. Unfortunately, people who lack communication are rarely taught communication in the way that typical children acquire language, through naturalistic experiences where there is rich input and interaction with an expressive communication system that is perceptible and usable to the individual. As a result, communication rarely expands to be fully generalized. This investigation included an interdisciplinary person-centered planning process to help two school-aged students with complex communication needs develop AAC in a pilot study with an AB format preliminary pilot study in preparation for a single-case design study.

Keywords

Augmentative and Alternative Communication, AAC, SETT Framework, MODELER, PODD

Introduction

Communication is valuable for interacting socially, developing friendships, making requests, and expressing knowledge. It is a skill that is useful in interpersonal interactions across environments, including school, work, and home life (Van Tatenhove). Students who lack functional communication skills are more likely to struggle academically and exhibit behavior issues than their typical peers (Beukelman & Mirenda). These communication skills also impact an individual's adaptive, daily living, and social skills (Alzrayer, Banda, & Koul). For individuals who are unable to use natural speech as a primary means of communication, known as people with complex communication needs (CCN), augmentative and alternative communication (AAC) systems are means with which they can access language typical to that of their peers (Beukelman & Mirenda). However, it is often challenging to provide a rich language acquisition environment for children learning to use AAC because of the large knowledge and skill gaps their primary communication partners often possess. One promising approach to close this gap is communication partner instruction in AAC modeling (Mirenda; Sennott, Light, & McNaughton).

Model, Encourage, Respond (MODELER)

In response to the need to raise the skill and performance of communication partners implementing AAC interventions, Model, Encourage, Respond (MODELER) is an instructional strategy built around shared experiences with the communication partner 1) modeling the AAC system the child uses to express themselves, 2) encouraging the child to respond through techniques such as providing wait time and 3) responding to the communication attempt using techniques such as modeling AAC with an expansion or conversational recast (Sennott & Mason). MODELER was derived from the results of a systematic review of AAC modeling

(Sennott, Light, & McNaughton) and this method more closely resembles the way children who develop language typically communicate with the people in their life. MODELER is typically coupled with a person-centered planning process using the Student, Environments, Tasks, and Tools (SETT) Framework (Zabala). MODELER interventions planned using the SETT Framework can use various assistive technology aides and AAC systems and in this study the Pragmatic Organization Dynamic Display (PODD) (Porter) was used (see Figure 1).

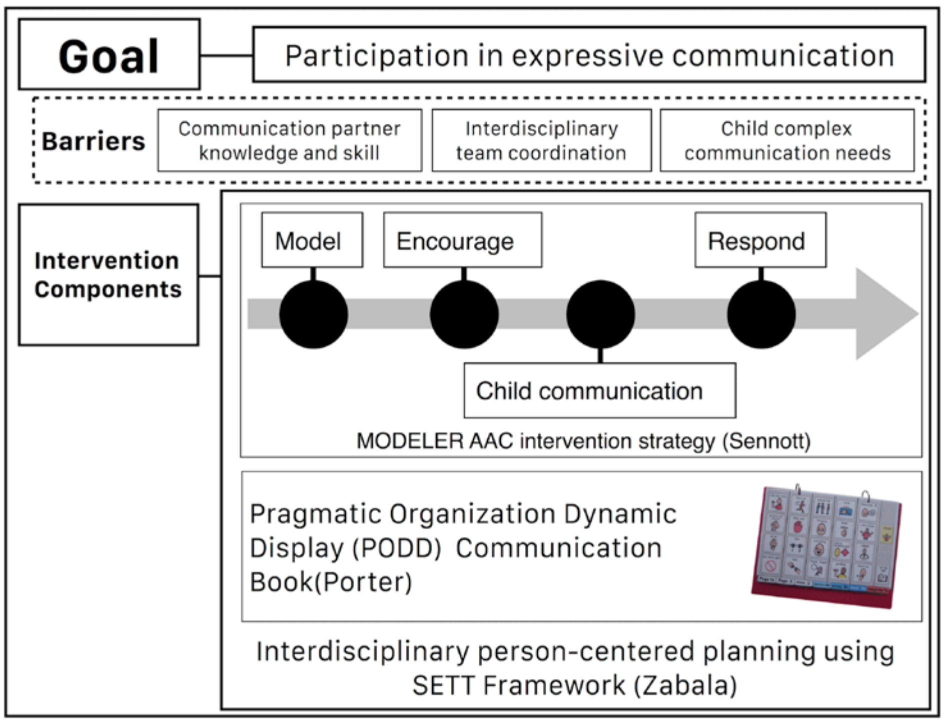

Fig.1. Study intervention model towards the goal of expressive communication skills

SETT Framework

The Student, Environments, Tasks, and Tools (SETT) Framework, developed by Joy Zabala, was designed to act as a guide, or framework, rather than a concrete protocol to follow. In developing the SETT Framework, Zabala shared a way for teams to organize their thinking as they gather key information about the student or individual being served, the relevant aspects of the environments they are engaging in, the tasks that the student is required to do in order to participate in the environment, and a description of the tools that have been used previously. Each area of the framework is guided by person-centered planning questions that get at the heart of each of the following areas: student, environment, tasks, and tools that can be revisited cyclically (Zabala, Bowser, & Korsten).

Pragmatic Organization Dynamic Display (PODD)

The Pragmatic Organization Dynamic Display (PODD) system created by Gayle Porter is both a method and tool for AAC intervention. While PODDs are frequently thought of as paper-based books or run on computer or tablet based AAC systems, the PODD system incorporates a method and approach towards the goal of generalized AAC usage. Porter defines the goal of AAC as, “for the person to meet his/her varied communication requirements as intelligibly, specifically, efficiently, independently and in as socially valued a manner as possible in order to understand others and to be understood (pg. 6).” To briefly summarize the approach, Porter advocates for aided language stimulation/ AAC modeling for authentic purposes in natural environments and an acronym (AARCH), standing for Autonomy (e.g. express own intentions), Accessibility, Requirements, Competence (e.g. across communication domains), and Habits (e.g. see the child, see the communication system). PODD books and computer based systems include a range of beneficial features for consistent navigation, efficient vocabulary arrangement, a range of pragmatic functions, predictably associated vocabulary, lists for adding vocabulary, and various access methods.

Research Question

The study investigated the following research question, “What is the impact of using the MODELER strategy to promote use of the Pragmatically Organized Dynamic Display (PODD)

(Porter) AAC system for students with complex communication needs in grades K-5 on the mean length of utterances and communication turns per session?"

Discussion

Setting and Participants

The study took place in and around a large urban city in the Pacific Northwest. The participants were primarily placed in a first-grade communication behavior classroom, and the sessions took place in the classroom and in the speech center. The participants were selected based on student parental permission and teacher willingness to participate in this Master's Degree project research study. In order to be included in this study, participants were required to meet the following criteria: (1) The students were to be school-aged; (2) They must have complex communication needs; and (3) Must be willing to participate in a SETT meeting with the parents, researcher, and the intervention package trained adult.

Sarah, a seven-year-old female elementary school student, was a first-grade student with Autism Spectrum Disorder. During her SETT meeting, the team expressed a desire to support her in communicating her needs and wants. Sarah engaged in self-harming behaviors at school and home which prompts ongoing concern for her safety; she has also been observed hitting teachers or peers in close proximity when upset or rejecting an activity. It is believed that the underlying factor for these behaviors is directly linked to her inability to communicate what she wants. She has very limited verbal skills and most of her phrases are echolalic or simple request like "all done" or "yes or no." Prior to intervention, Sarah was using a communication app on an iPad, but use was inconsistent between home and school which made it hard for her to learn how to use her AAC device efficiently. Additional concerns addressed at her SETT meeting suggested that Sarah struggled to view the iPad as part of her communication since it is utilized as a choice for free time and play. The suggested solution would be to designate an iPad solely for communication.

Robert, a seven-year-old female elementary school student, was also a first-grade student with Autism Spectrum Disorder. During his SETT meeting, his parents and the school team expressed a desire to support his ability to communicate his needs such as needing bathroom assistance, but also make requests when needed. The team was concerned that his lack of motivation with communication devices would interfere with his ability to excel. Prior to intervention, Robert was using a communication device on an iPad. This system was used only once a day, and due to the inconsistency in use Robert would only use this in one setting so his knowledge for the device was very little. He had a history of verbalizing some words, primarily echolalic phrases spoken by other people around him and not autonomous expressions of his wants, needs, or thoughts.

Research Design

This study was conducted as a AB format preliminary pilot study to prepare for a future single-case design experimental design of the MODELER technique when implemented with students with complex language needs using PODD based AAC. The dependent variable in this study was an increase in average symbolic communication turns through speech, AAC, sign or gestures. The independent variable in this study was the MODELER technique used to teach the participants how to appropriately express communication using their AAC methods as a language tool. The intervention used multiple visual representations in order to communicate, with the PODD AAC system as the primary tool. Throughout the baseline and intervention, a weekly observation was conducted to ensure communication partners' accountability and implementation fidelity.

Procedures

The study baseline and intervention duration was approximately four to six weeks. Throughout baseline, each participant used his or her pre-intervention modes of communication while engaging in a selected preferred activity. Choices for activities were selected based on student preferences and background knowledge about activities which have been previously enjoyed during speech lessons. The communication partner followed regular routines for speech lessons during baseline.

The first step for the intervention was to conduct a SETT framework meeting (Zabala, Bowser, & Korsten) with the parents, teacher, and researchers. Upon having this meeting, the group collectively decided which method of AAC would work best for the student's intervention and best fit their needs for communication. Both communication partners in the study who worked with the participants participated in a specially designed one-day introductory PODD training for the Universal Design Lab Teaching, Technology, and Theory Project conducted by Linda Burkhart. The communication partner also received training on the MODELER strategy until they fully understood the expectations regarding the consistency and fidelity of the strategy. A training session was performed with the communication partner and participant by the researcher to ensure the MODELER strategy was implemented correctly. The communication partner did not initiate any intervention until they were fully comfortable with the MODELER strategy used with AAC.

Data Collection

During intervention, the AAC system selected during the SETT meeting was used. The participant selected a preferred activity like they did during baseline, then the communication partner or interventionist used the MODELER technique to demonstrate the use of AAC with the participant. All sessions were conducted either during the participant's regular speech time or within their elementary school classroom. Data was collected during the academic day in a variety of settings. A language sample of interaction around a preferred activity was filmed and a five-minute clip was coded for the number of communication turns in that period. Internal validity was maintained by having an independent researcher who had not interacted with the participants' code 40% of the videos and comparing the data from the interventionist with the coder's data. Internal validity was maintained if the coding data reflected the same results for 80% of the scores. Coding scores reliably matched with over 90% accuracy.

Results

Prior to implementing intervention, all participants had limited choices for communication. A positive change in participant behavior was observed throughout the video based language samples and in anecdotal observations of the students throughout their days in the study. During baseline, all participants struggled to maintain focused attention that aligned with the planned activity with the communication partner. After intervention was initiated, participants began to become more engaged in the activity during the session and spontaneous communication began to emerge. The results of this short-term study demonstrate initial positive impacts on autonomous expressive communication.

Individual participant results overview

In one instance that vividly demonstrated the benefits of the intervention, Sarah was able to work through a personal problem with use of her AAC system and make a connection to her communication partner. In the language sample analysis, Sarah took an average of 10.33 communication turns during baseline, all of which were verbal, with an average MLU of 1.2

words. During intervention, she increased to 13.8 communication turns. Modes included 1 using AAC, .6 using gestures, and 12.4 verbal, with an average MLU of 1.55 words.

During baseline, Robert would pick a couple of books of his choice, but during the sessions he would have no way to verbalize what he saw in the books. For instance, during one baseline session he refused to finish the full session and got up, walked away, and refused to return to the session. Once intervention sessions started, Robert was showing progress in being able to express himself. In the language sample analysis, Robert took an average of 1.33 communication turns during baseline, all of which were verbal, with an average MLU of .7 words. During intervention, he took an average of 6 communication turns. Modes included AAC as well as verbalization and average MLU increased to 1.38 words.

Table 1. Participant Results Summary

Participant Information	Sarah (F), Age 7, 1st Grade	Robert (M), Age 7, 1st Grade
Special Ed Eligibility	Autism Spectrum Disorder	Autism Spectrum Disorder
Pre-intervention Communication	Simple echolalic verbalization, very limited iPad use	Simple echolalic verbalization, very limited iPad use
General EdInclusion	0% of day	0% of day
AAC Used for Intervention	PODD book & picture symbols printed from Proloquo2Go	PODD book & picture symbols printed from Proloquo2Go
Average Baseline Turns	10.3	1.3
Average Intervention Turns	13.8	6

Conclusions

Most children develop language rapidly between birth and age five. Yet, for a variety of reasons, many children with CCN do not develop language at that pace. Our participants fit that profile and this inquiry was an initial step in a line of research that studies both using the emerging practice of the MODELER strategy with the popular PODD approach to AAC. These initial positive results documenting increased symbolic communication using PODD by the participants points to the need to extend this research further. The researchers have worked directly with each participant's support staff to provide plans for continued use of both MODELER and the AAC systems used in the study. Participants are expected to continue to increase in both communication turns and MLU as they gain more familiarity with the AAC systems and see the role it plays in their life. Suggested next steps include training other classroom staff and professionals in contact with the participants as well as parents/guardians so that they might engage in more meaningful communication. Participants would benefit from increased use of the AAC system with modeling throughout their school day to promote generalization. The students in this study showed promising initial expressive communication gains.

In future research, a longer-term investigation of student development of communication competence using MODELER with PODD would offer a clearer picture of how MODELER and PODD effect the development of AAC for communication purposes. Additionally, more robust communication outcome measures, monitoring the range of what students are saying would offer insight into how MODELER affects student's abilities to use the full range of communication types. Future research can explore continuing to monitor the progression of the range of pragmatic functions expressed, vocabulary used, the child's MLU, and specific syntax and morphology structures used.

In summary, we see the value of providing enriching educational experiences for school-aged children who have complex communication needs as a way of translating into self-initiated and spontaneous outcomes with peer and teacher communication. The iPad and tablets have become popular tools for AAC intervention (Alzrayer, Banda, & Koul; Mirenda). However, it appears that despite increased access, the knowledge and skill of communication partners remains a substantial barrier to creating rich language learning environments for children with complex communication needs. At the individual team level and at the broader district, state, and national levels, we as an AAC community need to systematically close these gaps by increasing efforts towards ensuring all children develop expressive communication autonomy.

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Media Player Accessibility: Summary of Insights from Interviews & Focus Groups

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Abstract

Researchers conducted 13 interviews and focus groups with 37 individuals, primarily at the 2017 CSUN Assistive Technology Conference, to develop a better understanding of how persons with disabilities interact with video players. Insights that emerged include the following: (1) Screen reader users need better ways to seek to a new point in the media; a text input field might offer an effective solution; (2) Screen reader users prefer human-narrated audio description over synthesized speech, but if the latter is deployed, using screen readers to read the description text is a problematic method; (3) Screen reader users need access to captions and subtitles; (4) In order for a synchronized sign language window to be effective, users should be able to control its size, position, and opacity so they can place it in the perfect position relative to the video; (5) Having too many controls adversely affects usability, but there is no agreement as to which controls are expendable. One possible approach to address this problem is to offer users the ability to add/remove controls within Preferences. A recurring theme in the discussions is that of user preferences. Individuals should be able to customize their interface to best meet their unique needs.

Keywords

Web accessibility, video accessibility, captioning, audio description, sign language, usability

Introduction

Many people have difficulty fully accessing video content unless it includes specific accessibility features. The World Wide Web Consortium (W3C) Web Content Accessibility Guidelines (WCAG) 2.0 (Caldwell, et al.) includes multiple success criteria that apply to online media accessibility. For example, online video requires captions, transcripts, audio description, and synchronized sign language in order to meet the guidelines at various levels. HTML5 provides some of the necessary markup for delivering accessible video, including the <track> element, which can be used in conjunction with the <video> element to identify five distinct kinds of text tracks that can be synchronized with the video: Captions, subtitles, descriptions, chapters, and metadata (Hickson, et al.). All major browsers now support captions, and some support subtitles. However, none support all of the accessibility features made possible with HTML5. To address the gap between user needs and current support by browsers, the author of this paper created Able Player, a free open-source HTML5 media player (Able Player). Able Player has fully accessible player controls and where necessary, uses ARIA (Craig and Cooper) to expose interface elements to screen readers. Able Player is the only media player that fully supports the HTML5 <track> element, including all five kinds of text tracks (Thompson).

The goal of the current project was to develop a better understanding of how persons with disabilities interact with Able Player, and with online video players in general. The researchers conducted interviews with 37 persons with disabilities in early 2017, including 22 who are blind, 8 with low vision, 4 who are deaf or hard of hearing, 1 with physical disabilities that limit use of hands, and 2 who did not disclose their disabilities or use assistive technologies. Thirteen one-hour sessions were conducted, including 10 focus groups (with up to 6 participants each) and 3 individual interviews. One of each of these types of sessions was conducted on the University of

Washington campus; all others were conducted at the CSUN Assistive Technology Conference (California State University Center on Disabilities). In each of the sessions, participants were asked to describe their preferred technologies for accessing video online (e.g., device, operating system, browser, assistive technologies), where they tend to access video online, and their likes and dislikes about the media players they encounter on those sites. Participants had been asked to "bring your own device," and a wide variety of devices (Windows laptops, iPads, iPhones, and Android phones) and assistive technologies (various screen readers, ZoomText, and Dragon NaturallySpeaking) were represented in the sample. Participants were asked to try one or two of three online demos that were available. Each of the demos featured a simple web page with the same six-minute video loaded into Able Player. Participants were specifically asked to "explore the video player for two to three minutes." If they had questions during the demo, staff responded. Staff also pointed out specific features of interest (e.g., audio description, sign language, full screen, preferences) if, after two to three minutes, participants had not independently discovered these features. The specific demos participants were asked to try, and the specific features of interest that were pointed out to participants, depended on participants' individual characteristics: Demo 1 featured a video that included audio description, provided as a separate human-narrated video; Demo 2 included text-based audio description to be read aloud by users' screen readers; Demo 3 featured closed captions and synchronized sign language. After exploring the demo(s), participants were asked to describe their experience and talk about features they found most and least appealing, and improvements they would recommend.

Discussions

Key ideas that emerged from participant discussions tended to relate to one of six issues. Ideas are summarized below, grouped by issue in no particular order.

Issue #1: Seeking to a new point in the media

Several screen reader users said they experience frustration using the seek bar with most media players. Seek bars typically work by moving a slider left or right along a horizontal bar. Often this requires a mouse, or if it's keyboard-accessible, it provides insufficient feedback to be usable by screen reader users. The developers of Able Player have addressed this need in two ways. First, the seek bar is coded using applicable ARIA markup such as role="slider" and related attributes (King, et al.). Second, the seek bar is one of two ways to seek, the other being a pair of buttons labeled "Rewind" and "Forward." By default, both buttons and the seek bar move in increments equal to a percentage of the video duration, calculated automatically to balance precision with practicality (e.g., short videos have fewer stops than longer videos). After testing both seek methods, users generally rated these features favorably. However, many felt the interface could be improved in two ways.

First, the player currently fails to disclose the seek interval so users don't know where they will end up if they click a button or move the slider. This could be addressed by simply specifying the seek interval in the label or tooltip (e.g., "Forward 10 seconds"). Another option would be to offer preferences that allow users to define the jump unit (e.g., "seconds", "percent of video duration") as well as the value. For example, if users select a jump unit of "seconds" and value of "10," the seek interval would be 10 seconds.

Second, jumping in intervals, regardless of how the interval is defined, lacks the granularity that users sometimes need. If they need to jump to a very specific point in the video (defined in seconds or microseconds), this will be very difficult or impossible with an interval-based interface. Discussions yielded some possible alternative interfaces. One suggested by several users was a “Jump to time” edit box that would allow users to enter a specific time value in an intuitive format such as *hours:minutes:seconds*.

Furthermore, the participant who uses Dragon NaturallySpeaking expressed interest in using natural language commands like “Forward to eight minutes” or “Rewind to five thirty-seven.” Whether this sort of functionality should be handled by the media player or the speech-to-text tool requires further consideration.

Issue #2: Audio Description Preferences

Able Player includes a “Description” button that enables users to turn audio description on or off. This works differently depending on whether the description is provided as an alternative described version of the video (Method A) or as a timed text track (Method B). With Method A, the user receives the described version if the Description button is toggled on; otherwise they receive the non-described version. With Method B, the state of the Description button determines whether the description text is exposed to screen reader users.

Screen reader users who participated in the study said they were intrigued by the idea of having audio description read aloud by their screen readers; however, they noted several fundamental problems with this idea. One participant said they had learned to tune out their screen reader when it starts talking unexpectedly, as this often indicates an incoming message or other alert that really isn't critical. If this happens while watching a video, they suspected they would just ignore it and might take action to silence it. Another participant argued that the role of screen readers is to respond to user's commands, and while there can be latitude for alerts and other critical information, automatic reading of content generally falls outside this scope. This same participant demonstrated that pressing a key while description is being read interrupts the description, yet the video continues to play (without description, thereby breaking the accessibility feature). This illustrates why screen reader functionality and audio description playback should be separate.

Text-based description may still be viable, as producing it is much easier and cheaper than recording a human narrator to voice the description content. However, it may be preferable for the description to be self-voiced (e.g., with synthesized speech built into the media player, browser, or operating system) rather than read by the user's screen reader. Another benefit of self-voicing is that it can more gracefully support extended audio description, a technique in which the video is paused temporarily while description is read. Extended audio description is necessary if a video has too little suitable time to inject audio description content. Currently, Able Player handles this need by automatically pausing the video when description starts (a feature that can be enabled within Preferences). However, since Able Player depends on screen readers to read the description, it can't automatically resume playback because there is no mechanism by which screen readers can communicate when they're finished reading. Therefore, users have to resume playback themselves by pressing the spacebar. If a self-voicing solution were to be used, the duration of the voicing could be known and playback could resume automatically.

When screen reader users were asked whether, if given a choice, they would prefer human-narrated description or text-based description, all but one of the participants said they prefer human-narrated description. When asked why, they explained that human narrators speak with more natural inflection and emotion and are more likely to pronounce words accurately, whereas synthesized speech is more likely to be distracting. If asked whether this preference applied equally to dramatic and instructional content, all participants agreed that it was more applicable to dramatic content. Also, many participants were quick to stress that description by any method is better than no description at all.

One user reported a preference for text-based description because they want to be able to review it. They described a hypothetical interface in which the user is watching a video that includes text-based description. The user hears a block of detailed described content and wants to go back to review it, presses a keystroke that triggers a “Review description” function, which pauses the video and places focus at the start of the description block, and resumes playback by pressing the spacebar when finished.

Issue #3: Accessibility of Subtitles to Screen Reader Users

Although Able Player exposes text-based audio description to screen readers in sync with the video, it does not expose caption or subtitle text to screen readers. Currently, Able Player hides this content from screen reader users (using aria-hidden=“true”), based on the belief that a screen reader reading content in synch with spoken word in the program audio would be distracting and undesirable. Instead, Able Player reassembles all timed text content (chapters, descriptions, and captions/subtitles) into an interactive transcript, which can be read independently of the media playback.

However, one participant argued for captions and subtitles to be accessible to screen reader users, as these features provide critical content and functionality. Foreign language subtitles are particularly critical if the audio is in a language the user doesn't understand. Same-language captions can be similarly helpful, for example if the spoken audio is difficult to hear. If the various audio tracks have volume that can be controlled independently, a user could reasonably watch a video with the audio turned down slightly in favor of a louder caption or subtitle track, self-voiced with speech synthesis.

Issue #4: Synchronized Sign Language

Able Player currently supports sign language in a separate window. The window contains a separate video (e.g., a filmed video of a person translating the video into sign language). Both videos are operated by the same controller so they remain synchronized during playback. The sign language window can be toggled on/off using a “Sign Language” button on the player control bar. The window can be dragged or resized using either mouse or keyboard.

Currently the sign language video is fully opaque. Therefore, if users drag and resize the sign language window so that it's positioned on top of the program video, it obstructs any content that might appear behind it. Participants who are deaf or hard of hearing recommended including a user preference for sign language window transparency. If the signer's hands have sufficient contrast with their clothing, the entire window can be made semi-transparent without compromising understandability.

Participants suggested offering even greater customizability of the sign language window. In addition to having the ability to move and resize the window, users should be able to crop it in order to reduce the size of the video to the smallest size possible without compromising understandability. Users should also be able to resize the sign language window *without* preserving the aspect ratio.

Participants also suggested making it possible to move and resize the video window, as is currently possible with the sign language window. For sign language users, the optimum position of the video and sign language windows relative to each other may depend on being able to reposition both objects.

Issue #5: Quantity/Visibility/Order of Controls

One consequence of a media player having a large quantity of accessibility features is that it has a corresponding large quantity of buttons and controls, which can impede usability. One recurring suggestion was to hide less frequently used buttons behind a “More” button, exposing them to users upon request. However, when participants who suggested this approach were asked which buttons should be hidden, there was no consensus. Even buttons that are seldom used by individuals without disabilities (e.g., the Description and Sign Language buttons) were not considered “second-tier” by users who depend on those features. This suggests that there is no “one size fits all” arrangement. One participant suggested applying some intelligence to the problem and showing only the user's most frequently used buttons by default. However, this would result in a non-standard interface that varies across users, potentially changes over time, or perhaps worse, is self-fulfilling as hidden icons are less likely to be used, even if they might be useful. Another recurring suggestion was to provide users with the ability to control which buttons are included (e.g., a set of checkboxes within the Preferences dialog for all buttons and controls); users could toggle on and off which features they don't need or want.

Participants with eyesight differed on whether they wanted to see buttons on the screen all the time. Individuals with low vision expressed a preference for visible controls, as it can be difficult for them to find things that appear and disappear. Individuals with no reported visual impairments tended to prefer controls that are hidden during playback, especially in full screen mode. One participant felt very strongly about this, as they find the controls to be distracting and a barrier to their getting fully immersed in the video. All participants who favored hiding controls during playback felt that they should be easily recoverable (e.g., by pressing a key or moving the mouse).

Conclusion

A recurring theme in each of the discussions is that of user preferences. Individual users have unique needs. They should therefore be able to customize their interface and experience to best meet their needs.

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PERCEPT Navigation for Visually Impaired in Large Transportation Hubs

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Abstract

In this paper we introduce PERCEPT indoor navigation system deployed in North Station subway in Boston and the successful experimental results with Blind and Visually Impaired (BVI) users. This is the first time PERCEPT system is deployed in a large venue such as North station which is a crowded open space multimodal transportation hub. Using Bluetooth low energy tags we can localize the BVI users in real time. Given the user location, PERCEPT provides the BVI user with detailed landmark based navigation instructions to the chosen destination. Our experiments show that using PERCEPT system, the users can successfully and independently reach their chosen destination. All participants were very satisfied with PERCEPT and thought it was easy to learn and had a friendly user interface.

Keywords

Indoor navigation, blind and visually impaired, user interface, navigation instructions, transportation hub

Introduction

The World Health Organization reported that 285 million people are estimated to be visually impaired worldwide: 39 million are blind and 246 million have low vision (World Health Organization, 2016). There is a recognized positive correlation between independent travel employment, and issues of social equity. Independent navigation through unfamiliar indoor spaces is beset with barriers for BVI individuals. A task that is trivial and spontaneous for people without disabilities has to be planned and coordinated with other individuals for the BVI population. Although many improvements and aides are available to assist BVI individuals in outdoor settings, there has yet to be developed a reliable system that combines independence with accuracy and affordability for indoor navigation.

Currently there are no commercial systems that enable BVI users to independently navigate in indoor environments using real time localization and detailed navigation instructions that are automatically generated. There have been a number of research projects that aim to help BVI users navigate in unfamiliar indoor environments (Ahmetovic, 2017; Basso, 2015; Cheraghi, 2017; Doush, 2016; Garcia, 2015; Idrees, 2015; Jaffer, 2016; Jonas, 2015; Kim, 2016; Riehle, 2013; Rituerto, 2016; Serrão, 2014; Tandon, 2015; Waris, 2015; H. Zhang, 2016; X. Zhang, 2015). However, none of these papers has introduced an automatic generation of detailed navigation instructions which is necessary for a scalable and affordable indoor navigation system for BVI users.

PERCEPT system, first generation affordable and accurate indoor navigation system for the blind and visually impaired in buildings, which was introduced by the authors in (Ganz, 2014) was developed with the cooperation of the Massachusetts Orientation and Mobility division from Massachusetts Commission for the Blind. In PERCEPT system (Ganz, 2014) the user carries a Smartphone that runs PERCEPT application that provides landmark based navigation instructions helping the user navigate through indoor spaces to a chosen destination. PERCEPT includes three main modules: the vision free user interface using Android and iPhone accessibility features, the localization algorithm and the navigation instructions algorithm. The user downloads the application from PERCEPT server prior to his/her arrival to the indoor environment. The application flow includes the following steps: 1) start the application, 2) localize the user and determine current location, 3) select the destination using the accessible "vision free" interface, and 4) receive audible detailed navigation instructions.

In the first generation PERCEPT system we used Near Field Technology (NFC) for user localization which requires the BVI users to detect the landmarks (e.g. doors, stairs, escalators). NFC is a passive technology that does not require any maintenance (i.e., no need to replace batteries) and works well in buildings and indoor spaces where the users can follow the walls. We conducted IRB approved trials with 24 blind and visually impaired subjects that successfully navigated through a three-story building on the UMASS Amherst campus.

However, the users that participated in the trials requested changes so they can obtain navigation instructions anywhere in the physical environment. Motivated by the user feedback as well as the need to deploy the technology in large indoor environments (e.g. large transportation hubs) we developed the second generation of PERCEPT system. In this paper we introduce the second generation of PERCEPT system that involves Bluetooth Low Energy (BLE) tags deployed in the environment which enable PERCEPT to locate the users anywhere in the space and provide them with proper navigation instructions towards the chosen destination.

We have conducted a total of 6 trials in North Station subway. North Station is one of the main transportation hubs in Boston for the commuter rail and at peak time there are crowds filling the platform. Each study participant was asked to navigate from each of the main entrances to a unique subway platform in the station. When reaching the platform, they were asked to exit the station through a specific exit. Despite these environmental challenges all the study participants were able to successfully utilize PERCEPT to reach the subway platforms as well as find the specific exit. All participants were very satisfied with PERCEPT and thought it was easy to learn and had a friendly user interface. When asked if they would use PERCEPT in the subway if available, all subjects said yes. The feedback provided from the subjects was that overall the app is great for providing wayfinding in the subway and in its current state it would be beneficial in their daily lives.

In this paper we briefly introduce PERCEPT system without providing technical details on the localization and navigation algorithms. We focus on the system usability through a scenario as well as the trial results.

The paper is organized as follows. In the next section we outline the second generation PERCEPT system and in Section C (PECEPT in North Station) we provide a case study. The trials are described in Section D (Trials) and Section E (Conclusions) concludes the paper.

PERCEPT System

In PERCEPT system (Ganz, 2014) the user carries a Smartphone (Android or iPhone) that runs PERCEPT application which provides detailed landmark based navigation instructions helping the user navigate through indoor spaces to a chosen destination. PERCEPT includes three main modules: 1) the navigation instructions generation algorithm (Section B.1. Navigation Instructions), 2) the localization algorithm (Section B.2. Localization) and the vision free user interface using Android and iPhone accessibility features (Section B.3. Vision Free User Interface). Due to the complexity of the localization and navigation instruction generation algorithms we omit them from this document.

The user downloads the application from PERCEPT server prior to his/her arrival to the indoor environment. The application flow includes the following steps: 1) start the application, 2) localize the user and determine current location, 3) select the destination using the accessible “vision free” interface, and 4) receive audible detailed navigation instructions.

Navigation Instructions

In this system the user receives instructions through two modes: 1) detailed landmark based navigation instructions generated by the PERCEPT navigation instructions generation algorithm introduced in (Tao, 2015), 2) in case the user is lost he/she presses “Where am I” the user will receive a detailed description of the landmarks around him/her, the distance to the landmark and the orientation relative to the user orientation. In Section C (PECEPT in North Station) we illustrate the navigation instructions and “Where am I” modes through a detailed scenario.

Localization

The user is localized in specific zones (e.g., entrances, platforms, etc) in the venue using the receive signal strength indicator from multiple BLE tags which are deployed in the venue. BLE tags are used in many indoor venues such as malls. Retailers push to the users’ Smartphones advertising information when they are in the proximity of the product.

We have developed an optimal BLE tags deployment scheme which minimizes the number of tags while ensuring that every zone in the venue is covered by at least three tags. In case we deploy PERCEPT in a venue that has deployed infrastructure for localization we can use it in our system replacing the localization algorithm we developed.

Vision Free User Interface

The visually impaired user interacts with the Smartphone using vision free accessibility features provided by the Smartphone operating system. On Android this accessibility features is called “Talkback” and on iOS “Voiceover”. PERCEPT app is tightly integrated with these services to provide an accessible user experience. On both platforms the user can navigate the device through gestures on the screen. Using this accessibility service the users can immediately interact this application as they would with other common applications (Mail, Web Browser, Messaging, etc…). An example of the user interface is provided in Figure 1. In addition to vision free interface PERCEPT also is integrated with large font accessibility features for low vision users. This provides the user with consistent accessible font size across all applications that support this feature.

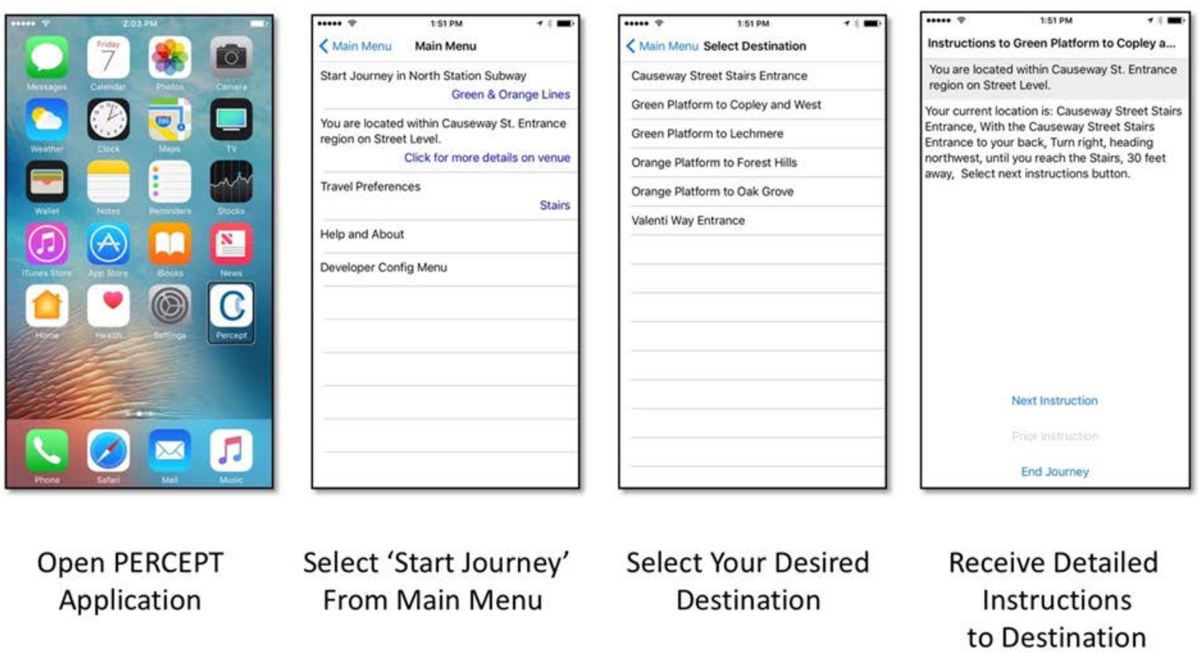

Fig.1. PERCEPT application user interface

PECEPT in North Station

We selected North Station Subway in Boston as an evaluation site for PERCEPT due to the following reasons:

- It is multi-modal hub for subway, commuter rail, bus, and Amtrak lines
- It gathers considerable foot traffic with often crowds of people waiting along the subway platform
- It has a large, complex layout, with vast open areas

Therefore, North Station is an excellent testbed for PERCEPT since it is a large, complex, open space, and crowded venue.

Figure 2 depicts the layout of all three floors of the North Station Subway starting from the street level entrance and going underground for two levels. We have deployed in all three levels 148 BLE tags in the environment (approximately 25 feet apart).

These tags are manufactured by Kontakt.IO which have a battery life of 5 years, have a small footprint (15mm x 55mm x 56 mm) as well as a replaceable battery. The cost of each BLE tag in quantities is approximately $15 (for larger quantities the cost is lower).

Scenario

The following scenario illustrates how PERCEPT system works in North Station. We follow the navigation experience of our hypothetical user, Kara, in North Station Subway. Kara would like to board the Inbound Green Platform to Copley and stations West. To get an idea of how Kara will use PERCEPT to navigate the station, we will cover the first five steps in her journey (follow the steps in Figure 3 using the markers):

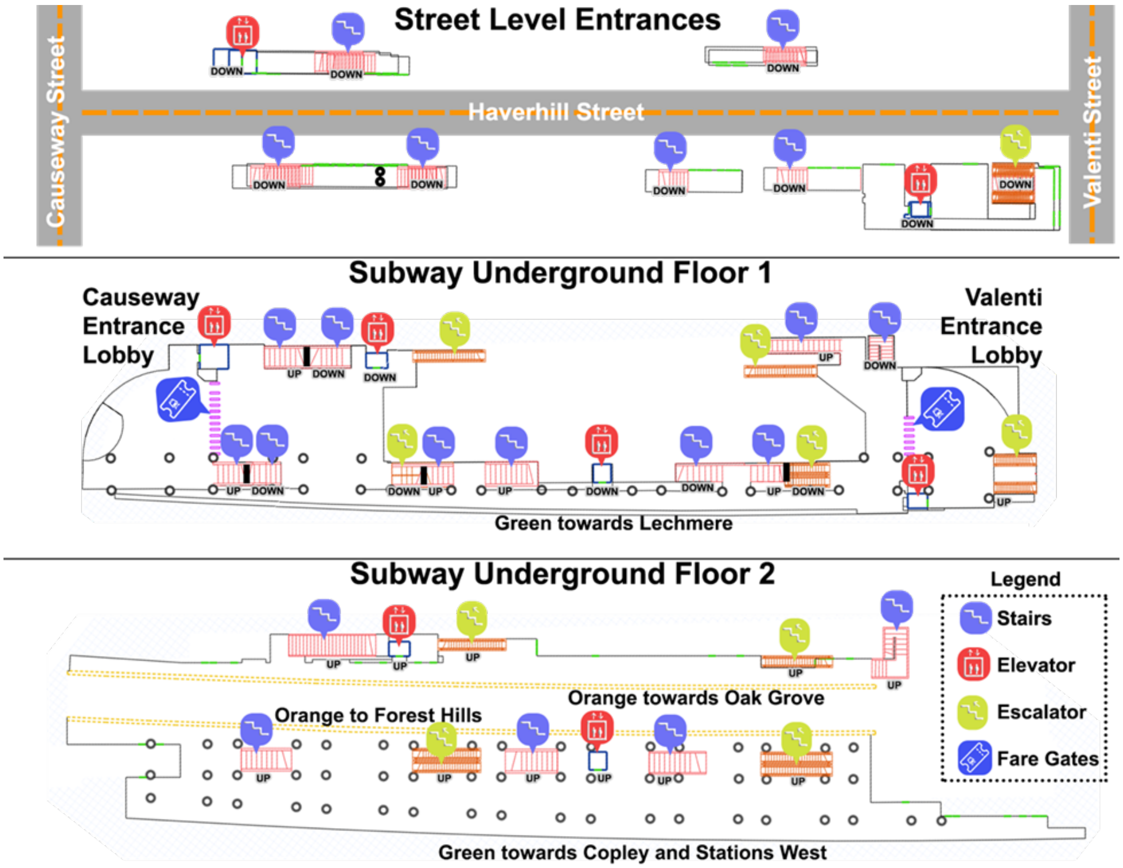

Fig. 2. North Station layout.

1. Valenti Street Entrance (Marker 1): Kara arrives at North Station and enters through the Valenti Street Entrance. Once inside, Kara takes out her iPhone and opens PERCEPT App. PERCEPT App informs Kara, “You are in North Station Subway that services green and orange subway lines. You are located on street level at the Valenti Street Entrance.” Kara selects ‘Start Journey’ in PERCEPT main menu, and then selects ‘Green Platform to Copley and West’ from a list of destinations. PERCEPT app responds: “Your current location is: Valenti Way Entrance, With the Valenti Way Entrance to your back, Walk straight ahead, heading north, reach the Escalator to your right side, 20 feet away, You will hear the escalator noise. Take the escalator down. Select next instruction button.”

2. Valenti Street Unpaid Lobby (Marker 2): After Kara reaches the bottom of the escalator she selects the next instruction button and the app responds: "With the Escalator to your back, Walk across the opening, heading north, until you reach the Fare Gates, 40 feet away, You will reach: Fare Gates. Select next instruction button."

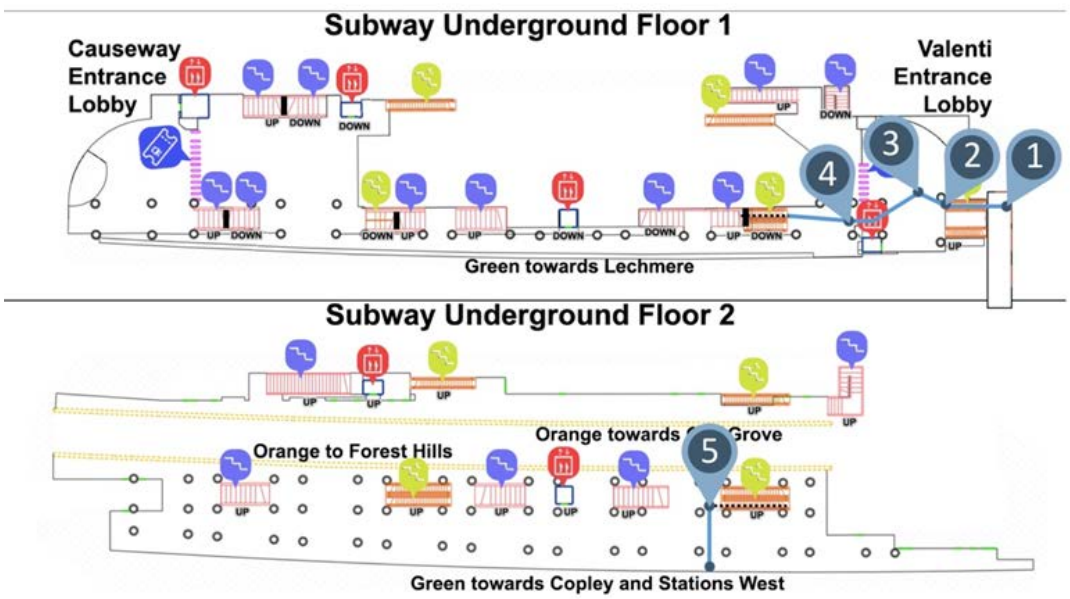

Fig. 3. User navigation journey in North Station (markers represent the navigation steps).

1. Lost in Unpaid Lobby (Marker 3): Kara follows the instructions but becomes disoriented along the route and is now unsure where to go. She shakes the phone to bring up the help menu and selects "Where Am I" option. The app then responds with the rerouting instructions: "You are currently in the Southern Unpaid Lobby region. You have been traveling northeast. The fare gates unpaid side is located 25 feet to your 11 o'clock in the northwest direction. Head towards fare gates unpaid side and go through the fare gates. Select next instruction button." Kara follows the rerouting instructions and is back on track and heading towards her destination.

2. Paid Lobby to Lower Platforms (Marker 4): Once through the fare gates Kara selects next instruction button and the app responds: “With the Fare Gates to your back, there is Escalator to your 12 o'clock direction, Walk across to the Escalator to your 12 o'clock direction, heading northwest, 50 feet away. Take the escalator down. Select next instruction button.”

3. To Green Platform to Copley and West (Marker 5): At the bottom of the escalator Kara selects next instruction button and the app responds: “Your current location is: Escalator, With the Escalator to your back, Turn left, Walk straight ahead, heading southwest, until you reach the Green Platform to Copley and stations West, 40 feet away, You will face the track. You have reached your destination: Green Platform to Copley and stations West. Select End Journey to end the journey.”

Trials

The user perspective is very important for our project. Given that our system is an assistive technology for the blind and visually impaired, it needs to be designed and constantly improved with user feedback. Users’ feedback helped us 1) identify the important landmarks to include in the navigation instructions, 2) determine level of details of the navigation instructions, 3) identify methods to reorient when the BVI user becomes disoriented in the venue, and 4) improve the user interface.

In this paper we report PERCEPT testing with 6 blind and visually impaired participants. None of the participants were familiar with the North Station venue and its layout although a few participants had shared that they have been in the station in the past. We do not collect information such as age, vision acuity, and other personal health metrics, however the participants did share the level of vision they had which ranged from no visual acuity, to some light perception, to some vision and shapes, to partial blurred vision with a limited field of view.

Each trial includes hands-on orientation, PERCEPT trial, and post-trial questionnaire.

Part I: Hands-on Orientation

The hands-on orientation includes sit down orientation and on site experimentation:

- Sit down orientation: The instructor goes over PERCEPT app functionality and answers any questions the participant has. When the participant is comfortable they proceed to on site experimentation.
- On site experimentation: the participant uses PERCEPT App in North Station subway along routes that will not be included in the actual trial. This allows the participant to become familiar with use of PERCEPT in the environment without compromising the trials. The Instructor answers any questions the participant has and when the participant is comfortable they move to Part II described below.

Part II: PERCEPT Trial

We asked the participant to accomplish the following four navigation tasks (see Figure 4) that include two entrances (to/from) and two subway platforms inbound/outbound (to/from):

- **Task 1:** Causeway Street Entrance (**A**) to Green Line Platform towards Lechmere (**B**) **– RED**
- **Task 2:** Green Line Platform towards Lechmere (**C**) to Causeway Street Entrance (**D**) **– BLUE**
- **Task 3:** Causeway Street Entrance (**A**) towards Green Line towards Copley and stations West (**E**) **– GREEN**
- **Task 4:** Green Line towards Copley and stations West (**F**) to Valenti Street Entrance (**G**) - **PINK**

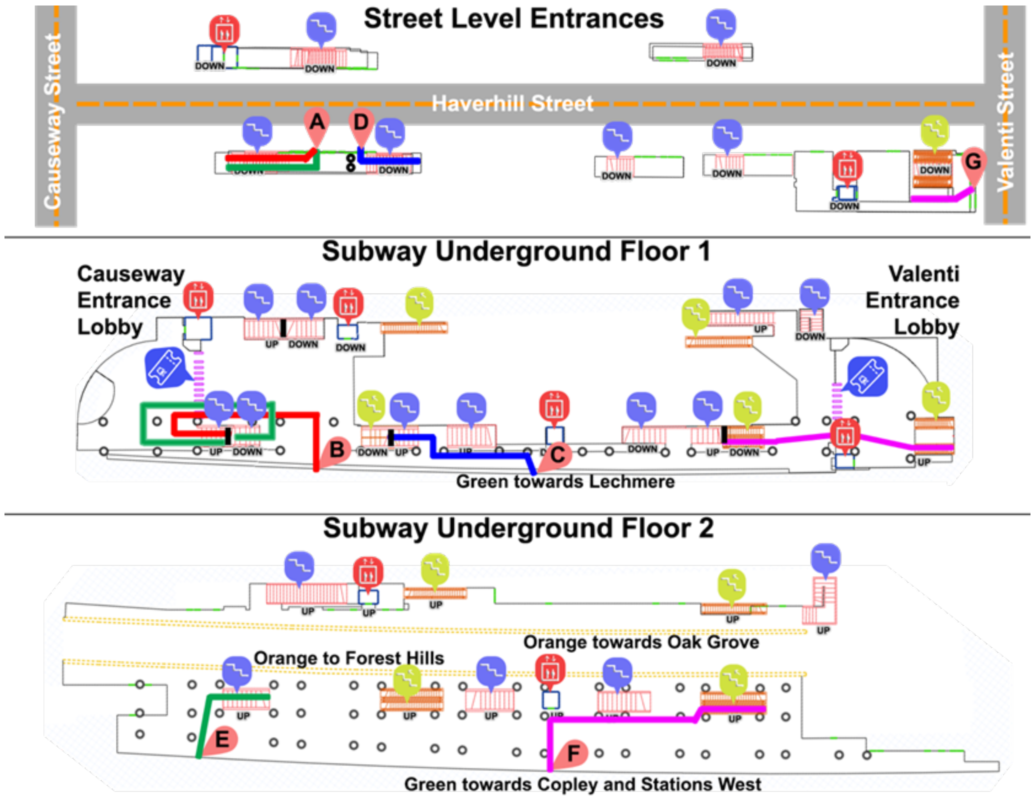

Fig. 4. Landmarks (markers A-F) used in trials navigation tasks

During the trial the participant is asked to complete these tasks relying only on their mobility skills and PERCEPT App. The Instructor accompanies the participant at all times but will no longer answer any questions. For each navigation task each participant was brought to a specific starting location in the venue and was told to navigate to a specific destination. Once the study participant had confidence that they reached the destination, they were required to indicate to the instructor that they had reached the destination. In the circumstance that they had indeed reached the destination the instructor would bring the participant to the next starting point to begin the next navigation task. If the participant was not at the location they would be informed by the instructor and asked to continue to the destination. In case the participant cannot proceed without assistance we determine the navigation task as unsuccessful. The trial ends either when all tasks are completed or the participant decides to stop.

Part III: Post Trial Questionnaire

After the trials we collected the participants' feedback and experience using a qualitative questionnaire. All six participants were able to use PERCEPT to complete each of the four navigation tasks with no outside assistance.

It is important to note that we expect for that the user will make mistakes (i.e., reach wrong landmarks or just get disoriented in the environment) and therefore require rerouting as provided by the application. Rerouting assistance in the application includes the ability to press "Where am I" as well as getting instructions from any landmark to the chosen destination. It was interesting to observe that the participants reported that they have built a mental map of the environment using the application rerouting feature as well as the "Where am I" feature.

Feedback per Task

The study personnel observed each one of the trial participants (P1-P6) while performing each one of the four navigation tasks. Table 1 includes these observations quantified as follows:

1. Reached destination with no issues

2. Reached destination with few issues

3. Reached destination with issues and required rerouting

4. Unable to reach destination.

Table 1. Users (P1-P6) feedback for the four navigation tasks

Navigation Tasks	P1	P2	P3	P4	P5	P6
Task 1	2	1	1	1	1	1
Task 2	1	1	1	1	1	1
Task 3	2	1	2	2	1	2
Task 4	3	3	3	1	1	3

We observe that the study participants had the most trouble with Task 4 which is indeed the most complex. In Task 4 the participant begins in a large open area and is asked to cross this large open area to reach an elevator in the middle of the open area. However after some time, the participants reached the destination.

Trial Feedback

Each participant was asked to score their agreement with specific statements related to their experience during the trial. The score followed Likert scale from 1 strongly disagree to 7 strongly agree with, with 4 being neither agreeing or disagreeing with the statement. The six statements, individual participant scores, and averaged score are provided in Table 2.

Table 2. Post-Trial questionnaire using Likert Scale scores

Statements	Average Score	P1	P2	P3	P4	P5	P6
Easy to learn how to use system	6.7	7	7	7	7	6	6
Easy to use the system	6.7	7	7	7	7	6	6
Trial design was easy to complete	6.3	6	6	7	7	7	5
Easy to use User Interface	6.5	7	6	7	7	5	7
System provided sufficient re-orientation information when lost	5.5	5	7	7	6	3	5
I am confident I will reach the destination using the system	6.7	6	7	7	7	7	6

Conclusions

In this paper we introduced the second generation PERCEPT system which enables independent indoor navigation in large and open indoor environments such as subway stations. The system was deployed at the North Station subway in Boston. We describe in details the experiments conducted with BVI users. All six BVI users successfully navigated through this subway station using PERCEPT application. Moreover, all participants were very satisfied with the system as evidenced by their very high scores in the post-trial questionnaire.

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Intellectual Disability, Literacy, and Assistive Technology in the Community College Setting

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Abstract

This pilot project utilized a mixed-methodology approach to investigating assistive technology (AT) with students enrolled in a college program for students with intellectual disabilities. Its purpose was the provision of AT-based software, training, and support to examine changes related to academic learning and independence. Twelve college student participants were assessed using pre- and post-intervention assessment tools. Six student participants and five front-line Learning Facilitators also participated in focus groups. Focus group data were analyzed inductively resulting in seven emergent themes; assessment data were analyzed statistically and showed an increased trend in scores over time.

Keywords

Assistive technology, college, post-secondary, intellectual disability

Introduction

The Community Integration through Cooperative Education (CICE) college program began in Ontario, Canada in 2012 to provide post-secondary learning support in an inclusive environment primarily for students with intellectual disabilities (ID). Ontario Colleges (2017) advertises CICE as:

> The opportunity to experience college life and pursue postsecondary education, with courses tailored to meet your individual needs. You will learn the skills you need to be independent in your community and find employment in your chosen field. (para. 1)

CICE is also described as: “the opportunity to pursue a postsecondary education, develop skills to help prepare for employment, and experience college life” (Mohawk College, n.d.). Students are supported by Learning Facilitators (LF), part-time paraprofessionals. The LF role focuses on individual academic potentials (Mohawk College, 2014). The use of assistive technology (AT) in this role, however, was not a widely used or an inherent part of related programming. The purpose of this project was to provide AT software, training, and support to examine changes related to academic learning outcomes and levels of independence.

Literature Review

Post-secondary programs are seeing an increase in enrollment of students with intellectual disabilities (ID); however, such students need effective strategies to access course information and complete course requirements (Chezan, Drasgow, & Marshall, 2012) such as accommodations (including AT), explicit instruction, strategy instruction, and systematic evaluation (Cannella-Malone, Konrad, & Pennington, 2015). Accommodations can include note takers, extra time, lighter course loads, quiet places for exams, or copies of visual aids. One accommodation area that is gaining ground is the use of AT: “any piece of equipment, software program or product system that increases, maintains or improves academic capabilities" (Malcolm & Roll, 2017). Three broad groups of AT exist: general use (e.g. word processing), assistive computer technologies (e.g. Braille printers), and adaptable technologies (e.g. dictation software) (Fichten, Asuncion, & Scapin, 2014). Additionally, AT falls under multiple functional domains, including communication, education, inclusion, employment, and leisure (Wehmeyer, Smith, Palmer, & Davies, 2004). Malcolm and Roll (2017) students used available AT frequently, in multiple settings, enjoyed its use, and found that it supported their studies.

Technology can improve quality of life for students with an ID (Palmer et al., 2012) and promote independence. Additionally, technology can contribute to learning and increasing skills through effective and efficient strategy use (Chezan et al., 2012). For students with ID, AT can improve home and community functioning ,transitioning, time management, and organization skills—amongst others (Mechling, 2011; Wehmeyer, Tassé, Davies, & Stock, 2012). Research has shown that AT is helpful in secondary school for students with ID; however, less research has been completed on post-secondary programs (Bouck & Flanagan, 2015).

Students are dynamic in their needs, and a key aspect of helping them with their studies is to assess their specific needs and match them with appropriate AT. Students who are supported and can participate in school and community based activities benefit from their use of AT. AT should have a universal design, to help eliminate barriers, gain independence and environmental control for individuals with ID (Wehmeyer, Tassé, Davies, & Stock, 2012). With proper training in demonstration of the AT, combined with strategies, students with ID can greatly improve their educational experience and outcomes.

Despite the fact that AT is predominant in schools, studies suggest that individuals with ID have limited access to technology and use computers much less than their peers (Palmer et al., 2012; Wehmeyer et al., 2004). Barriers to fully utilizing AT are problematic, and include cost, knowledge, and beliefs, as well as areas of impairment (Ayres, Mechling, & Sansosti, 2013; Carroll, 1993 as cited in Wehmeyer, Smith, Palmer, & Davies, 2004; Copley & Ziviani, 2004; Derer, Polsgrove, & Rieth, 1996; Mechling, 2011). Computers, for example, can be costly (e.g., purchase, upgrading, maintenance, repair) (Mechling, 2011). Thought Palmer et al. (2012) found 49.7% of families with at least one member using computers, 12.7% noted a lack of access to this potential benefit. AT use requires training and strategies so that students get the most out of their technology—such as what AT is, which devices meet individual needs, and full utilization of AT potential (e.g., fairness during assessment) (Ayres et al., 2013; Copley & Ziviani, 2004; Cohen and Spenciner, 2015; Wehmeyer, Smith, Palmer, & Davies, 2004).

Most research on AT to date has focused on students with learning disabilities rather than an intellectual disability; most AT research has focused on reading assistance, and less research has been completed on AT for improving writing skills. To date, the most supported and researched method appears to be *strategy instruction* for writing skills; most commonly, "self-regulated strategy development" (SSRD) (Joseph & Konrad, 2009). SSRD focuses on learning strategies and teaches knowledge for planning and composing writing, using a gradual release of responsibility mode where students have more efficacy as they proceed through development, discussion, modelling, memorization, support, and independence. Students who learned SSRD produced longer, more complete, qualitatively better pieces (Graham, Harris, & Mason, 2005). Most research into writing strategies has focused on writing quality and accuracy, and less on planning and other prewriting tasks (Asaro-Saddler, Knox, Meredith, & Akhmedjanova, 2015; Joseph & Konrad, 2009).

Methodology

This project is an example of a mixed-methodology pilot study, utilizing techniques from qualitative and quantitative traditions to provide a fuller understanding of a research purpose; in this case, from the point of view of the disabled student participants themselves as well as their front-line LFs (Mertens & Hesse-Biber, 2013). The quantitative component (measuring academic learning outcomes) and the qualitative components (exploring levels of independence) provide complementarity, where “the intent is to measure overlapping but different facets of a phenomenon” (Frels & Onwuegbuzie, 2013, p. 185).

Participants & Resources

Following ethics clearance (June-July 2015), CICE students were recruited primarily through a group presentation including a question and answer period with researchers. Interested students completed written consent forms distributed and collected by a research assistant (Sept.-Dec. 2015). From three cohorts of 20 students each, 12 students initially agreed to take part. Ten students fully completed both pre- and post-intervention assessments (six female, four male; aged 19-23), and six students took part in at least one focus group. Five LFs (two male, three female) took part in at least one focus group. Three researchers, two research assistants, two WordQ-specific trainers, seven LFs, and nine student LFs supported this applied research; the latter provided intermittent, rotating support in this short-term student LF role. Technology programs and training for students included WordQ (ST4 Learning, 2015), Dragon NaturallySpeaking (speech-to-text) (Nuance, 2014), Livescribe Smartpens ™ (audio recorders) (XYZ, Inc., 2015), NaturalReader (screen reader) (NaturalSoft Ltd., 2014) as well as individual training on built-in smart device preference settings (e.g., text-to-speech, word prediction, font size) (see Table 1).

Table 1. Student AT Training. (*Brackets indicate approximate training time)

Student	**Word Prediction (WordQ)**	**Speech-to-Text (Varied) S= Siri™ D= Dragon Naturally Speaking**	**Text-to-Speech (Natural Reader)**	**Audio Recording (Livescribe Smartpen)**	**Word Prediction (Smart Devices —Varied)**	**Preference Settings (Smart Devices Varied)**
1	Y		Y (15)	Y (20)	Y (10)	
2	Y		Y (15)		Y (10)	
3	Y	Y (20)* S			Y (10)	
4	Y	Y (20) S	Y (15)		Y (10)	
5	Y				Y (10)	
6	Y	Y (120) D	Y (30)		Y (15)	Y (30)
7	Y	Y (20 x 2) S	Y (30)	Y (40)	Y (15)	Y (30)
8	Y				Y (10)	
9	Y		Y (40)	Y (40)	Y (15)	Y (30)
10	Y					
11	Y	Y (120) D	Y (40)		Y (15)	Y (30)
12	Y					

Training Processes

Each student participant individually completed approximately 30-minute needs assessments, recording responses to open-ended questions around goals and needs. Responses guided the selection of individual AT (see Table 1), and training was provided to students and LFs to ensure its ongoing support and use. All participants initially attended a 30-minute workshop-style group training with follow-up individualized support provided by LFs throughout the duration of the research project. Students were trained along with researchers, representing Patton's (2015) categorization as *learning with* participants. LFs were further trained in three-hour group workshops by the LF supervisor, researchers, and a technology developer (e.g., WordQ, AT options) and were provided with ongoing independent training opportunities (e.g., videos) delivered through an online learning management software system.

Data Collection

The below data collection techniques would be categorized as *learning about* participants (Patton, 2015).

Quantitative Assessments

Student participants were assessed using two pre- and post-intervention assessment tools to examine reading and writing skills. Initial writing samples were taken for *Readability* analysis; post-AT training writing samples were also taken. Readability, a built-in mechanism of Word, provides one-click information about written text, such as number of words per sentence (see Table 2 for a full listing of subtests). The *Diagnostic Online Reading Assessment* (DORA) was also completed pre- and post-intervention. DORA was designed as a K-12 measure that provides assessment data across eight sub-skills of reading (see Table 2) allowing for AT utilization. During post-intervention assessments, students were permitted to utilize assistive technology tools. Assessments were scored, scores were compiled on Excel spreadsheets, and analyzed for quantitative change (see Results).

Table 2. DORA & Readability Subtests. (Passive sentences is the only measurement that is a percent rather than a whole number)

DORA Measurement	Readability	Type & Measurement
High frequency words	Counts	Words
Word recognition	Counts	Characters
Phonics	Counts	Paragraphs
Spelling	Counts	Sentences
Oral vocabulary	Averages	Sentences per paragraph
Reading comprehension	Readability	Words per sentence
Reading comprehension	Readability	Characters per word
Reading comprehension	Readability	Flesch Reading Ease
Reading comprehension	Readability	Flesch-Kincaid Grade Level
Reading comprehension	Readability	Passive sentences (%)

Qualitative Focus Groups

Independent focus groups were carried out with both LFs and student participants mid- and post-intervention to examine shifts in independence as well as social validity. Focus group interviews were facilitated using a semi-structured interview (see Table 3), audiotaped, and transcribed. See Table 4 for further details.

Table 3. Focus Group Questions.

CICE Students	**Learning Facilitators**
How do you feel about using AT to complete your homework?	How do you think the AT study for the CICE students are going?
What do you like best about using AT?	Is there any additional AT training you would like to receive in order to support the students' Individualized Assistive Technology plan?
What do you like least about using AT?	How are you doing with tracking the hours you're working with the students?
Can you share any ideas where AT could help you more?	How are the students using the AT?
How do you feel about using AT for social communication (such as Facebook, email, texting, etc.)?	Do you think the students are becoming more independent with their studies? Why or why not?
Before being introduced to assistive technology you may have needed to wait for help from a LF to do your homework. How has AT changed this, or not?	
Do you feel using AT for homework or social communication has increased your independence? If so how?	

Table 4. Focus Group Participants.

Type of Intervention	**Learning Facilitator Participants (Facilitated by researcher)**	**College Student Participants (Facilitated by RA with presence of researcher)**
Midway Intervention	*n* = 5	*n* = 4
Post-Intervention	*n* = 2 (completed as individual interviews)	*n* = 3

Results

Paired t-tests were completed for pre-post DORA and Readability assessments. This small sample size impeded the detection of a significant change; however, the average percent change for each student was also calculated and showed an increasing trend for most participants (6/10; 60%); all male participants showed improved Readability scores (4/4; 100%). Figures 1 and 2 are presented in order of descending percent change for each assessment tool. Figures 3 and 4 are sorted by identified gender.

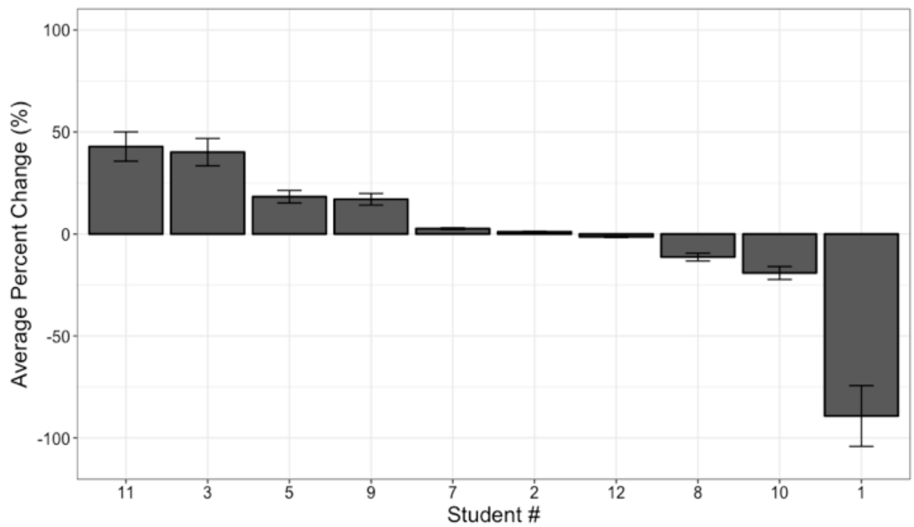

Fig. 1. Paired t-tests pre-post DORA presented in order of descending percent change.

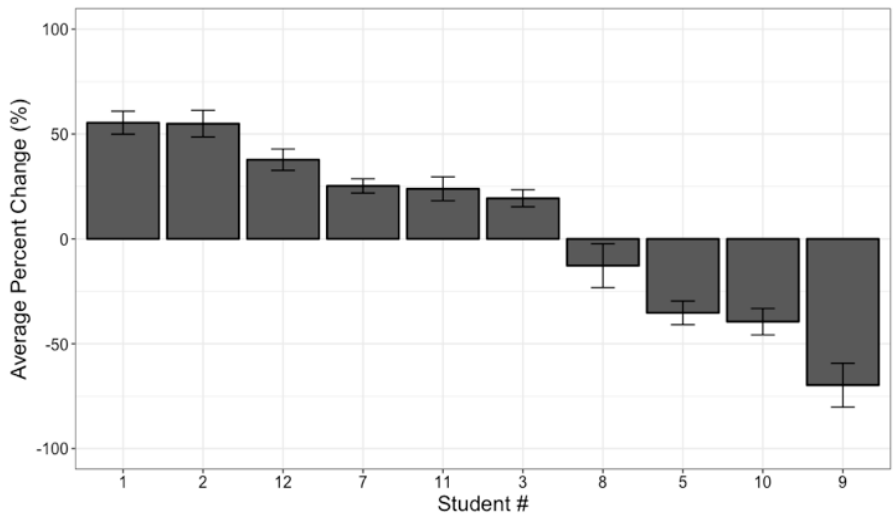

Fig. 2. Paired t-tests pre-post Readability presented in order of descending percent change.

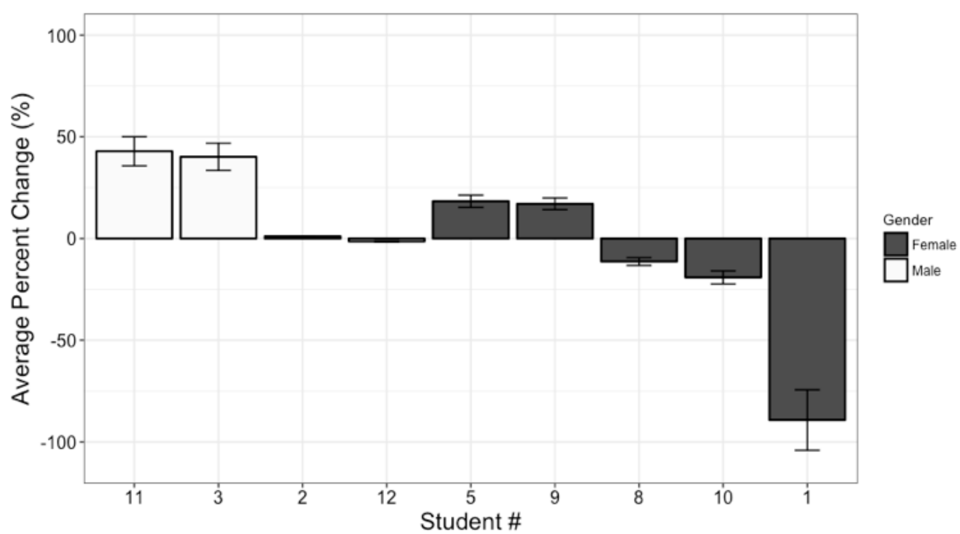

Fig. 3. Paired t-tests pre-post DORA are sorted by identified gender.

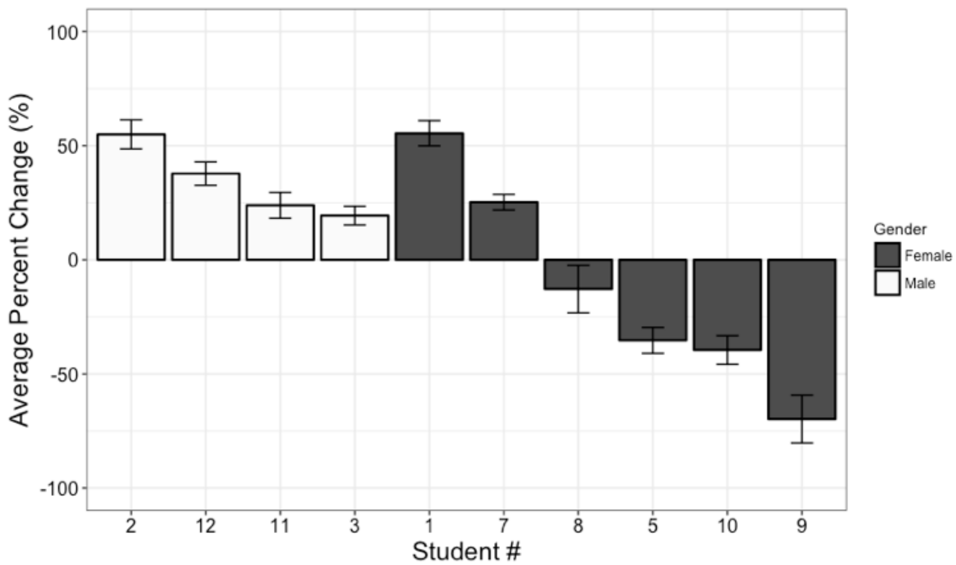

Fig. 4. Paired t-tests pre-post Readability are sorted by identified gender.

Focus group transcripts were duplicated in *Dedoose* (SocioCultural Research Consultants, 2016), coded, and thematized (Braun & Clarke, 2006; Creswell, 2018). Quantitizing these data (Frels & Onwuegbuzie, 2013) for student participants, seven codes emerged with 59 excerpts of text; most commonly, 39 segments focused on positive outcomes and 23 focused on WordQ. For LFs, six codes emerged with 44 excerpts; 22 were focused on next steps and 10 on skills for life. Examining only quantitatively robust coding patterns, it appears that students are looking back with positivity on their experiences, and LFs are looking ahead for future improvements. Five overall themes also emerged.

Efficiency, Effectiveness, and Productivity Develop

CICE students found positive outcomes of their AT related to efficiency, effectiveness, and productivity. One student expressed that: “It has changed [homework time] greatly. Before it used to take me an hour and it [AT] cut it down into 30 minutes” and “It cuts the time down in half ... why struggle” (Student 3)? A second student described his increased productivity in everyday tasks:

> What I like best about using assistive technology, [is] it works great for emails and that now it takes half the time it used to take me to make emails; it makes me more productive … so that way I can get my work done faster. And I can [make] time for other things that I really enjoy in life. (Student 5)

Student 3 also pointed out that we should use available tools for beyond homework—like social media:

> Making a post on Facebook, the last thing I want is misspelled words; it doesn't look good on your Facebook profile to have everything misspelled, right? That hard word that you're just trying to think [of] and then ... maybe it'll come later … you don't want to post and then that one word in that sentence is wrong and then you'll be the talk of the town on that.

The LFs, however, were not sure that the students' perceived positive outcomes translated to classroom success. For example, one reported that it was too early to tell:

> Confidence in their academic abilities has allowed [students] to expand when doing written essays in everything so in that sense the academic has improved. I think it would take a little bit longer for grades, and I don't know for sure if grades would improve [from AT use]. (LF 1)

These student participants, then, appeared to see the potential and possibility in developing positive outcomes like efficiency, effectiveness, and productivity with the use of AT. It appears unclear, though, whether this translates to higher evaluations in the post-secondary environment.

Skills for Life Emerge

Beyond its immediate applications to their college program, some student participants saw or envisioned generalization of their new skills to other environments such as home [“so you don't have to rely on your parents to help you.” (Student 5)] and school work task without additional supports [“the LFs won’t always be there.” (Student 5)]. One participant specified vocabulary [“I've learned words that now that I didn't know before.” (Student 3)]; another, spelling as positive outcomes:

> I've learned words from it that I have never learned before how I could spell, so it's also a bit of a teaching tool. ‘Cause now ... you can hear [the AT] say the word and then I can remember that [word] and now I'm learning to spell words. So it's actually more than just a word prediction or word correction software; it also teaches the person on how to improve for the future so the next time they make fewer errors and that is good for the future for jobs and anything like that. (Student 4)

As well, knowing that AT exists will be an area to attend to for the future: “as technology evolves and newer technology comes out, maybe they'll have something [else] in the future” (Student 3).

Participants also expressed that AT provided an increased level of independence: “It's more easier if we have the assistive technology to help … so [we] don't have to rely on [an LF]” (Student 5) —or parents, as above-noted. One participant shared that, “I find it's kind of embarrassing that I have to ask someone [at] my type of age [that] I don't know how to spell one word or two" (Student 3). He found that AT is, “Basically a second set of eyes; you can basically say to proof your stuff … which makes you feel more professional and independent and [it] makes you look more smarter … it's boosted your self-esteem, right?” (Student 3). One LF agreed: “Independence is the main factor that I have seen … they are able to do it on their own and ask for less support. I think their overall confidence has improved" (LF 1). However, not all LFs concurred. Other LFs noted that, to get there, willingness and capability must converge for a movement towards independence to happen.

Willingness and Capability are Intertwined

One LF reflected that, "It's [AT] definitely limited the amount of effort I need to put in one-to-one … it's given me much more time to work with other students." She further reflected that there is potential for a level of independence, but that independence depends on willingness: "I think if we encourage the use of it here as much as possible, and also translate it [to] everyday life, then they are most likely going to do it." She feels that the capability is there, but that, "Some of them just don't like some things and then they won't follow through" (LF 1). Another LF provided an example with Livescribe Smartpens:

> If they use it properly--I know that one of my students is actually using it right now, and she goes back and puts it into her computer, it comes right on there so she's actually getting what's supposed to get out of it … where[as] I know another student; she just refuses to use it. (LF 3)

Not surprisingly, it seems that students are more likely to utilize tools that they enjoy.

Ease of Use Impacts Use at All

One LF mentioned that the student participants often needed prompting and convincing to get over some moments of resistance that came up around the use of AT. She noted that students did see the benefits of its use and did become more independent. For example, "WordQ I've noticed is now a staple for whenever they are doing homework … as soon as they log on, WordQ's up" (LF 1). Another LF said that, in their role, she tends to *push* the software that appears to provide ease of use with fewer steps: "I push (WordQ) the most ... only because it's easy for them to be more independent with that one … it has to be really simple for our students" (LF 3). A further LF added: “Yeah. Turn it on and go” (LF 4). This seems to be true for LFs, too, with more training and refreshers desired to better support its use.

Too Little Too Late

In a contradictory theme, some LFs noted that they did not necessarily feel that CICE students were indeed becoming more independent; rather that the use of assistive technology is too little and too late—they have already learned *dependence*. They feel that AT gives students *some* skills for more independence, but not all skills. One LF articulated that: “Assistive technology to help them get the words out, and they don't have the assistive technology to help them get the support that we give them” but that they also “need *our* support in staying on task and staying focused and pulling information that's kind of at the back of their heads to the front of their heads” (LF 2).

At times, they found that students needed step-by-step verbal prompting to utilize the AT: “They forget to use it so we need to remind them … some of them will say ‘I don't know how to read that,’ and [we respond], ‘It's on the computer, turn on this program and then use [it]" (LF 4). But they also expressed hope: “I think there's potential for there if we started right from the beginning of day one … and [set] that expectation” (LF 6). Another LF imagined what it could potentially be like for CICE students to use AT through their program—from the beginning:

> They ... will probably have a better chance of succeeding in their electives with less support. So right now, a lot of their assignments are modified because they are just getting used to assistive technology. So, as they progress through the semester and as they're finished, they'll need a lot less support, so they're most likely to do it as is, instead of a heavily modified assignment. (LF 1)

Discussion

Results for each student were aggregated to obtain a clearer image for both DORA and Readability; however, because the scales for subtests varied widely, variables with a larger scale become more important. For example, the average number of characters was 385.1 pre-intervention and 962.5 post-intervention. These results are similar to the results of previous research that indicated that the use of speech-to-text assistive technologies can enhance writing productivity (Evmenova, Graff, Jerome, & Behrmann, 2010; Garay-Vitoria & Abascal, 2010; Palmer et al., 2012; Stoop & van den Bosch, 2014; Tam & Wells, 2009). As indicated by the research participants that noted how the use of AT reduced homework completion time, "It has changed [homework time] greatly. Before it used to take me an hour and it [AT] cut it down into 30 minutes," speech-to-text and word prediction software enabled students with ID to write faster, with greater spelling accuracy and more complex word usage (Evmenova et al., 2010; Stoop & van den Bosch, 2014). Consequently, using a device equipped with word prediction technology, people with intellectual disabilities can increase their communication rate considerably as it reduces the number of keystrokes, thus saving time and preventing mistakes.

In contrast to the significant improvement in the number of characters written by student participants, the average number of paragraphs pre-intervention was 2.4 and post-intervention was 1.2. What appears to be an anomaly in the quantitative results indicating a decrease in the number of paragraphs written is not an unusual outcome when using assistive technology. Providing learners with speech-to-text software that reduces cognitive load can result in the students becoming more focused on the structure and complexity of word usage rather than lower-order writing tasks (e.g., spelling, grammar) (Arcon, 2015; Stoop & van den Bosch, 2014). Therefore, percent change was also individually graphed for overall DORA and Readability (refer again to Figures 1 and 2). It should be noted that student one had a pre-post difference from 6.5 to 1.83 on one subtest, creating a -255% change and affecting the overall average for that student. Percent change, therefore, is not a perfect solution to such analyses, but does give an alternate, more informative way of viewing these data. In any case, conclusions from this initial pilot research project with a small group of participants at a single college site should be regarded with cautious enthusiasm. A future solution beyond this initial pilot would be to include more students in a follow-up study, multiple sites, multiple data points (e.g., standardized assessments midway) as well as a control group.

As noted earlier, students are more likely to utilize tools that they enjoy and find useful. Thus, individual perception about the usefulness of technology is the most important consideration in determining the behaviour of adopting or accepting new technology (Venkatesh, Morris, & Ackerman, 2000). This highlights the importance of ensuring that the selection of specific assistive technology resources is carefully matched individual needs and abilities. Galla (2010) insists that effective technology implementation begins with ongoing assessment of student's progress and assurance ensuring that the technology meets the particular needs of the students.

Conclusions

This mixed-methodology pilot study provides useful information both for developing further studies, refining related methodology, and for teaching and learning using assistive technology in community-college based programs for students with IDs or other impactful learning challenges. It is important, however, to keep in mind that this is a small-scale pilot study and its results are not meant to generalize beyond the context of this particular research project. Methodological recommendations emerging from this pilot project include: (1) the addition of a control group at the same or different provincial college CICE program; (2) the inclusion of a more formal or standardized AT assessment or decision-making tool prior to implementing AT supports; (3) the collection of duration data to see if direct support time and/or type of supports (e.g., verbal prompting versus full physical prompting) from LFs changes as a result of interventions; and, (4) the provision of an opportunity for LFs and CICE students to rate the ease of use of various AT tools used.

Related programming suggestions for teaching and learning with AT in the college CICE context continue: (5) scaffolding AT use at the beginning of the program and implementing it into all courses post-intervention; (6) systematically building rapport between faculty, LFs, and students and their peers; (7) providing clear task analyses for students with visuals to create further independence; (8) including any built-in AT tools, such as screen readers built into online learning management systems; (9) continuing an individualized approach with individual supports from both faculty members and LFs, framed through Universal Design for Learning; (10) build in structured, ongoing training and face-to-face refreshers for LFs in order to maintain and improve usage skills; perhaps, formalizing this into a continuing education certificate program or including it as a job requirement; (11) Utilize low cost or no cost AT alternatives (e.g., Google tools or built-in smart device apps); and, (12) when possible, provide instructors with ongoing AT training and refreshers in a community of support so that they can offer their recommendations as to when and how the AT resources should be used to complete coursework. This should result in the course-specific benefits of using AT to be highlighted throughout the course of study.

There is much potential for the use of AT to make a difference in the teaching, learning, and independence of adult students with intellectual disabilities and other significant learning challenges in a manner that is respectful and inclusive of similar strategies used by their peers in the college and community. Though the outcomes of this pilot study show tentatively positive conclusions, further research must be done to fully explore the potential of such resource use as an everyday part of inclusive community college-based teaching and learning programs for this student population.

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Using a Mobile App to Reduce Off Task Behaviors in Classrooms: A Pilot Study

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Abstract

A mobile app, modeled after social media apps, was developed to apply token based response cost procedure intervention in special needs classrooms. Our pilot case study showed that when afforded user friendly mobile apps special needs teachers will utilize such apps to apply and track interventions in their classrooms.

Keywords

Off Task Behaviors, Mobile App, Special Needs Classrooms, Fragile-X Syndrome

Introduction

A gap exists between scientific research on using technology for interventions in special needs classrooms and the actual application of such interventions in classrooms. While research shows effectiveness of using technology based interventions, such as video modeling, in teaching special needs students new skills and reducing off task behaviors, research (Abualsamid 123) and anecdotal evidence indicate that technology based interventions are seldom used in special needs classrooms. Human factors, such as difficulty of use, are indicated as the main reason for already overwhelmed teachers to not use technology based interventions in the classrooms. Lack of awareness is cited as another main reason for teachers not using such interventions (Abualsamid 123).

Our expectation is that a discoverable, easy to use system, would increase the level of utilization of technology based interventions in special needs classrooms. To test that theory we developed an easy to use, open source, mobile application that implements a response cost intervention procedure for reducing off task behaviors. We sought four goals in building the system: i) ease of use, procurement and training was the main goal when designing the system. ii) implementation of an intervention that is familiar to teachers, specifically a token based response cost procedure that is already used by many special needs teachers, though in manual fashion. iii) off-loading some of the tasks that the teachers conduct in their classrooms to the app such as the app reduces the workload on the teacher and not increases it. iv) discoverable through app stores and sites dedicated to curating special needs apps, allowing teachers to discover the app even if they are not familiar with the scientific research that lead to its development.

In order to achieve our first goal we developed an html5 cloud based app that requires no installation and works the same on smartphones, tablets and desktop computers. We modeled the app after familiar social media applications, such as Facebook, leading to minimal training requirements for using the app. For our second goal, the app implements a token based response cost intervention procedure. Specifically, when a student exhibits an off task behavior, the teacher adds an entry in the student's timeline indicating the off task behavior and any optional notes and context. The app keeps track of the time of the event and the number of off task behaviors for each student. The app displays a visual model representing the number of off task behaviors for the day, the model is comprised of a bold red thumbs down icon for each occurrence of an off task behavior for the day. Thus, the first off task behavior would be represented with one thumb down icon. Five off task behaviors in a day would be represented by five thumbs down icons. The app would also read out the count of off task behaviors out loud to reinforce the visual model. Our third goal is focused on the teacher's already busy daily routine. Special needs teachers are often overworked and under-supported; adding to their daily workload would lead to teachers to not implement any new system. Thus, the app allows the teachers to automate some of the tasks they already conduct in their daily routine. The app allows the system to track off task behaviors with few clicks, keeping track of the time and frequency of occurrences, and providing daily, weekly and monthly rollup reports. The tracking and reporting, automate tasks that teachers already had to conduct, reducing their workload. The app also allows teachers to communicate with parents via the same timeline. The parents can post events to the timeline, for example, the student had a healthy breakfast today, and can view entries made by the teacher. The familiar timeline interface, that many parents, students, and teachers are familiar with, through using social media apps, makes it easy for all parties to use the app to communicate on daily or weekly frequency, reducing the teacher's workload.

In order to establish a preliminary baseline to test our theory that an easy to use app would be utilized by special needs teachers we conducted a 16-week, A-B-A case design, pilot case study. The case study had a single participant, a male student with Fragile X syndrome that exhibits frequent off task behaviors that interfere with his ability to learn as well as henders his social interactions with his peers. The student attends a private special needs school that focuses on Applied Behavioral Analysis. All students in the school are students with special needs with cognitive challenges and autistic behaviors.

Fragile X Syndrome is a genetic disorder affecting nearly 1 in 4000 boys in the US and roughly half that rate for girls (Oakes et al. 54). Its effects are more pronounced in males where it causes severe intellectual disabilities, severe developmental delays, unintelligible speech patterns such as fast speech and/or mumbling, and stereotypical behaviors such as tantrums, hyperkinesis, hyper anxiety, repetitive behaviors, as well as limited theory of mind (Crawford et al. 359; Hagerman et al.). Fragile X is the leading genetic cause of autism, with autism occurring in approximately 30% of the population while another 30% suffering pervasive developmental disorders not otherwise specified (Wang et al. 264). While the cognitive disabilities of students with Fragile X syndrome are challenging on their own we hypothesize that some of the off task behaviors they exhibit act to reduce their learning opportunity both by removing them from the learner role as well as reducing the effectiveness of their teachers. Reducing the aforementioned behaviors is a primary concern for parents who often resort to administering stimulant drugs to try to control those behaviors (Garber et al. 666).

Children with Fragile X syndrome, as well as the more general population of children with autism, show better performance using visual learning than other forms of learning (Schwarte 290). The population also struggles with abstract concepts, such as math and time, but performs better with concrete visual and auditory signals (Schwarte 290). In other words, utilizing visual models interventions in this population caters to their relative strengths and avoids their weaknesses.

We conducted a sixteen-week A-B-A design pilot case study in a small private special needs school. The student's classroom has eight total students, a primary teacher, a full-time teacher assistant and an assistant who splits his time between several classrooms. The student is pulled out for basic math once a day, but otherwise spends the day with the same group of students, while supervised by the same group of teachers. The students learn basic skills, eat snacks and lunch, participate in PE, watch videos, as well as receive basic reading, writing and math tutoring. The study tracked off task behaviors exhibited in four specific behaviors based on the student's Individual Education Plan (IEP) and input from his parents. The behaviors were hyperkinesis, uncontrollable outbursts, unintelligible speech and disorderly eating. In the first phase of the study, the baseline (A) phase, the teachers collected data via the app for three weeks. The teachers used the interval recording procedure to record the student's behavior every 30 minutes during the school day. In total, the teachers observed 42 off task behaviors in the baseline phase of the study. The observations, once noted in the app, where available in real time to the study authors. The intervention phase (B) lasted for four weeks during which the teachers continued to record the off task behaviors every thirty minutes but also used the response cost procedure to apply an intervention, via showing the visual model of the number of thumb downs to the student and explaining to him that he earns an extra red thumb down with every off task behavior. In those four weeks, the off task behaviors totaled 19 occurrences, with the numbers dropping every week. The student started expressing to the teachers that he does not want any more thumbs down and became more self-aware. The next calendar week was a school holiday.

After which the withdrawal phase (A) was conducted. For eight calendar weeks, that included two weeks of winter holiday school break, the teachers recorded the off task behaviors without applying any interventions. The student exhibited 12 total off task occurrences during the six week that school was in session.

Discussion

The goal of this work was to explore whether modern mobile apps can increase the utilization of research-proven, technology-based interventions in their classrooms. Our pilot case study showed that teachers would use such apps if they were easy to use and reduced their workload instead of increased it. At the end of the study, the teachers requested access to the app to use it for all students in their classroom. As a secondary result, the study showed that the student with Fragile X learned to improve self-control of off task behaviors through visual intervention applied through the app. Results are preliminary and need to be validated using larger studies. We continue to develop the app and are currently recruiting participants from another school to conduct a larger multiple baseline study across multiple participants.

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A Second Look at What High School Students Who Are Blind Should Know About Technology

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Abstract

This article presents an overview of mainstream and assistive technology skills and tools to be mastered by high school students who are blind in preparation for postsecondary education. It is an update to an article written on this exact topic fifteen years ago. The recommendations focus entirely on what is necessary in today's high-tech society for high school learners who read and write braille competently (e.g., read braille tactually at a minimum rate of 30 words per minute). The number of recommendations from the original article in 2004 has more than doubled. There were only 14 recommendations in 2004. In 2018 there are more than 30 recommendations for students who are blind to relate to their use of assistive technology. The Certified Assistive Technology Instructional Specialist for People with Visual Impairments (CATIS) provides a Scope of Practice and Body of Knowledge that is sufficient for supporting the substantial growth in the assistive technology-related knowledge, skills, and tools recommended in this article.

Keywords

Assistive technology, blind, certification, education, visually impaired

Introduction

This article represents a "second look" at the issue of competence in the use of appropriate technology to be mastered by students who are blind and who may be enrolling in some type of postsecondary educational program. The first attempt was made fifteen years ago by Kapperman and Sticken (2004). Research prior to and after this first attempt occurred consistently shows that the vast majority of students who are visually impaired are not receiving the training they need with assistive technology (AT) (Abner and Lahm; Candela; Edwards and Lewis; Kapperman, et al.; Kelly, 2008, 2009, 2011, 2016). In order to remedy this most unfortunate situation, a new AT specialization for people who are visually impaired has been developed after several decades of effort (Augusto and Schroeder; Kelly, 2016). This specialized training leads to a credential in the use of AT that has been developed for use by individuals who are visually impaired. The Certified Assistive Technology Instructional Specialist for People with Visual Impairments (CATIS) is the new certification that was launched by the Academy for Certification of Vision Rehabilitation and Education Professionals (ACVREP) in 2016 (Kelly, 2016). The new CATIS certification has established competencies and standards in the area of AT training for people with visual impairments.

Thus, at this important juncture we are updating that first attempt by Kapperman and Sticken (2004) in direct response to the new CATIS competencies and the ongoing need for AT training among learners who are visually impaired. Since the first article was published in 2004, the AT arena has changed dramatically for braille-reading students.

Discussion

The skills and proficiencies that should be acquired by students who are blind prior to their high school graduation and enrollment in postsecondary education programs are described below and outlined in Table 1. Also, Table 1 compares each of these skills and proficiencies to recommendations from Kapperman and Sticken (2004). There are significant alterations to the recommendations. Considerable progress has been made in the development of technology since the first attempt to summarize their needs was made. Table 1 shows that there were 14 skills or tools specifically identified in 2004 that students who are blind needed to acquire prior to high school graduation. Fifteen years later, this list has more than doubled to 35 essential skills or tools. It is likely that this list will continue to grow exponentially over time.

Table 1. Comparison of Prior and Current Recommendations for Essential Skills and Tools Related to the Use of Assistive Technology by High School Students Who are Blind.

Essential Skills and Tools	**2004** *n = 14*	**2018** *n = 35*
Amazon products and services (e.g., Alexa, Echo, and Tap)	No	Yes
Apps (i.e., accessible apps for portable devices)	No	Yes
Beacons	No	Yes
Braille embosser	Yes	No
Braille reading (reading braille tactually at a minimum of 30 words per minute)	No	Yes
Braille notetakers connected to a computer and monitor	Yes	Yes
Braille notetakers connected to a tablet and smart phone	No	Yes
Cloud-based storage	No	Yes
Configuration of technology	No	Yes
Dictionary and encyclopedia (standalone programs)	Yes	No
Dictionary and encyclopedia content available from online search engines and built into programs	No	Yes
Downloading and storing of ebooks (no format specified)	Yes	Yes
Downloading and storing of ebooks in multiple formats (e.g., audio, brf, DAISY, and EPUB)	No	Yes
Downloading and storing of music legally	Yes	Yes
Email program (skill with only one program is sufficient)	Yes	No

Essential Skills and Tools	**2004** *n = 14*	**2018** *n = 35*
Email programs (skill with multiple programs is necessary)	No	Yes
Exploration of emergent technology (e.g., 3D printing and haptic technologies)	No	Yes
Gestures for accessing Apple/iOS devices	No	Yes
Global Positioning System (GPS) and wayfinding accessible applications/devices	No	Yes
Google-based products (e.g., Google Chrome, Chromebooks, Drive, and Home)	No	Yes
Internet browser and search engine (skill with only one program is sufficient)	Yes	No
Internet browsers and search engines (skill with multiple programs is essential)	No	Yes
Keyboarding (touch typing a minimum of 50 words per minute)	Yes	Yes
Keystroke commands for both desktop and laptop computers	No	Yes
Keystroke commands for Apple	No	Yes
Keystroke commands for Windows	Yes	Yes
Maintenance of technology (e.g., installing updates and antivirus protection)	No	Yes
Microsoft programs (i.e., Word, PowerPoint, and Excel)	Yes	Yes
Optical Character Recognition (OCR) technology and supporting applications	Yes	Yes
Refreshable braille display connected to a computer and monitor	Yes	Yes
Refreshable braille display connected to a tablet and smart phone	No	Yes
Screen reading program (skill with only one program is sufficient)	Yes	No
Screen reading programs (skill with multiple programs is necessary)	No	Yes
Smart phones (e.g., Andriod and iPhone) and built-in accessibility features	No	Yes
Social and professional networking online platforms (e.g., Facebook and LinkedIn)	No	Yes
Talking book player	No	Yes
Third-party software setup and customization	No	Yes
Troubleshooting of technology	Yes	Yes
Voice-activated personal assistants (e.g., Cortana and Siri)	No	Yes
Video calling applications (e.g., FaceTime, Skype, and Zoom)	No	Yes

Summary of Current Recommendations

In addition to being able to read and write braille competently (e.g., reading braille tactually at a minimum rate of 30 words per minute), we recommend that the student use a standard keyboard and be able to touch type competently at the rate of at least 50 words per minute. Being able to use a standard keyboard is essential for the effective use of a computer.

We believe that among the many important areas of competence is being able to use screen reading software. We recommend that the student should have mastered the intricacies of at least two screen reading programs. For example, Job Access with Speech (JAWS) and NonVisual Desktop Access (NVDA). JAWS is the most widely used screen reader worldwide (WebAim). As a consequence, many programs have been in some fashion adapted for use with JAWS. There are many special scripts which have been written to enable JAWS to be used with a large assortment of commonly used software utilized by sighted individuals. For example, JAWS can be used very effectively in the study of foreign languages (Kapperman et al., 2017).

The mastery of at least one other screen reader such as NVDA is recommended. We believe that students who are blind and attend college should have at least one “backup” screen reader along with several other alternative pieces of hardware and software. Depending on one single, very vital piece of technology is not recommended. Having multiple methods of using technology to accomplish the same task is a recent development with these recommendations that is evident with many regularly used programs (e.g., email, internet browsers, and search engines). It is now common place in today’s society to have multiple email accounts and to use more than one search engine online.

Thus, it is recommended that the student should have mastered all keystroke commands to be able to function expertly using at least two screen reading programs. To facilitate this, for example, the settings in NVDA can be set to use "JAWS" key stroke commands. Thus, the student need to master only one set of keystroke commands. In addition, the student should be well-acquainted with all major keystroke commands which are used in whichever version of the operating system is found on the student's computer. This includes both Windows and Apple/iOS keystroke commands and gestures. Likewise, knowledge of both the desktop and laptop configuration of keystroke commands is important for flexibility in the use of various devices available to the student throughout their education and professional career.

The student should be competent in the use of several Microsoft programs including Word, Outlook, Excel, PowerPoint, and Skype. Skype is one example of a video conferencing application. A range of video calling applications are available such as Google Hangouts, Zoom, and FaceTime that can be used by a students who are blind to facilitate their academic and professional networks. In addition, the student should know how to use cloud-based storage such as Dropbox, iCloud, or OneDrive and the many additional Google-based products designed for information sharing among global communities.

Thus, the student should be competent in the many resources that the Internet can offer. Chief among these for a student who is blind is the seeking out, downloading, and using of books in multiple formats (e.g., audio, brf, DAISY, and EPUB) from such sources as Bookshare, the Library of Congress, and Learning Ally. An accessible talking book player is one of several tools that a student who is blind should be able to use to read these readily available materials.

Also, the student should be effective in sending and receiving email from a range of email service providers, seeking out information, downloading files, and making purchases online as well as taking advantage of the other wide range of benefits that the Internet offers for digital social networking (Kelly and Smith).

To reiterate as we described above, the student should be a competent reader and writer of braille. Thus, he or she should be competent in the use of refreshable braille displays and portable braille notetakers that are supported by screen reading programs. The use of a braille displays and portable braille notetakers alleviates the need for large amounts of hard copy braille which can result in difficulty with organization and storage.

Obtaining access to the printed word is one of the most challenging aspects of education for a student who is blind (Presley and D'Andrea). Thus, he or she should also have expertise in the use of accessible scanning applications and hardware that utilize the latest optical character recognition (OCR) technology to convert print documents into accessible digital formats. He or she will find this capability of vital importance given that not all printed information that he or she needs to read may be easily acquired through other means.

In the previous article which was written fifteen years ago, the use of a braille embosser, online dictionary, and online encyclopedia were all recommendations. We no longer recommend those items here. With the advances in technology and refreshable braille devices, we believe that a hard copy braille embosser need not be necessary. A similar situation exists for online dictionaries and encyclopedias that we believe need not be necessary as standalone applications. The internet has this information readily available through online search engines, for example.

The student should be competent in the use of a smart phone such as an iPhone or an Android and the accessibility features built into these smart phones. In addition to the many specially designed apps which can function on these devices, special attention should be paid to the use of accessible Global Positioning System (GPS) and wayfinding apps designed for use by individuals who are visually impaired.

The use of other wayfinding devices and emergent technology that exists in smart cities is important too. A talking handheld GPS system can be used for navigation within local communities and around the world. Beacons provide indoor and outdoor turn-by-turn directions as well as location descriptions that a designed specifically for people with visual impairments.

Equally as important to the smart cities technology is the smart home technology that is readily available. Voice-activated personal assistant such as Amazon's Alexa and Google Home are in high demand on today's market. For students who are blind, these devices can provide instant access to information, home appliances, music, products, and services.

The student should be proficient in configuring technology in order to be able to use it. This includes the ability to connect to peripheral devices as well as access points using technology such as Bluetooth, Wi- Fi, and Near Field Communication (NFC) (ACVREP, 2017). Built-in features and third-party software should be able to be setup and customized by the student. When it comes to refreshable braille displays and braille notetakers, for example, this means being able to connect them not only to computers and supporting screen reading applications but also to smart phones, tablets, and other forms of portable technology.

The competent user of access technology should have the capability of troubleshooting effectively. This set of knowledge includes a fundamental understanding of the technical aspects of operating systems and how to make needed alterations in settings. The ability to perform routine maintenance such as software updates and antivirus protection is an essential skill. Also, the individual needs to know how to find help by reading user documentation and working together with others. This includes contacting existing technical assistance agents who represent the various manufacturers of the pieces of hardware and software which populate the student's assortment of AT.

In additional to all of the skills involved in using existing technology, the student should have the ability to use emergent technology and to adapt with the technology as it continues to evolve. Exploration is a key component of this competency. The student's review of technology tools should occur whenever possible through opportunities such as public beta testing, online vendor training, and free trials (ACVREP, 2017).

Providing Students Who are Blind with the Necessary Assistive Technology Instruction

It is evident that there has been substantial growth in the scope of the assistive technology skills and tools recommended for high school students who are blind over the past fifteen years and the shortage of instructional expertise to support this growth is a longstanding problem in the field. The new certification in the area of assistive technology for people with visual impairments has an emphasis in instruction and has been developed to alleviate this problem. In fact, the letter "I" in CATIS stands for "Instruction". These newly certified individuals are instructional specialists in the area of assistive technology for persons with visual impairments. For the first time ever, there are individuals who have met national standards and qualifications in this area of instruction. Figure 1 overviews the instructional strategies from the CATIS Scope of Practice. In addition to the information about instructional skills provided in the CATIS Scope of Practice, there is a comprehensive list of 21 specific instructional skills outlined in the CATIS Body of Knowledge in the ACVREP CATIS Handbook (2017). These instructional strategies are used by CATIS to support the wide range of ever-growing assistive technology knowledge, skills, and tools now required of high school learners who are blind. In addition to the instructional domain there are similarly exhaustive lists of practice and knowledge skill sets in the assessment, configuration, and exploration domains. CATIS are required to master and demonstrate each of these domains to become certified. The CATIS is an integral component of the effective instructional delivery of the recommended skills and tools outlined in this article.

CATIS Scope of Practice General Instructional Strategies

- Guides individuals to make appropriate, informed decisions on the most appropriate and efficient toolsets based on their abilities, needs and goals
- Applies learning styles and learning theory to suit the individual
- Creates a training plan specific to individual's abilities, goals and needs
- Instructs in integrating assistive technology, devices, hardware and software into daily activities that enhances daily life or the educational or work environment
- Instructs in multiple ways via hands-on experience or lecture, (best practices for children and adult principles)
- Instructs in home, classroom, other school environment, workplace or community
- Adjusts scope, structure and pace of instruction based upon learning styles and capacity for new information
- Adjusts scope, structure and pace of instruction based upon changes and advances in technology
- Instructs in planning, implementation, and record keeping for short-term and long-term instruction
- Instructs in local, regional and national assistive technology resources and teaches strategies for troubleshooting
- Provides resources for further learning

Fig. 1. Instructional Strategies from the ACVREP CATIS Scope of Practice.

Conclusions

The world has become an increasingly more complex environment to be negotiated and it requires much more highly developed expertise to be a success at that very daunting task. The challenges are even greater for those individuals who cannot see and who face the aforementioned longstanding challenge of the lack of AT training (Abner and Lahm; Candela; Edwards and Lewis; Kapperman, et al.; Kelly, 2008, 2009, 2011, 2016). However, the newly developed CATIS certification is designed to address these barriers to information for people who are visually impaired. Furthermore, the recommendations that have been outlined are well-represented in the CATIS Scope of Practice and Body of Knowledge (ACVREP, 2017). These recommendations are intended to support learners who are blind in taking their place in the twenty-first century where skill in the use of a wide range of mainstream and assistive technology is paramount for success.

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Authoring Semantic Annotations for Non-visual Access to Graphics

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Abstract

Semantically-enhanced graphics are annotated with formal underpinnings in order to augment them with the semantics of what they depict. Among their many potential uses they provide means for more efficient accessibility of graphical data going beyond the traditional use of textual alternative descriptions, such as natural language interfaces. However, no efficient way of authoring these graphics currently exists. This paper aims to bridge the gap between authoring graphics and enhancing them with semantic formal structures in the form of ontologies by introducing Semantic Annotator for Inkscape (SAI), an authoring tool that allows for seamless addition of semantics to an SVG file supported by a given upper ontology in RDF format. The traditional disjointed approach of authoring a vector image and editing its supporting ontology using independent software tools has thus been unified into a single workspace, improving the efficiency of authoring semantically-enhanced graphics. Evaluation of SAI has shown greatly improved annotation times of semantically-enhanced graphics that can be later used for efficient non-visual natural-language-based content retrieval.

Keywords

Blind/Low Vision, Software, Ontology, SVG, Web

Introduction

The World Wide Web has been designed with the ultimate goal of being accessible to everybody, regardless of age, location, device used, or whether the user has some disability. However, the presence of large amount of graphics on web sites can still present sometimes a huge barrier for specific user groups (Altmanninger and Wöß 378). One of the groups having the greatest difficulties accessing graphics is that of blind and visually impaired web users. Worldwide, 285 million people are estimated to be visually impaired, of whom 39 million are blind and 246 million have low vision (World Health Organization).

The easiest way of making graphics somehow accessible for visually impaired people is by describing them in text. On the web, this is generally done by means of the “alt” and “longdesc” attributes of HTML image elements ” (World Wide Web Consortium, *Web Content Accessibility Guidelines (WCAG) Overview*). This is a valid alternative for simple graphics whose meaning can be conveyed by means of short textual descriptions. However, in many cases an alternative textual description does not suffice for full understanding of the graphic. For instance, even though a textual and a diagrammatical representation might be informationally equivalent, they are generally not computationally equivalent, as verbal descriptions of diagrams easily overload short-term memory and do not provide any means of gaining an overview of data (L. M. Brown et al. 1).

Besides textual approaches, diagrams can be made accessible by means of spatial simplification e.g. by transforming a graph into a two-dimensional table in which each row and column represents a node and each cell the relationship between its two nodes (Blenkhorn and Evans, 22-25), sonification (representation of data through sound), tactile output, or using a hybrid approach. However, these methods suffer from a number of drawbacks that hinder their take up as an alternative to graphics on the Web. Sonification is not a suitable means of representing complex diagrams, whereas tactile and hybrid approaches require expensive equipment that moreover cannot be used by blind persons in an autonomous manner. Moreover, these methods are inherently incapable of displaying certain domains of graphical information, such as real-world photography. Recent methods to accessibility of Web graphics have thus shifted to audio- and speech-only approaches that do not require of any specific hardware or software, such as natural language interfaces.

Discussion

An innovative model for access to previously annotated pictures is the so-called communicative images (Plhák). A communicative image (e.g. Figure 1) is a two dimensional graphical object integrated with a dialogue interface (Natural Language Interface, NLI) and linked to an associated knowledge base in the form of ontologies which stores the semantics of the objects depicted. They consist of three data structures: (1) The graphic information itself, in vector or raster format; (2) identification of objects in the image, by exploiting the SVG (Scalable Vector Graphics) format to locate and give information of the objects within an image; and (3) semantic data associated to the graphic's objects, stored as metadata within the image in the form of ontologies encoded in OWL (Web Ontology Language).

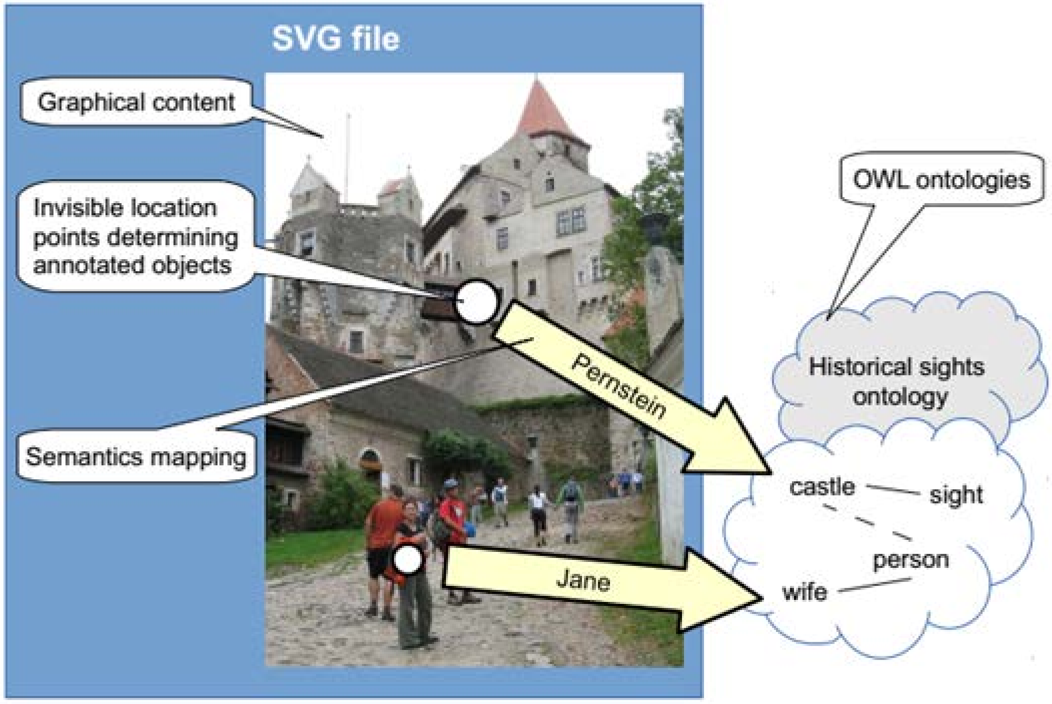

Fig. 1. Structure of a communicative image (Plhák)

Research shows that sound and speech interfaces to semantically-enhanced graphics are a fitting approach to display alternative accessible versions of real world images (Plhák 90), diagrams (A. Brown et al. 27) and charts (Ferres et al. 3). The serial nature of speech has an obvious disadvantage over tactile or sonification approaches which do not impose such a cognitive load on the reader's processing capabilities. Despite of this fact, blind readers much prefer speech feedback when reading charts and other means are preferred only rarely (Ferres et al. 3). Therefore, accessing the semantic information embedded in a communicative image by means of natural language allows blind users to autonomously infer the meaning of the graphic.

A required first step before annotating a communicative image is to segment it into regions. Several techniques for image segmentation are in use nowadays, such as edge detection methods, region growing methods, statistical methods or knowledge-based methods (Kopeček et al. 4-6). The resulting regions can then be recursively interpreted and given semantics by associating them to ontological instances (Kopeček et al. 8), as seen in Figure 1.

Within structured domains, using automatic object recognition techniques can greatly speed up semantic annotation. However, automatic object recognition techniques are currently far from being entirely reliable even with the use of large corpora of training data. Only in strictly controlled environments are these systems able to outperform the capabilities of the human visual system (Andreopoulos and Tsotsos 827).

Given the current imperfect nature of automatic annotation techniques, some sort of manual addition or edition of the semantic annotations present in a communicative image is commonly required. The manual annotation process is generally divided into two phases: (1) Authoring SVG – a variety of suitable tools are available for processing vector graphic elements, such as the proprietary Adobe Illustrator (Adobe Systems Incorporated), the free and open source Inskcape (The Inkscape Team) and GIMP (The GIMP Development Team). SVG elements either represent the graphic data themselves or interesting parts and objects in the bitmap image. In both cases, the created elements do not contain any semantical data and current tools do not allow the user to add them. (2) Annotating SVG elements – the most common tool for handling the semantical meaning is the free and open source application Protégé (Stanford Center for Biomedical Informatics Research). Protégé allows the user to efficiently process ontologies. However, it does not allow them to work directly with graphics and their constituent regions and semantic elements.

To the best of our knowledge, there are currently no available tools that allow users to process vector graphic images and annotate SVG elements enhanced with ontological data at the same time. Therefore, to tackle this issue the rest of this article presents an authoring tool for semantically-enhanced graphics. Semantic Annotator for Inkscape (SAI) provides an efficient bridge between the tools for processing vector graphic images and tools for assigning semantics to their elements. Its basic overview is given in the following section.

System Overview

The SAI prototype has been implemented as an extension of Inkscape, written in Python (https://www.python.org). Inkscape is one of the most popular graphics editors, working primarily with SVG files. In a typical usage workflow, the author may import an already existing SVG file, trace a raster image into its vector counterpart, or create a new SVG image from scratch. At any time during the authoring process, the user can choose to semantically annotate parts of the image by running the SAI extension from the Extensions menu or via a keyboard shortcut. This launches the SAI window (see Fig. 2). Therefore, complex graphics can be imported or created by the user in the same place as the semantic markup is added, and no further software is required, saving the user in both time and authoring complexity.

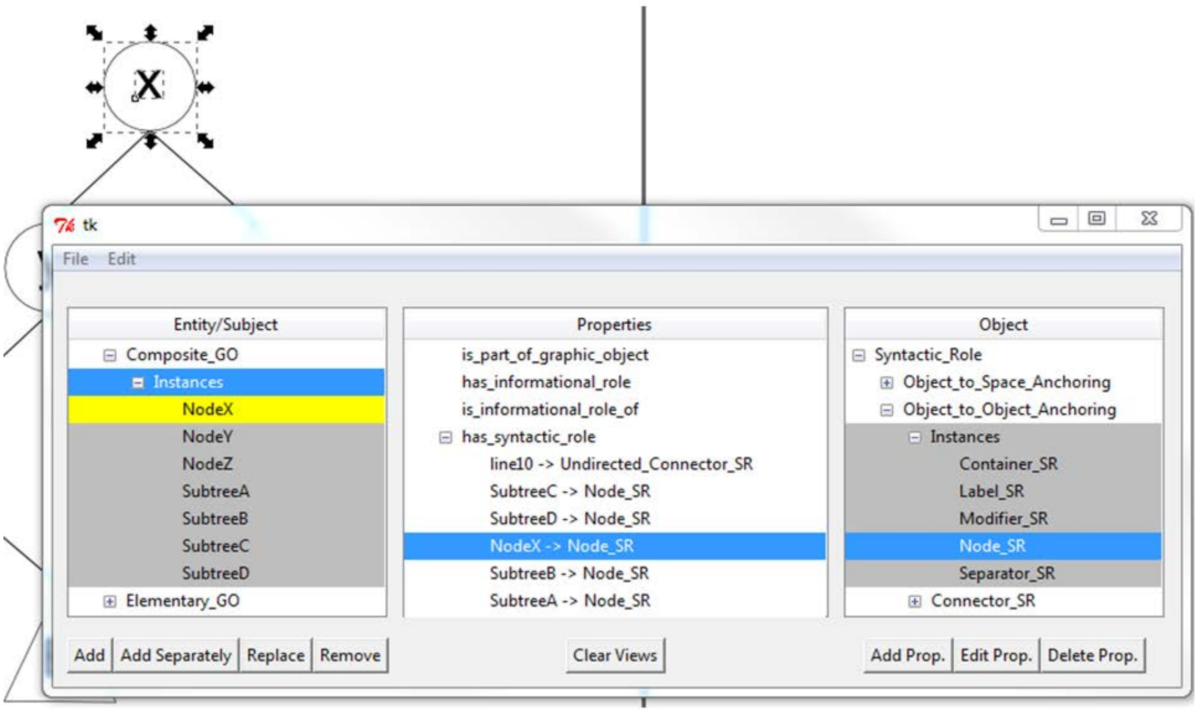

Fig. 2. The annotator GUI (foreground) in the process of annotating a red-black tree drawn in Inkscape (background).

Before any annotation of the graphic can take place, the user has to load a visualization ontology in RDF format by choosing the relevant option under the "File" menu. The extension tries to automatically infer the namespace used by the visualization ontology that semantically underpins the elements of the graphic and their relationships. If the namespace is not found, it prompts the user to manually input it.

SAI also checks whether the necessary datatype properties to link ontological entity instances to SVG elements (i.e. to semantically annotate the graphic) are present in the ontology. We associate the constituent SVG elements of an instance by means of datatype properties, which are added or edited automatically by our tool in a transparent manner to the user.

Any number of SVG elements present in an image (paths, shapes, text) may be selected by the author before running the annotator extension in order to relate them to certain ontological elements. A hierarchical list of entities and instances from the ontology appear on the left-hand tree view of the GUI. Instances can be distinguished from entities by their background color. At the same time, those instances to which some of the currently selected SVG elements belong are highlighted in the Entity/Subject tree view. The author can select entities and instances and then press one of the buttons underneath to perform the following functions:

Add: if an entity has been selected in the Entities tree view, a new named instance of said entity containing the chosen SVG elements will be created. The user will be prompted to add a meaningful name to this annotation. If an instance is chosen instead, the selected SVG elements will be added to it.

Add Separately: this functionality is similar to that of the "Add" button when used to create new instances of an entity. However, a new instance will be created for each of the selected SVG elements, instead of grouping them all together under the same instance. An automatic naming mechanism has been implemented in order to make the annotation faster. It takes into account the type of SVG element selected in order to give a meaningful and unique name to it.

Replace: substitutes all SVG elements present in the chosen instance for the currently selected SVG elements in Inkscape.

Remove: when one or more SVG elements have been selected in Inkscape, it will remove those elements from the chosen instance if possible. If no SVG elements have been selected, it allows the user to remove whole instances from the ontology.

Once a semantic annotation has been created by defining which SVG elements belong to an entity instance of the ontology, the user may define property assertions in which the annotation (instance) is involved. The system supports both object and datatype properties.

Properties and their occurrences within the ontology are also hierarchically displayed in the middle tree view of the GUI (Properties tree view). When a user double clicks on a property, the Entity/Subject (leftmost) tree view gets updated showing only those entities and instances that belong to the domain of the property, if defined. If the chosen property is an object property, the Entity/Object (rightmost) tree view will then display those entities and instances that belong to its range (i.e. the set of possible objects of the property triple). In case the user double clicks on a property assertion, the leftmost tree view will highlight the triple subject while the rightmost one will do the same for its object. This assists the user when choosing the elements of a triple to be added, edited or removed.

After selecting a property or property assertion in the Properties tree view, three operations can be carried out depending on which button below the Object tree view is clicked:

Add Property: lets the user add a new object property triple by selecting a subject (entity instance), property and object (entity instance). In case a datatype property is chosen, no object will appear in the rightmost tree view and the user will be prompted to add a value (e.g. a string or a number) to the triple instead. If the triple already exists, the user is informed and no triple is added.

Edit Property: lets the user select a property occurrence and modify its subject, object (value if the chosen property is a datatype property) or both by choosing a different instance in the Subject and/or Object tree views.

Delete Property: deletes the chosen property occurrence, regardless of the chosen subject and object.

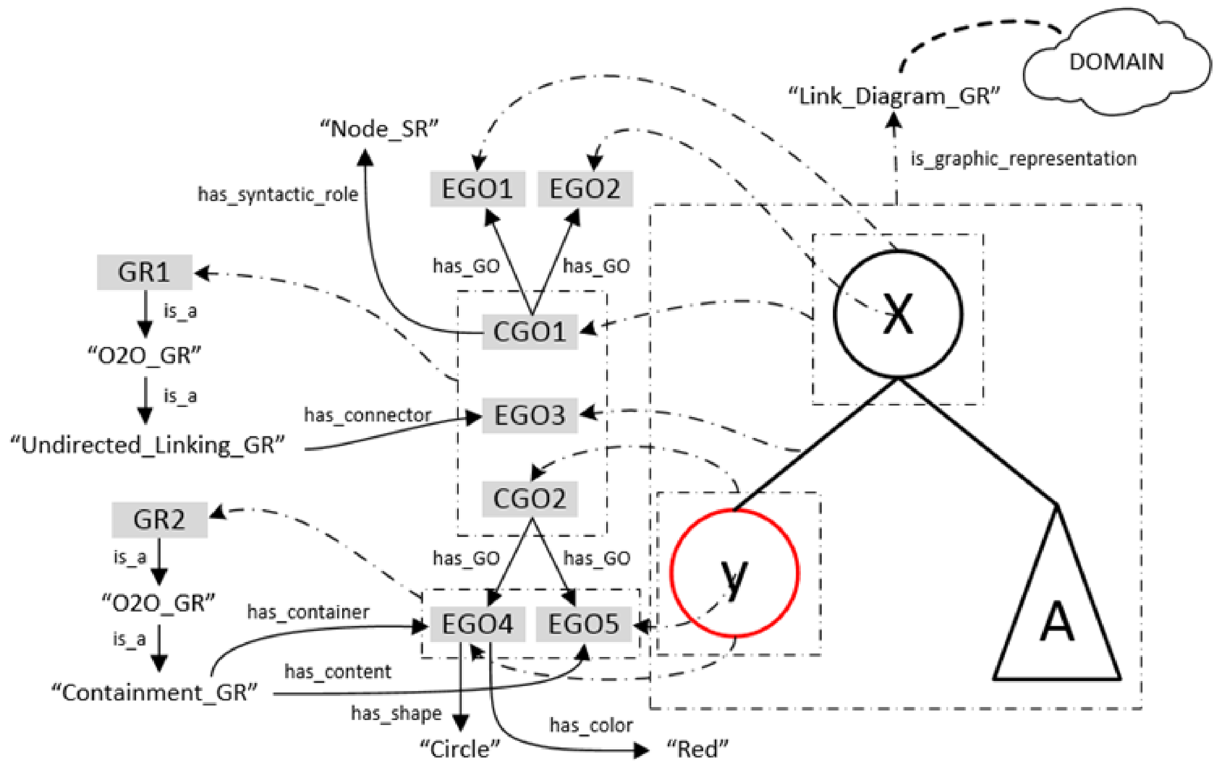

Fig. 3. Partial annotation of a red-black tree. EGO: Elementary Graphic Object; CGO: Composite Graphic Object; GR: Graphic Relation; O2O_GR: Object-to-Object GR.

Once the author has finished editing the image, the changes can be saved into the original ontology or a different one by choosing the appropriate option under the "File" menu item. All new instances and properties will be added into the selected ontology, and any edited/removed ones will be modified as well.

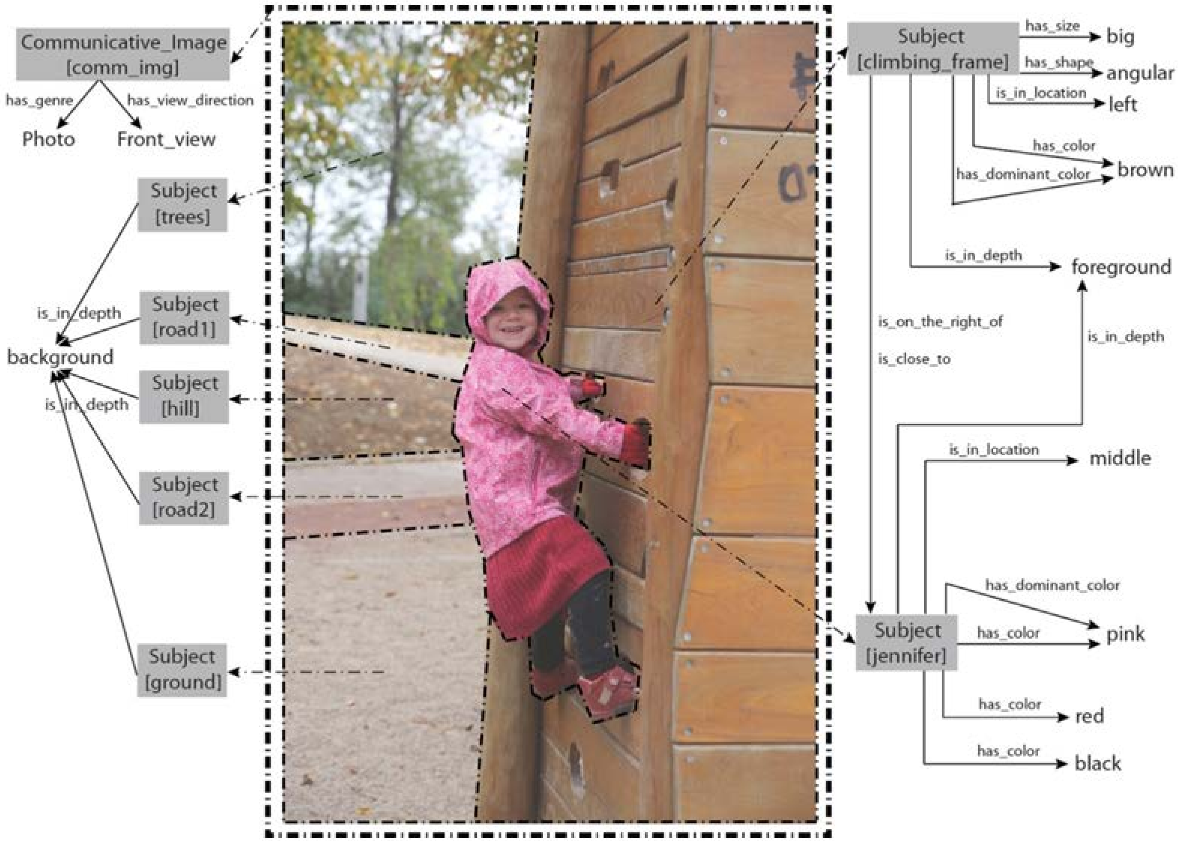

Fig. 4. Partial annotation of a personal photo using a graphical ontology.

Working Examples

The partial annotation of a red-black tree can be seen on Fig. 3. An upper ontology underpinning syntactical aspects of visualization (Murillo-Morales and Miesenberger, “Ontology-based Semantic Support to Improve Accessibility of Graphics”) is used. In the example, syntactical annotations about some of the elements that make up a tree diagram, such as nodes, connectors and linking relationships have been added. Domain-specific semantic annotations might be added later on by loading a specific domain ontology. Fully annotated diagrams may then be non-visually explored by means of natural language (Murillo-Morales and Miesenberger, “Non-Visually Performing Analytical Tasks on Statistical Charts” 343-345).

Fig. 4 shows the partially annotated photo from a personal album using a graphical ontology that restricts abstraction to the aspects that are suitable for dialogue-based exploration of graphical content. This graphical ontology contains general concepts common across different knowledge domains (Ošlejšek).

Benefits of SAI vs. traditional annotation workflow

Heuristic evaluation (Nielsen and Molich) of SAI with authors of semantically-enhanced SVG images both at the University of Linz and the Masaryk University Brno has shown a great reduction in annotation times, especially in the case of complex graphics. The rest of this section discusses some benefits of using SAI over traditional semantic annotation workflows.

Whereas using traditional tools such as Protégé requires naming each one of the entities in the ontology individually, SAI's automatic naming mechanism of ontological elements underpinning elementary graphic shapes along with the "Add separately" feature implemented in SAI saves the user substantial time in the naming process.

Highlight of selected SVG element in the user interface notably speeds up the authoring of property assertions by selecting their constituent elements in the graphic itself, instead of having to look them up by name (which might be non-descriptive). For example, a user might choose to add a syntactic role to all bars in a bar chart by selecting them in Inkscape and then launching SAI, where all entities they belong to will be highlighted and may be chosen to create new property triples.

SAI saves the author substantial time when adding several instances of the same entity to the supporting ontology. It remembers the last class chosen when adding a new individual, so its parent Entity is automatically selected in the GUI when relaunching the extension. This way, the author simply needs to click on the 'Add' button after selecting the SVG elements that will make up the new individual. This is especially useful in knowledge representation graphics, as the same graphic relations may apply to many different elements e.g. labelling relations on a map with one label per geographical landmark.

For every instance in the ontology, their approximate coordinates within the SVG canvas are computed by taking into account the coordinates of its constituents SVG elements and included in the ontology as datatype properties. Authors can make use of the transform SVG attribute (automatically applied by Inskcape) to scale, rotate or translate elements, and the resulting end coordinates on the SVG canvas are calculated by using transformation matrices (World Wide Web Consortium, *Coordinate Systems, Transformations and Units*)

Conclusions

The question of adding semantics to graphics has received much research attention in recent years. SAI is a first prototype of an authoring tool that bridges the existing gap between authoring graphical information and adding semantic underpinnings to it. Authors can avoid using complex tools for processing ontologies, and annotate images in a more convenient way directly in the vector graphics editor.

Currently, SAI supports loading RDF ontologies from a single file and is oriented to processing upper ontologies. In the future, we plan to support loading more ontologies from multiple files and extend the functionality to support processing domain ontologies, e.g. for touristic sights, personal relationships, specific tree structures, etc. Moreover, we would like to include automatic processing of metadata in the EXIF data (date, GPS coordinates) as well as automatic image segmentation techniques and other authoring time-saving techniques.

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