Touch-Screens are Not Tangible: Fusing Tangible Interaction with Touch Glass in Readers for the Blind

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ABSTRACT

In this paper we introduce the idea of making touch surfaces of mobile devices (e.g. touch phones and tablets) truly tangible for Individuals with Blindness or Severe Visual Impairment (IBSVI). We investigate how to enable IBSVI to fuse tangible landmark patterns with layout of page and location of lexical elements -- words, phrases, and sentences. We designed a tactile overlay that gives tangible feedback to IBSVI when using touch devices for reading. The overlay was tested in a usability study, and the results showed the role of tangibility in leveraging accessibility of touch devices and supporting reading for IBSVI.

Author Keywords

Tactile, Overlay, Reader, Touch screen, Blindness.

ACM Classification Keywords

H5.2. Information interfaces and presentation: User interfaces.

J.m. Computer applications: Miscellaneous.

K.4.2 Computers and society: Social issues

General Terms

Design, Experimentation, Human Factors, Standardization.

INTRODUCTION

Mobile multi-touch devices have become a mainstream. The recent advances in technology lead to the production of touch phones and touch tablets, and these devices become available in market with a wide range of applications and use cases. Interaction with touch devices depends mainly on the visual interface. While touch is the main input to the touch devices, there is nothing on a smooth glass screen that provides information to the user about what is beneath the glass. Sighted users employ vision to tell the user what and where to touch, but this interface lacks accessibility for IBSVI because it lacks physical landmarks and tangible buttons. A typical solution is to provide voice over to provide this information, but there is nothing to guide the IBSVI to that location in the first place, and there are no landmarks other than dead-reckoning and pure spatial memory to support navigation for the IBSVI. For example, the Apple operating system, iOS, has VoiceOver function, and the Android OS has a Talkback function. iOS' VoiceOver reads aloud the icon name if the user touches it. To activate the icon, the user should double tap on that location without the benefit of vision to ensure that the finger does not stray from the touch point.

The problem with such accessibility modes is that the user can develop a spatial mental model for the interface or the screen only through dead reckoning to find VoiceOver locations, in the absence of any landmark other than the boundary of the device. This problem is exacerbated for the IBSVI especially if the size of the screen is relatively large as in tablet devices. Additionally, the accessibility mode requires the user to learn more sophisticated gestures than the sighted user uses to perform the same action.

In order to solve this problem, we propose to use a physical overlay on the top of the touch screen. The physical overlay should have a tactile pattern that can guide IBSVI to interact efficiently and effectively with the touch device. However, there are different kinds of interactions, and each type of interaction will require different tactile pattern design. For example, in our work in developing a Reading system [4], we found that reading, as a highly cognitive activity [5, 6], requires significant interaction support. This Reading system displays pages of text and can read aloud each word touched by the user. However, IBSVI have difficulty in locating individual text lines, or even in keeping on a particular line. IBSVI readers need to understand the spatial mapping of the page to make sense of the material. Typical 'button-based' interaction, on the other hand, requires that the user locate button locations as discrete spatial locations, and to activate the button once it is found. Interfaces for drawing, have yet other needs (e.g. locating a line drawn earlier).

In this paper, we introduce guidelines on how to design the tactile overlay that supports reading on touch screens. We investigate the elements and the parameters that should be considered when designing an overlay. We focused our research on the tablet size screens because of their relatively large screen, which makes it more challenging than the phones for IBSVI to use. Also, the size of the tablet, that resembles the physical dimensions of pages in printed books, is better suited for presenting textual material. We began our design with the basic intuition that the landmarks should guide the IBSVI more accurately in the horizontal dimension (corresponding to lines of text), and have sufficient vertical resolution to help the user to locate the text lines in the first place. Also, because we do not know the line separation of different documents, the purpose of the overlay is not restricted to having a one-to-one correspondence with the text on the page. This gave us a few design choices from which to begin. Based on the literature, we added elements to the initial overlay.

We varied the parameters of these elements, which lead to 3 different overlays. We introduced the 3 overlays to 3 IBSVI who worked with us as consultants for our project. The 3 overlays were used on the top of the custom reading software installed on iPad to read standard PDF documents. These formative studies with our consultants allowed us to eliminate one design as impracticable, leaving two basic designs for further tests and modifications. Our formative studies also informed the adding of new elements to the overlay. We then engaged 12 IBSVI in a usability study and tested these 2 overlays with the Reading system.

Reading material on touch interaction devices is essentially text under featureless glass for the IBSVI. The contribution of our research is to imbue touch screens with tactile landmarks enable the IBSVI to read. This goes beyond what voice over technologies can provide. While it has been shown that ‘trial-and=error’ exploration can allow an IBSVI to decide what screen button to activate [7], this does not help reading. There is no such thing as ‘trial-and-error reading’. Our work will inform the design of touch overlays that can transform touch surfaces into effective spatially accessible reading material for IBSVI.

LITERATURE REVIEW

In this section, we review the research efforts that are dedicated to enable IBSVI to use touch devices. Also, we describe the design ideas in previous work that inspired our initial overlay design.

Leveraging accessibility of touch devices is usually achieved by introducing sonifications and auditory feedback, or on haptic feedback. Some systems tried to combine both the auditory and haptic feedback in their design. Examples of systems that use auditory feedback on touch screens are [8-10], which have the purposes of accessing menus, maps and relational diagrams, respectively. Another study in [11] showed that earcons and speech synthesis could be used in video annotating for IBSVI. For mobile phones, an interaction technique to speed accessing icons and advanced functions for IBSVI is proposed in [12]. Accessing large screens using auditory overlays was investigated in [13]. The overlays they used are software-based techniques that provide auditory feedback for spatial navigation and interaction. The studies

Figure 1 Left: Tactile keyboard [1]. Right: Tactile grid [2]. Bottom: Overlay for MP3 player [3].

they conducted showed that their overlays are better than Apple’s VoiceOver. Their results, also, show the need for supporting spatial awareness for IBSVI especially on large touch screens.

We can see from the literature that different kinds of information cannot be accessed using only one auditory structure. This need is obvious when we consider the varied visual formats used for different kinds of information. For example, geographical information or tabular financial information employ significantly different visual presentation and cues.

Another body of literature is devoted to provide accessibility for touch devices using haptic feedback. Trying to find the best characteristics of the haptic feedback on touch screens, for example, the authors of [14] tested different tactile clicks produced by piezo actuators and a standard vibration motor. A recent study targeted the design of tactile stimuli using variable-reluctance actuators to give feedback for tapping soft buttons on touch screen [15]. Another study used the haptic feedback to acknowledge the user’s navigation and locating on the touch screen before starting interacting [16]. Turunen et al. conducted a series of studies to achieve a usable multimodal design to make media centers more accessible to both IBSVI and low vision users [17]. They combined gestures, speech, and haptic feedback as models of interactions.

The authors in [18] provide a good discussion of the main existing techniques used by blind users to have graphical access and communication. Their contribution was to describe a grid- based model that gives blind users feedback for relocating important points, determining angles and lines length. Their study highly affected assistive technology literature, as their model is the basis for various systems and applications for unsighted users. This paper influenced our design to use a modified grid-based interface that is more suited to reading standard text layout. This interface will help them relocating lines they previously

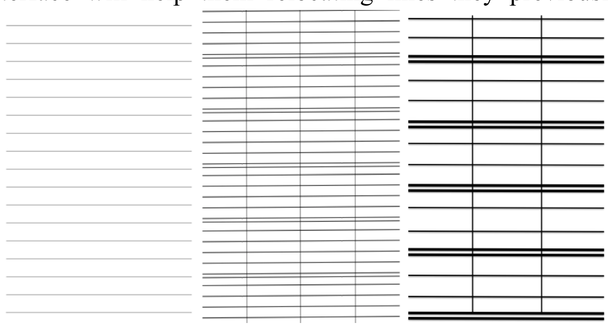

Figure 2 **Left: Overlay A, Mid. Overlay B, Right: Overlay C**

read or notes they had taken.

Examples of tactile surfaces are shown in **Error! Reference source not found.**. The top-left of **Error! Reference source not found.** shows a tactile keyboard design for iPhone to enable better and faster typing on the iPhone [1]. The top-right of **Error! Reference source not found.** shows a tactile grid for an iPad application that explores relationships between musical pitches [2]. These tactile overlays were developed for personal and commercial reasons. To the best of our knowledge, no research studies are reported for their usability or rationale. The picture shown at the bottom of Figure 1 is a raised paper that covers an MP3 player touch screen [3]. The overlay was evaluated by 2 studies, the first one was with blindfolded participants, and the second was with one blind participant. The authors discussed the problems with touch screens accessibility for IBSVI, and suggested a set of design rules to solve the lack of accessibility of touch devices.

In order to help researchers and developers with their work in the field of accessibility, the authors of [19] proposed an accessibility toolkit. The toolkit can be used for creating various accessible mobile applications.

APPROACH

To leverage the usability of touch screens for IBSVI for reading purposes, we designed several prototype overlays with tactile patterns to assist IBSVI to explore and interact with touch screens effectively, especially for the purpose of reading text. The physical overlay should help IBSVI engage their spatial cognition, perception, and sensing resources while interacting with the touch screen. The overlays are designed with patterns and landmarks that support spatial access to touch screens. The tactile overlay covers the touch device screen, where an IBSVI can use its tactile patterns to locate the text/icons/buttons in the touch device interface. The overlay is intended to operate in conjunction with other technologies that provide auditory feedback (e.g. VoiceOver or other sonification) that informs the user of 'what' is at that location on the screen while the overlay helps the user to know 'where' it is.

Our strategy is to employ a standard embosser designed to produce Braille and raised line drawings [20] to produce our tactile overlays. We designed different sets of embossed patterns that can support navigation, exploration, spatial referencing, and location awareness on touch screens for IBSVIs. A trial and error approach was employed to find a transparent material that can be embossed and does not impede touch interaction. We used Embossables [21], which are label material, to produce the overlays. They are transparent thin plastic sheets that can be glued to the iPad screen and removed easily. We believe transparency of material is important because of two main reasons. First, some IBSVIs have residual vision capabilities and being able to see the iPad screen will help even with low visual acuity. Second, transparency helps the researchers in usability and accessibility studies to observe how users interact with the system, and may help users to read along with sighted compatriots.

Our initial 3 prototypes are shown in **Error! Reference source not found.**. The initial design of the overlay consists of a set of horizontal lines and vertical lines. The horizontal lines should help IBSVI keep their fingers moving horizontally on lines of text. The horizontal lines are arranged with equal spaces between each line. Moreover, the horizontal lines can be defined in terms of sets, where each set consists of number of horizontal lines and a thick horizontal line. So that the IBSVI can locate their place by finding the thick lines, and for more precision they can count and move a number of raised lines above or below the thick line. The vertical lines combined with the horizontal lines serve as a grid or a map that help IBSVI to formulate a mental reference for location awareness to maintain place on the screen. The vertical lines are also spaced equally apart. The density of these lines (or spatial interval between lines) is determined by the expected use of the overlay. For example, for reading text, we may need only 3 vertical lines to mark the quarter-locations of the screen. For reading graphics or a spreadsheet, the inter-line interval would be closer.

The parameters of these basic elements that we investigated are:

Horizontal lines parameters: number of raised lines, thick line interval (number of thin lines between thick lines), length of raised lines, thickness of normal raised lines, thickness of thick raised lines, left offset of normal raised lines, and left offset of thick raised lines. *Vertical lines parameters:* number of vertical lines, position of vertical lines, and thickness of vertical lines. *General Overlay Parameters:* overlay punch depth (this is specified per overlay), and overlay material. The punch depth is set during the process of embossing using the embosser software. Varying the punch depth is important when it comes to emboss different types of materials with different thickness. Also, the punch depth setting can be useful in producing special tactile graphics.

We varied the parameters of the overlay elements and designed 3 different overlays, as shown in Figure 2. The overlay on the top left (Overlay A) consists of only horizontal lines. The distance between them is even and they are all of equal thickness. The overlay on the top right (Overlay B) consists of sets of horizontal lines, each set consists of 4 raised lines and one thick (doubled) line. The rational behind this thick line is to facilitate counting for IBSVI. By locating a thick line, they can guess their place and go back to a previous place easily. Also, Overlay B has 4 vertical lines. The overlay at the bottom (Overlay C) is similar to Overlay B as it has vertical lines and thick horizontal lines. However, the distance between lines is larger. Hence, the number of lines is fewer.

We introduced the 3 overlays to 3 IBSVI who worked with us on this project as consultants. They are 2 females and one male; their ages are 32, 65, and 70. They are all legally blind. At the beginning of the participatory design session, we introduced the iPad and the Reader system to the consultants. We gave them the 3 overlays to explore with their hands. Each consultant used the 3 overlays and after each trial, s/he was asked about the good and the bad of the overlay, and what would be the pattern of the best overlay according to her/him. Also, they were asked about the vertical lines and whether they found them useful.

The conclusions of the participatory design session are driven by both the consultants' feedback and the researchers' observations. We grouped the consultants' feedback and their subjective opinions. All consultants found the overlay is useful in adapting to the iPad. They did not like the Thick lines and found them confusing. One of the consultants said that she likes the overlay to be even like a notebook page. They had different opinions about specific parameters of each overlay. For example, 2 of them said that the vertical lines helped them to remember their place on screen and to go back to a previous visited location. The third consultant said that she didn't make use of the vertical lines but they did not cause any harm. The consultants suggested adding haptic icons on the overlay to mark soft buttons in the application and to mark the application's touchable icons (or buttons). During the session, the researchers realized that the consultants were

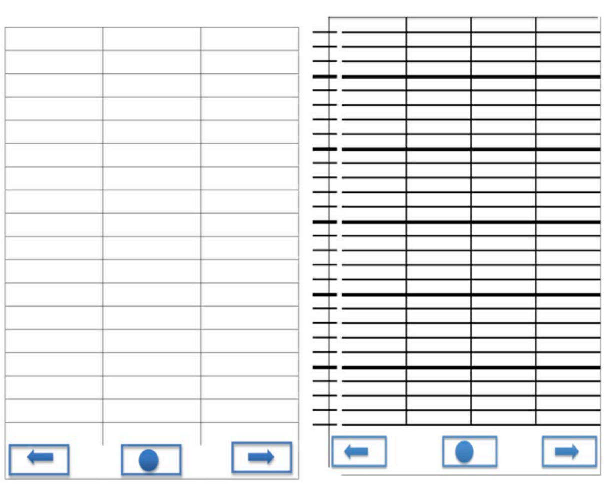

Figure 3 Left: Dense overlay. Right: Simple overlay.

not able to differentiate between the active area of the iPad screen and the black inactive border. This is because none of the tested overlays have landmarks for the active area of the screen. Also, the system does not respond to the user's touch unless s/he touched the active area. We define the active area of the touch device as the area of the surface where the user's touch is tracked. Additionally, we realized that the consultants tended to use multiple fingers during their interaction with the iPad. Usually, IBSVI used one finger as an anchor or reference location, and one finger for interaction. We incorporated the consultants' advice and feedback to the overlay design and reduced our design space to the 2 overlays shown in Figure 3 In the design of these overlays we introduced 3 elements:

1. The border: The border marking (raised points) of the overlay serves two purposes. The first is to help the IBSVI locate the active area of the touch device. The second is to provide a kind of ruler marking to support grid-based landmarking or spatial referencing of the device surface.

2. The rulers: These rulers reside at the border (typically top and left) of the device. A vertical ruler comprises a vertical line that is spanned by short horizontal lines at fixed intervals. A portion of the horizontal line will be inside the active area of the surface, and a portion will be outside. This allows the user to use the markings outside the device surface for landmarking without necessarily or inadvertently activating the device, and the portion of the marking in the active area allows the system to track the location of the touch along the vertical ruler, and to provide appropriate feedback. For example, a program for reading text can use the touch inside the active area to know if the user is at a line of text. The user can use the markings outside the active area to help navigate from memory. The horizontal ruler is identical to the vertical ruler except that it marks the vertical columnar position of the surface.

3. The tactile buttons: The buttons are used as tactile landmarks for the soft buttons on the touch screen. Each button consists of a rectangle with a distinguishable haptic icon mapped to it.

The different possible elements of overlays that we investigated are compiled in **Error! Reference source not found.**. We want to point out that certain elements were not of use for Reading as depicted by our pilot studies. The horizontal ruler, for instance, was never used by IBSVI while reading in Portrait orientation.

STUDY

We designed 2 overlays shown in Figure 3 with the hypothesis that they can enable IBSVI to engage their spatial cognition, perception, sensing, and memory while interacting with the touch screen for reading, provided that the system provides adequate audio feedback for the user's touch. The 2 overlays have different combinations of the elements we want to test. For example, the Simple overlay has an even and uniform grid, while the Dense overlay has

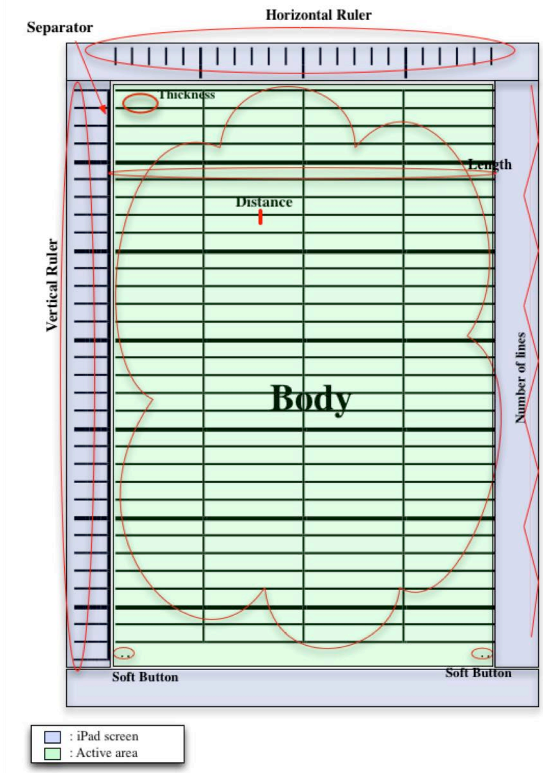

Figure 4. A graphical illustration for the different possible elements of our overlays.

thick lines. The Dense overlay has a vertical ruler, while the Simple overlay does not, and each horizontal line begins at 0.25 inch from the right side of the vertical ruler, and extends to the *right border*. The line spacing in the Simple overlay is 0.4 inch separation, while the Dense overlay is 0.25 inch separation.

Methodology

We conducted a usability study to know which overlay tactile features in our test overlays provide more effective landmarking affordances. We used the iPad 2 with operating system iOS 5.1 as a platform. A custom reading system that reads each word touched by the user [Reference is blanked for review] was installed on the iPad. We provided two ways for interacting: 1. Gestures, such as swiping with 3 fingers and tapping with 4 fingers; and, 2. Fixed soft buttons with physical landmarks on the overlay. We glued the overlays on the iPad screen, one after another.

The participants were asked to read different pages with different layouts and text sizes, with the overlays on. The participants were asked about their opinions of the 2 overlays. The order by which the overlays and the pages were given to the participants, was counterbalanced. The overlays details are summarized in Table 1.

Participants

We recruited 16 IBSVI with the help of a local community group. The participants' ages ranged from 34 to 91, with

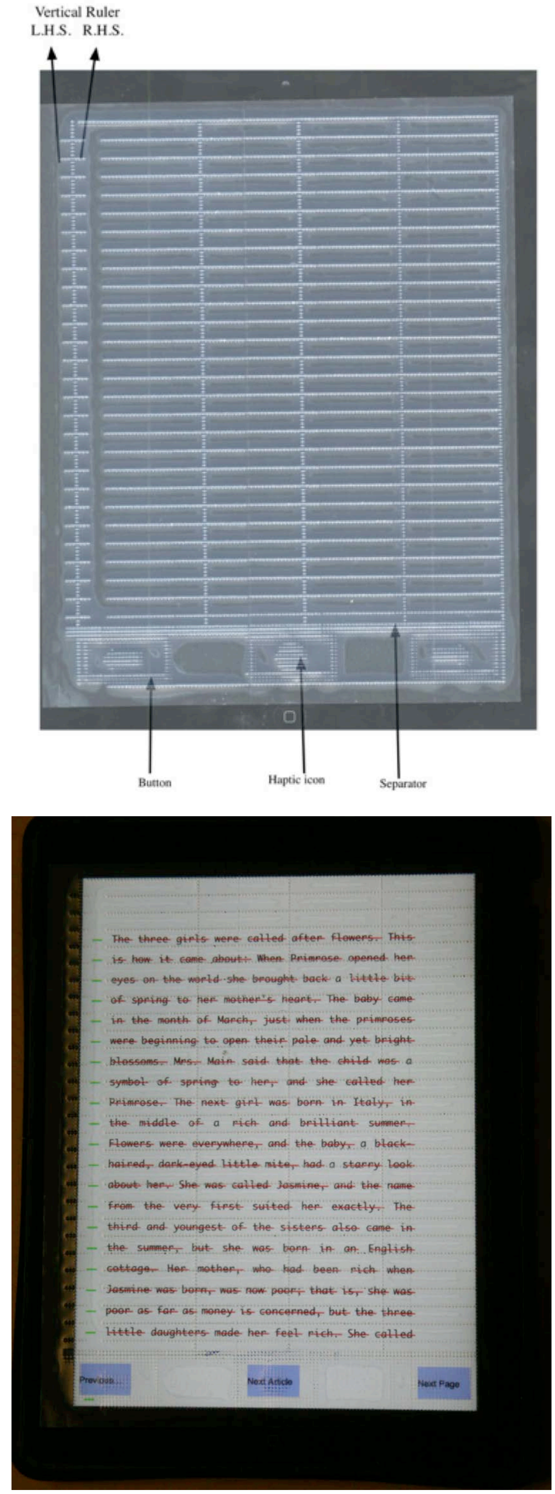

Figure 5 Top: Overlay on the iPad. Bottom: Overlay on the iPad running the Reader system.

mean age of 69 (SD = 33.3). This reflected the demographics of the population supported by the community group. Nine participants were females and 7 were males. Three participants were born blind, 4 participants had total blindness and 8 were legally blind.

Six of the participants could read Braille and 15 participants preferred audio as a reading medium. In this paper, we

Table 1. The Overlays' specifications.

	Simple Overlay	Dense Overlay
Punch depth	2	2
Orientation	Portrait	Portrait
No. of Horizontal lines (HL)	20	31
Distance between HL	0.4	0.25
Thickness of HL	1.50	2.25
Thick line (TL) interval	N/A	4HL 1TL
Thickness of TL	N/A	4.50
No. of Vertical lines (VL)	2	3
Thickness of VL	1.50	2.25
Vertical Ruler (VR)	No	Yes
No. of VL in VR	N/A	23

report results for 12 IBSVI because the other 4 participants data are incomplete.

Study Description

In this study, we have 3 different parameters; each has 2 possible values. 1. The overlay: can be Simple or Dense. 2. The text size: can be Small or Large. The speed of the text-to-speech (TTS) reading: can be Fixed or Varied according to the speed of the user's touch. In this paper, we will focus on the aspects of the study that answer our research question regarding the effective elements of the overlay.

Each participant participated in a familiarization session where they were given a brief description of the iPad device, the reader system, and the overlays. During the familiarization session, the participants were free to explore the iPad and the overlays, and to ask questions. Each participant was then given 8 pages of text. Each page has different content and layout. 4 pages have small font size and the other 4 have large font size. Small: font size=14, and space between lines=1.0. Large: font size=20, and space between lines=1.5. With each reading page, one of the overlays was glued on the screen. The order of content and page parameters were counterbalanced in our study.

The top of **Error! Reference source not found.** shows a picture for the overlay on the iPad screen turned off. The bottom of **Error! Reference source not found.** shows a picture for the overlay on the top of the iPad screen and the Reader software. Participants were encouraged to explore both gestures and landmarked haptic buttons. At the end of each task, a questionnaire was administered to each participant in which her/his opinion to that particular combination of parameters was solicited. At the end of the

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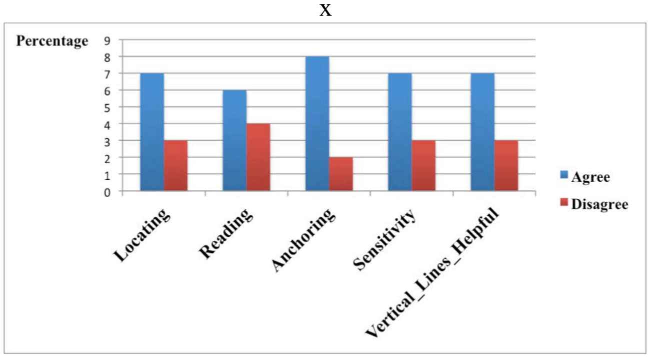

Figure 6 . Subjective evaluation of the users' feedback for the spatial-interaction features of the overlay.

study, the participant was asked about her/his general opinion in the overlay and the overall user-satisfaction. Also, we collected background information about each participant that is relevant to our study, such as the participant's experience level with touch devices, and familiarity with and use of Braille.

DISCUSSION

In this section, we discuss the results we obtained from the usability study. Then, we analyze the meaning of these data and our observations during this study and the previous participatory design sessions.

The Study Results

The background information showed that only 2 participants reported prior use of touch devices. One of the participants who is totally blind since birth said: "*I do not like touch screens, I like buttons; large buttons*." One participant who uses a touch phone and enables its VoiceOver mode, uses a QWERTY keyboard attached to the phone and she said: "*It happened several times that I dial phone numbers with no intention when I use the touch surface.*"

The questionnaire on overlay features given to the participants contains questions that can be grouped into 5 categories. These categories are *Locating*, *Reading*, *Anchoring*, *Sensitivity*, and *Vertical Lines*. By *Locating*, we mean the spatial awareness on the touch screen. We asked, for example, about how easy or difficult it is to find a button or section of text. The *Reading* category contains questions about the usefulness of the overlay to stay on line and to find next line. Also, the participants were asked about the effect of the vertical ruler and whether it helped them in *anchoring* or not. The forth category, *Sensitivity*, comprises questions about the material of the overlay. We wanted to know if the material we used is sensitive enough for the user's touch or it blocks interaction. The last category of questions is about the *vertical lines* and whether they supported the formation of spatial awareness about the page layout and location of reading.

The answers to the user satisfaction questionnaire are graphically plotted in **Error! Reference source not found.**. The subjective evaluations of the feedback for the different tactile elements are summarized in the below points:

1. Nine participants found the overlay useful in locating places of text on the screen,
2. Three participants found the vertical lines not useful.
3. Two participants said the overlay did not help them to anchor.
4. Three participants found the material of the overlay were not adequate for the sensitivity level of their finger touch. (Note. A number of our participants were older and/or had diabetic conditions that reduced their touch acuity).

The answers of the open-ended questions we asked the participants about the overlay are summarized as follows:

1. Tactile features provides visual/spatial queues:

- Vertical lines were used as a guide
- Participants like the wider overlay
- Vertical lines were helpful for navigating to the next page
- Vertical lines were helpful to find next paragraph
- The overlay provided good landmarks for reference
- The overlay helped anchor the reading finger.

2. Most participants preferred using the haptic buttons to gestures. However, one of the participants said: "*I find the gestures more fun*".

The Overlay Overall Evaluation

The main function of augmenting the touch screen with a tactile overlay is to provide tactile references on the top of the smooth screen. The tactile landmarks and references increase the accessibility and usability of touch screen for IBSVI. The tactile overlay can support complex activities such as reading. The tactile overlay enables IBSVI to interact with touch screens while engaging their mental spatial capabilities. In short, the while system features like iOS' VoiceOver can tell the user *What* s/he touches on the screen, the tactile overlay is needed to tell her/him *Where* s/he is on the screen.

The clear advantages of the tactile overlay are the ease of production, and low cost, and that it requires minimal training to use. However, it has limitations that are inherited in its static nature. The static nature of the overlay makes it difficult to situate all use cases. For example, if the overlay is embossed to be used in the Portrait mode, it will be hard to use the device in the Landscape mode.

This begs the question of whether overlays have to be designed for each specific software, or if they can be generalized for use with a broad category of software? We believe that different types of software will need different patterns on the overlay. However, software programs can be grouped into categories and one overlay may be sufficient for most programs under this category. For example, an overlay for reading can be used with PDF reading programs, iBooks or Kindle, and web readers (e.g. Mozilla Firefox). However, such a reading overlay may not be applicable for use with Musical or Drawing software. Combining the tangible interaction with the software components leads to more intuitive interaction and enables users to have more control.

Guidelines for Overlay Design

The overlay is used to provide extra structural details of the display beneath. Our goal is to express these structural details in tangible language or format. The structural details span both the device structure and the running application. From our observations and the data we collected, we suggest the following elements to be included in overlays for touch devices in general:

1. **The Border:** Most touch devices have inactive frame around its touch screen. This inactive frame helps users to carry the device without initiating any action or function. If this frame cannot be felt due to its lack of tactile physical landmark, we highly recommend that the overlay be used to provide this physical distinguishing feature to IBSVI.
2. **The Vertical Ruler:** We found that IBSVI need to anchor otherwise they will lose place. The vertical ruler secures the spatial reference for IBSVI. The number of horizontal lines and the distance between them can be varied according to the screen size. However, its existence in an overlay is a necessity.
3. **The Grid:** Dividing the screen into squares in the form of grid helps IBSVI know their place on the screen. Moreover, the horizontal lines help them follow straight lines more accurately. The number of horizontal lines, vertical lines, and the distance between them can vary from one overlay to another. For example, if an overlay is designed for Spreadsheets software, the user may want to increase the number of vertical lines and decrease the distance between them.
4. **The Tactile Buttons:** For operating systems that have position-fixed soft buttons such as "Unlock Screen" in the iOS, it is important to include a tactile landmark on the overlay that refer to the position of the soft button.

Overall discussion

Our study shows how the addition of a properly-designed tactile overlay may enhance the usability of touch-enabled devices of which the iPad is prototypical. For the sighted, these devices employ visual cues to inform the user of the spatial interaction afforded by the device. For the IBSVI, such devices are essentially features glass surfaces. While voice over technology and 'trial-and-error' exploration can provide some degree of interaction, this is not optimal. The overlay designs proposed provide the IBSVI with the capacity of spatial anchoring, turning the featureless surface into a more usable device for IBSVI.

More importantly, the research reported here is a part of a larger project targeted at enabling IBSVI engage in active self-paced reading on touch-enabled devices of which the iPad is prototypical. We observe that screen-reading technologies such as Apple's VoiceOver and Android's TalkBack do not really enable IBSVI to read on these touch surfaces. They enable the surfaces to become interactive devices for IBSVI by enunciating what is under the glass, so the IBSVI to know which 'button to press'. Reading requires that the user be able to access the material beneath the glass as continuous textual information. The overlay promises to provide the spatial structure to enable iPad-type devices to become the reading enablement that is one of their chief uses for the sighted.

CONCLUSIONS

In this paper, we addressed the problem of accessibility of touch devices for IBSVI. We introduced the idea of augmenting touch screen with a tactile overlay. We drove design ideas from other tangible interactions that are related to our design. We focused our research on tactile overlays that support reading activities on tablets. We suggested guidelines for the design of tactile overlays. A typical tactile overlay for touch devices consists of: a border, a vertical ruler, horizontal lines, vertical lines, and landmarks for soft buttons. The participatory design sessions with IBSVI consultants helped us better understand the accessibility problems of touch screens. IBSVI deployed different strategies trying to accommodate with the touch screen. The consultants' interaction styles, their feedback and suggestions helped us redesign the patterns of the overlay. The new design gives more spatial support and eliminates the elements that the consultants found confusing. The new overlay was tested in a usability study and the results show that tangibility leverages the usability of touch screens for IBSVI, and spatial awareness on touch devices can be provided by the physicality of the overlay for IBSVI.

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