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## Use of Participatory Design to Enhance Accessibility of Slate-Type Devices

Gurjot S. Dhillon<sup>1</sup>, Yasmine N. El-Glaly<sup>2</sup>, William H. Holbach<sup>3</sup>, Tonya L. Smith-Jackson<sup>1</sup>, Francis Quek<sup>2</sup>

<sup>1</sup> Department of Industrial and Systems Engineering, Virginia Tech, Blacksburg, VA, USA

<sup>2</sup> Department of Computer Science, Virginia Tech, Blacksburg, VA, USA

<sup>3</sup> Assistive Technologies and Research Applications, Virginia Tech, Blacksburg, VA, USA

Individuals with Blindness or Severe Visual Impairment (IBSVI) have not had equivalent access to reading materials, especially for slate-type devices. Features such as highlighting and note taking are essential for active reading and engagement. The purpose of this project is to iteratively design a software system for slate type devices (e.g., iPad) to provide IBSVIs with equivalent reading experience as to sighted users. A participatory design (PD) approach is being adopted throughout the project by designing 'with' IBSVI users. The first PD session aimed to explore and obtain feedback on the different layouts of the overlays (tactile pattern over iPad to guide reading), different text densities, sonification, and navigation through the STAAR (Spatial Touch Audio Annotator and Reader) system. IBSVI consultants gave significant feedback and design inputs. Consultants also brainstormed with researchers for ideas to improve the features of the system.

### INTRODUCTION

The National Health Interview Survey (NHIS) reported that there are 21.5 million adults in the US who are experiencing vision loss (NHIS, 2010). This vision loss applies to individuals who could not see after wearing glasses or lenses and also includes individuals with complete vision loss. In the U.S., an individual becomes blind every 7 minutes (Mroczka, 2005). Worldwide population of blind is approximately 45 million which increases every year by 1-2 million each year (National Institutes of Health, 2002; West & Sommer, 2001). Age-related vision degeneration is one of the most common reason for vision loss in the adult population above 65 years of age. Two-thirds of individuals with visual impairment are over 65 years of age (Ross, 2004). This population is predicted to grow from 35 million to 86.7 million between 2000 and 2059 (U.S. Census Bureau, 2005), thus the population of individuals with visual impairment will increase in coming years.

Only 10 percent of the total legally blind population in the U.S. is Braille literate (Petrie, Morley, McNally, O'Neill, & Majoe, 1997). There is a need to have other assistive devices that support reading for individuals and provide independence in reading. In past few years, there has been a push for introducing slate-type devices in pedagogy. Students with visual impairments will be a part of these classrooms where slate-type devices are introduced and cannot be neglected as a student population. Some research needs to focus on making the slate-type devices more accessible for the visually impaired.

Participatory design has been put forward as one of the most useful approaches for designers to incorporate in the design process. Participatory approaches are rarely used by practitioners (Gould et al., 1991, Gulliksen et al., 2003) due to resistance within the organization (Clement & Besselaar, 1993), lack of a precise definition of 'participation' and 'participants' (Olson 2004, Carmel et al. 1993), and designers/practitioners not knowing how to involve the participants in the process.

### STAAR (Spatial Touch Audio Annotator and Reader)

Primarily there are three assistive technologies that are used by IBSVIs for reading: audio based devices, optical readers, and devices using Braille translations. Users prefer audio-based assistance as usually audio books and text-to-speech software or screen readers (like JAWS) are easily available as compared to Braille books or optical readers.

The STAAR system (Figure 1) consists of two primary components; one is the software application in which the text-to-speech engine reads text from a document as the user rolls their finger over a line on the slate-like device; and the second component is a static overlay with embossed dots that guide the user over the screen of the slate-like device. Three overlays with different density of lines and prominence of the dots were used. Users with blindness have started using mobile phones with touch interfaces but there has not been much adoption of slate-like devices. A primary reason for this being the large screen area of slate-like devices on which the visually impaired users can easily lose their place. Some additional aids for the IBSVI to help them better localize themselves on the large screen of slate-like devices are required.

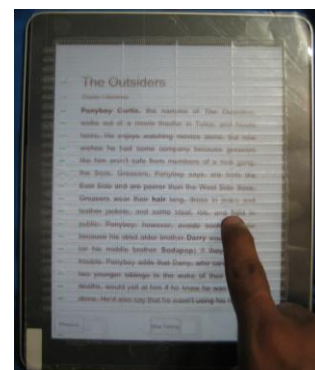


Figure 1 – STAAR system with an overlay. (No-text area is all the space around text body where no text is present.)

STAAR aims to provide BSVI users with the ability to read all types of textual and graphical information that are available in electronic form. Though the system could be used by all the users with visual impairments but the users who need or want to access digital textual materials readily would benefit most from the STAAR system. For example, a graduate engineering student might not be able to find audio version of research papers he/she needs the same day. Using STAAR, the student will be able to download the desired paper to the system and then read it by rolling their finger on the screen of the slate-type device. Research suggests that accessing graphically oriented information is still difficult for IBSVIs and screen readers are not of much help. The STAAR system doesn't modify the layout of the page i.e. font size or font type, page and paragraph spacings, etc. are maintained in the same manner as present in the original document. As the layout of the page is not modified, it is highly likely that the embossed lines on the overlay might not overlap with the lines of the text.

Some auditory cues were also provided to help users stay in the active text area of the system. Whole of the iPad screen was sensitive to touch of the user. The active text area was where the body of text was present on the "page", the area beyond the text was considered to be empty space or 'no-text' area. A sound notification was added to the system to let the users know if they strayed into the 'no-text' area of the page. A beep-like sound played as long as the user had their finger in the no-text space of the page. Additional auditory feedback was used to announce the 'Next' and 'Previous' page buttons that were placed at the end of the active page area of the iPad.

### Overlays

The three overlays used in the study were embossed using a ViewPlus Imprint Braille embosser. Screen protective films (made of plastic) for the iPad were used in place of paper to emboss a certain pattern of lines. Plastic protective films were chosen as a material because of the lesser chances of degradation of the embossed dots over the time of use. Researchers not only aim to find a pattern of the overlay with which the IBSVIs are most comfortable with but also a material that could be easily accessible to the users.

Overlay A (Figure 2) had 14 embossed horizontal lines. A horizontal line on this overlay was made such that two lines without any space between them ran together from one end of the plastic overlay to another.



Figure 2 – Overlay A

Overlay B (Figure 3) had 30 embossed lines. This overlay had more embossed lines but the embossed dots making up these lines were less pronounced than overlay A. Overlay A was embossed with a line thickness of 2 points whereas overlay B had a line thickness of 1 point. After every 4 single embossed lines, double-embossed lines (i.e. two rows of embossed dots without any space between them) were provided in this overlay. Three vertically embossed lines that divided the horizontally embossed lines were also provided on the overlay. The vertical and the double-embossed lines were provided to help the users better understand the page spatially.

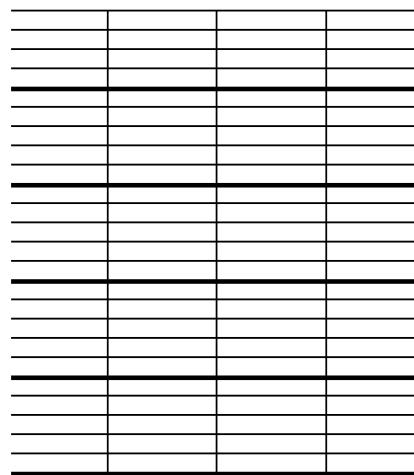


Figure 3 – Overlay B

Researchers had the premise that these double-embossed and vertical lines will help the users in positioning the textual information on the page and also help them to locate themselves on the page. For example, when a user gets to the second vertically embossed line they can interpret that they have reached the middle of a line. Similarly when a user reaches a double-embossed horizontal line, they will be able to spatially locate where they are on the page lengthwise; and knowing the position of the double-embossed lines the user can also trace back to a particular line in the text. Overlay C (Figure 4) had 30 embossed lines and vertically embossed lines similar to overlay B. But in the overlay C, all the 30 lines were double-embossed i.e. each line was a

combination of two embossed lines and in place of three there were two vertically embossed lines.

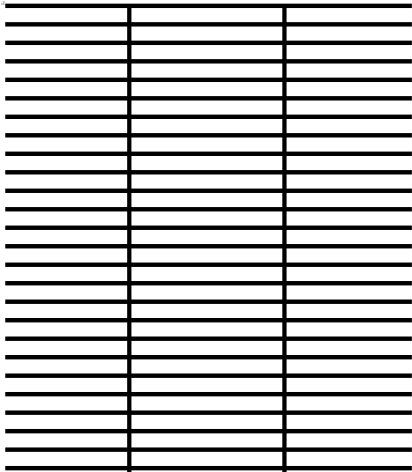


Figure 4 – Overlay C

## METHOD

### Consultants

Three IBSVIs from a nearby community for individuals with blindness were the consultants in the design session. These three individuals were added as “design consultants” to the project and each iteration of STAAR system will be discussed and design features will be brainstormed with them before testing it with other IBSVI users.

The age of the three consultants was 32 years, 65 years and 70 years. All the three consultants were legally blind with some residual vision. One of the participants had no vision in left eye but 5% vision in the right eye. Other two consultants had residual vision in both the eyes. One of the consultants who was 65 years old was blinded at birth and the other two consultants lost their vision as adults, one at the age of 25 years (now 32 years old) and other at 60 years (now 70 years old). None of the consultants were Braille literate. One of the consultants had completed her education till 1 year of college and another had attended community college. The younger participant was attending college and had to do intensive reading as required by her course work. Two of the consultants could read text larger than 14 point Arial – bold. Audio books or large print was preferred reading medium for all the consultants. One of the consultants had started using Amazon Kindle for reading daily and from Jan 2011 till Oct 2011 this participant had read 24 novels on Kindle. The consultants shared with the researchers that they don't like writing and taking notes as they found writing to be ‘frustrating’.

### Equipment and set-up

Two iPad-2s with the STAAR application installed were used in the study. Three different overlays (labeled A, B, C) were used to help guide the consultants over the iPad screen.

Two video cameras mounted on tripods were used to record the participatory design session. One of the cameras was mounted at the face height of the consultants and the second camera was mounted so as to capture the hand gestures of the consultants from the top view.

### Procedure

In this participatory design session, the consultants were given a familiarization session in which they were told about the iPad and its functions. They were using the iPad for first time so they were given ample time to feel the surface of the iPad screen and explore some of its features. After introduction to the iPad, they were given a thorough demo of the different features of the STAAR system. When all their questions were answered about the system functions, consultants completed some reading tasks. Before giving them the reading tasks, they were given an easy reading exercise in which numbers in large font size were written. This exercise was designed to introduce the consultants to reading using the STAAR system. In the reading task, the consultants had to read two pages from the novel “A Tale of Two Cities”. The second page in the STAAR system was provided so as to explore the use of ‘Next’ and ‘Previous’ page buttons present at the bottom of the page. The consultants were asked to read both pages of text by using all the three overlays. As they read the text, they gave feedback and suggested some design ideas to the researchers.

Due to logistic reasons the third design consultant was unable to attend the participatory design session with other two consultants. The participatory design session with the third consultant was conducted two months after carrying out the session with other two consultants. Some improvements as suggested by the two design consultants were made to the STAAR system and an updated design of the system was given to the third consultant. In the updated version of the system, the text-to-speech voice, overlays, and the no-text area sound notification were modified. Plastic embossable sheets were used as the embossing material for the modified overlays. The embossed dots on these overlays were more pronounced than the overlays used in the previous participatory design session. A smoother no-text area sound notification was used in the updated system. The text-to-speech voice was also modified to reduce its machine-voice like characteristic.

### Data Analysis

The videos recorded in the participatory design session were analyzed using the critical incident technique (Flanagan, 1954). Critical incidents are incidents when some functions of the system can either obstruct or support the comfortable use of the system by the users. To avoid bias during the critical incident video analysis process, an independent coder was selected. After training, the coder conducted a video analysis by logging both a priori critical incidents and incidents the coder deemed critical to system performance.

## RESULTS

After video analysis and gathering information from notes taken during the PD session, the design team prioritized the user requirements. Examples of user requirements were to provide more guiding landmarks on the overlay, synchronizing the speech rate with finger-sliding motion of the user, guiding the user to the next line in text, providing more feedback to the user and improving the auditory cues while performing the task of reading.

The broad range of observed critical incidents were categorized under localization, sonification design, overlay design, and iPad functionality categories. Localization refers to locating the textual information on the iPad's "page" by the consultants. Sonification design refers to the auditory tones, signals and text-to-speech engine related functions of the STAAR system. Overlay design is related to the layout and placement of embossed lines on the overlays. Lastly, in iPad functionality category some of the functions that did not belong to specific category of the design of the STAAR system but were related to some of the functions in iPad that were important part of the system as a whole. Figure 5 gives the number of observed critical incidents for each of the above mentioned four categories.

### Localization

Consultants had difficulty locating themselves on the "page". They asked for additional functionality and features in the STAAR system to better help the user with localizing the text. Eight critical incidents were observed related to localization of text. All the consultants mentioned that they had difficulty transitioning between the lines of the text. After reading a line of text, it was difficult for them to find the beginning of the next line. They could not tell if they were on the right next line (with respect to previous) or if they skipped some lines when they picked up the finger to go to the next line. They mentioned that there was no feedback to help them cope up with this situation of locating the lines. No presence of a reference point for the beginning and ending of lines was also pointed out by the consultants. It was suggested to add some sound notification feature to let the users know where a line has ended and where a new line starts. The no-text space

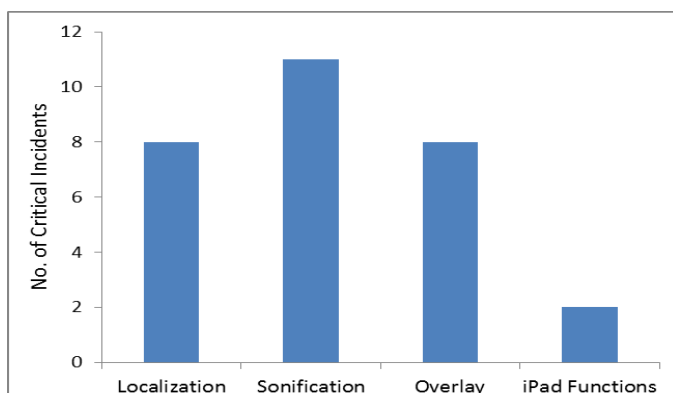


Figure 5 – Number of Observed Critical Incidents according to categories

sound notification did inform the consultants about the ending of a line and was also supposed to help them to find the beginning of a new line but it didn't help the users as much as was expected by the researchers. Another reason for this problem is due to the fact that the lines of the text do not overlap with the embossed lines of the overlay. This was communicated with the consultants in the beginning of the design session so that they don't expect the overlay lines to exactly follow the text below. The consultants still tried to follow the lines of the overlay and got lost when there was a line of text between the two lines on the overlay. The third consultant also had similar problems with locating the text as the other consultants. She was not able to map the speed of sliding of her finger over the text to the speed of text-to-speech reader. Other consultants had not mentioned or noticed this lack of feedback for the speech rate while reading by rolling their finger over the text.

### Sonification

There were eleven critical incidents observed related to the sonification of the system. Consultants had difficulty comprehending the voice used for the text-to-speech reader and mentioned that a lot of their mental resources were used in paying attention to the text-to-speech reader's voice. The text-to-speech reader also couldn't keep up with the reading speed of the consultants i.e. the consultants moved their finger faster over the text than the text-to-speech reader could convert their touch into speech output. Consultants found the no-text area notification to be "annoying" and too distracting. Consultants suggested having an option to choose between male and female voice for the text-to-speech reader. Sound notification to help the users locate themselves over the active area of the iPad was also mentioned as a design feature that could be added to the STAAR system. One of the consultants shared with the researchers that the text-to-speech reader was sometimes reading two words together and didn't give enough pause between the words. A feature so that the tempo of the speech could be controlled was also discussed with the consultants.

The third consultant was given a modified version of the STAAR system that had an improved text-to-speech reader's voice and no-text area notification sound. She didn't find the no-text notification sound to be "annoying" and was able to understand the text-to-speech reader's voice. She had fewer grievances with the sonification than she had with localization of text on the page.

### Overlay

Overlays were found to be helpful by the consultants in understanding the iPad surface as a "page" but overlays didn't completely aid in the task of reading. Eight critical incidents were observed in the videos related to the overlays. The overlay material sometimes prevented the user's touch to be recognized by the system. One of the users didn't find the overlay material sensitive to their touch. Both consultants felt that the embossed lines of the overlays needed to be more pronounced. They suggested that the overlays can have a



boundary so as to help the users know where the active area of the iPad is and where they need to restrict themselves while the task of reading is being carried out. Both consultants could not feel and find the embossed vertical lines present on the overlays B and C. All the consultants liked overlay C the most. They found the combination of vertical and horizontal lines on an overlay helpful in locating themselves on the page. The consultants preferred more number of embossed lines that were closer to each other on the overlays over the less and widely-spaced embossed lines.

Overlay C seemed like a "notebook page" to the third consultant. She felt most comfortable using the overlay C and had very few skipped lines while doing the reading task. But she didn't find the vertical lines on the overlay to be very useful.

### iPad Functions

Two observed critical incidents, one related to the brightness and contrast of the iPad screen and another related to the volume control of the iPad were observed. As these consultants had some residual vision, they wanted to zoom the text to a larger size and have a bright screen so as to try reading it with their eyes. Consultants had difficulty adjusting the volume of the iPad using the volume button present close to top-right corner of the iPad and wanted a more readily available control in the STAAR application itself.

### DISCUSSION AND CONCLUSIONS

Some design ideas for improving the STAAR system were brainstormed with the design consultants. For improving localization of text while reading, a vertical ruler on the left will be added to the overlay design to provide for anchoring user's non-reading hand. A sound notification will be added to help users know when they are close to the beginning of a new line. The no-text area sound notification was found to be "annoying" by the design consultants. More common and pleasant sound icons can be used for this notification. New materials which are comparatively thinner than the material used for the overlays in this participatory design session will be researched so that the embossed lines are pronounced enough to guide users over the lines of text. Thinner overlay might allay the problem of system being less responsive to user's touch as had been pointed out by the design consultants. There was a time gap between user's finger touch and response from the system. This made it difficult for the users to have a constant reading speed. Some mathematical models are being considered to be incorporated into the system design to better predict the user's finger movement and match the text-to-speech reader to user's finger touch.

The participatory design session provided the research team with new information that can be used in further development of STAAR system. This participatory design session also bolsters the point made by previous research that users need to be involved in the design process as the designers' and users' mental models might not match resulting in a system that doesn't work for the target population. Involving users with certain disabilities in the design process becomes even more

important. In this participatory design session, other than improving some features of STAAR, the most crucial information was that IBSVI users needed constant feedback for locating themselves on a page. The critical incidents observed in the videos were mainly the issues with the STAAR system that prevented its comfortable use by the consultants. Their experience with using the STAAR system was significantly affected by the amount and timing of the feedback they received from the system.

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