Pre-print: Kuber, R., Hastings, A., Tretter, M. & Fitzpatrick, D, 2012. Determining the Accessibility of Mobile Screen Readers for Blind Users In proceedings of IASTED Conference on Human-Computer Interaction, Baltimore, USA, 182-189.

DETERMINING THE ACCESSIBILITY OF MOBILE SCREEN READERS FOR BLIND USERS

Ravi Kuber, Amanda Hastings and Matthew Tretter
UMBC
1000 Hilltop Circle, Baltimore, MD 21250, USA
{rkuber, ahasti1, mtrette1}@umbc.edu

Dónal Fitzpatrick
Dublin City University
Glasnevin, Dublin 9, Ireland
dfitzpat@computing.dcu.ie

ABSTRACT
As mobile interfaces are often designed with sighted users in mind, difficulties can be experienced by individuals who are blind, when using a mobile screen reader to access content. In this paper, we describe a data gathering study to determine the day-to-day challenges experienced when performing tasks using mobile screen readers. Challenges can be faced when gaining an overview of specific document types, processing multiple streams of audio, when performing complex web-based tasks, and instances where the device is accessed while the user is in motion. The findings provide an insight into the needs of diverse users, which can help to inform the design of inclusive mobile applications.

KEY WORDS
Accessibility, Accommodating People with Disabilities, Blind, Mobile HCI

1. Introduction

As mobile technologies improve in fidelity and reduce in cost, their popularity continues to grow. Estimates from the International Telecommunications Union [18] suggest that the number of mobile cellular subscriptions has reached 5.9 billion. While mobile telephones are used primarily for voice or text communication, advances in technology have enabled users to access email, the web, and applications while on-the-go. As devices continue to reduce in size, research suggests that difficulties are faced when locating objects on the interface, due to the small sized text and cramped nature of graphical icons [1], and deep menu hierarchies [16] which can be cumbersome to traverse. The case is more complex for individuals who are blind, who use assistive technologies (e.g. screen readers) to translate the visual content in to an accessible format.

This paper describes a study designed to uncover the difficulties faced when interacting with mobile screen readers and to profile mobile information needs. Findings could then inform the design of mobile interfaces, to enable blind users to gain access to content, thereby addressing the 'disability divide'.

2. Assistive Technologies

Mobile screen readers are often used by individuals who are blind, to provide an overview of interface content by outputting information in speech-based format. A recent study by WebAIM [20] revealed that 66.7% of participants surveyed used mobile screen readers, with larger numbers of novices utilizing these technologies. Examples of third-party applications include MobileSpeak[1], SmartHal[2] and Talks[3], which have been designed to provide access to a range of features including contact directories, caller IDs, text messages, email and web content. More recently, Apple[4] and Google[5] have included screen reading technologies which are integrated as part of their Operating Systems. Customized handsets such as the Touch Messenger[6] (Figure 1) provide a tactile alternative, reducing the need for a graphical user interface. The device enables users to compose Braille-based messages using the keypads, and view messages using a Braille display integrated within the device. While these assistive technologies provide a vital role translating visual content into a non-visual format, research suggests difficulties continue to be experienced when using mobile devices [8, 19].

Barriers to mobile access can be attributed to the design of content on the graphical user interface, coupled with restrictions of assistive technologies. If graphical icons on the mobile screen are inappropriately labelled, or

[1] MobileSpeak - http://www.codefactory.es
[2] SmartHal - http://www.yourdolphin.com
[3] Talks - http://www.nuance.com
[4] Apple Voiceover – http://www.apple.com/accessibility
[5] Google TalkBack – http://www.google.com
[6] Samsung – http://www.samsung.com

are not accessible via the screen reader, it can lead to problems gaining an overview of interface content. Navigation through an interface can be cumbersome, as users are forced to move sequentially item-by-item until they reach their intended target, placing additional demands on the user's memory. This can be more of a challenge depending on the design of the menu hierarchy. According to St. Amant et al. [16], menus can contain as many as 12 items, buried within hierarchies four levels deep. The auditory presentation can lead to the formation of a representation which is linear, rather than the rich, spatial layout presented on a phone. However, the emergence of screen readers on devices such as the Apple iPhone have gone some way towards alleviating the lack of positional awareness of objects on the interface, discussed later in the paper.

Figure 1. Samsung Touch Messenger

Many tasks that sighted individuals take for granted are not as straightforward for their blind counterparts, leading to feelings of frustration among users. Providing access to a handset is not only a matter of good practice by manufacturers, it is required by law in some countries [17]. While previous studies have focused on improving the design of the physical handset to ensure that the user is able to gain access to the phone, research has yet to concentrate on the problems faced using mobile screen readers themselves.

3. Related Work

Through a series of studies, researchers have identified recommendations for enabling disabled users to interact with mobile technologies. Smith-Jackson et al. [15] have recommended the use of contoured shapes to improve grip, greater spacing between buttons to aid perception of targets, and additional awareness of selections through feedback to aid blind and physically disabled mobile phone users. Kane et al. [8] have suggested using larger, more recognizable buttons on mobile devices. The authors have recommended improving screen magnification and contrast for users with some levels of residual sight.

Burton [3,4] has provided an overview of mobile functionality using a range of criteria (termed 'the Sweet 16'), which are judged to be factors to determine levels of accessibility. These include access to documentation, keys which are identifiable through touch, GPS functionality, and various software-related issues (e.g. accessible indicators for the battery, signal strength, power, volume and roaming). In a comparison between Talks and MobileSpeak [3], small differences were noted between applications. For example, while both offered the ability to silence the ringtone for an incoming call in order to listen to the caller name and number (caller ID), the researcher has suggested that Talks can be configured to repeat the caller ID in case it is not heard the first time. Similarly, both applications were found to offer one-touch speed dialling features to assign telephone numbers to the 2 through 9 keys on the dialling keypad. By pressing one of these numbers for a short period of time, a call would be placed to the corresponding number in the user's contact list. However, MobileSpeak enables the user to turn off the Speed Dial feature, and instead assign the 2 through 9 keys to other applications on the phone, thereby simplifying access to other software [3].

In terms of the capabilities of mobile screen readers, Burton [4] has compared the features offered by SmartHal and the MobileSpeak Smartphone software. Findings from the study revealed that while both assistive tools present a large amount of content from the screen, levels of access tend to differ, thereby impacting levels of usability. For example, the MobileSpeak Smartphone software was found to offer a Help mode, where the user is able to listen to the functions associated with help through making various keystrokes. The Help feature in SmartHal reads out each command and its function, in sequential order, meaning that the user spends more time in locating his/her desired option. The MobileSpeak Smartphone software hosts the benefits of a review cursor, enabling the user to explore the contents of the whole screen, even areas to which are difficult using the 'system focus' alone [4]. The MobileSpeak Smartphone software was also found to read from both the cursor position and the top of the document, message, or web page, providing the user with more flexibility, should he/she not want to read all the content in order.

A variety of challenges are also faced using mobile touch screen devices. Due to the lack of positional awareness of objects on mobile interfaces, Kane et al. [7] suggest that blind users may need to be shown the locations of on-screen items by a sighted person, or may require an alternative accessible interface. In the worst case scenario, they may be completely unable to use the device [7].

4. Existing Solutions

The 'Eyes-Free' project[7] has aimed to provide increased accessibility to blind smart phone users (Figure 2). The user is able to interact with a suite of applications, accessing content via the Talkback screen reader on Android operating systems. Examples of applications include 'Stroke Dialer', which provides an alternative to using a conventional touch screen virtual dial-pad. The dial-pad constructs itself around the point where the finger has been positioned on the mobile touch screen device, with the virtual key representing '5' underneath it. Dialling can be performed by sliding the finger in the direction of the number required. Vibrotactile and auditory feedback provide confirmation of the key selected. For example, if the user were to slide the finger upwards and to the left (i.e., in a north-westerly direction) a click-sound and a vibrational alert would indicate when they had found the number "1". The text messaging application uses a similar format, where characters are arranged in circles, and the user selects the one they require using up to three movements of the finger. The aim is to reduce the errors associated with the targeting process, to aid blind users to compose messages.

Figure 2. Eyes-free Android shell with gesture recognition

Continuing the theme of reducing erroneous entry via touch screens, Guerreiro et al. [5] have developed a text entry system where common vowels are positioned towards the left of the screen. Blind users are able to develop a structural representation of the location of vowels and consonants on the virtual keyboard, aiding entry of messages. Kane et al. [7] have explored the potential for a multi-touch based solution when using a touch screen. The user is required to make various gestures to perform functions. For example, a one-finger scan can be made to browse lists, a second-finger tap is used to select items, and a flick gesture is used to flip between pages of items or a currently playing song. In terms of low-cost solutions, McGookin et al. [10] have used additional props, to address the lack of positional information provided by the interface. The researchers attached a tactile adhesive dot (termed 'bump on') to provide awareness to the users, so they were able to locate a central point on the handset. The feedback provided aided users to reduce error levels when performing phone-based tasks.

The proposed research would build on the studies undertaken to identify the challenges with the screen readers themselves for both key-press (including smart phones) and touch screen interfaces. The research would examine the interactions with the technologies that are faced on a day-to-day basis (e.g. utilizing devices while in motion), rather than on the physical design of the handsets. This will aid mobile application developers when designing new products.

5. Study Objectives

The objectives of the data gathering study were to:

- Identify the technical abilities, and functions which are most commonly accessed when using a mobile phone.
- Determine the common and infrequently performed tasks for the phone.
- Understand the challenges using a screen reader to perform tasks such as making and receiving calls and text messages, using the web and other applications.
- Identify which functions and icons are not currently accessible.
- Determine the difficulties gaining an overview of content and navigating.
- Understand the challenges faced when using smart phone functionality (e.g. mobile TV, video, music, Microsoft Office-style applications).
- Identify the difficulties faced multitasking (i.e. walking and sending a text message at same time)

We also aimed to solicit views on the type of tasks which participants would like to perform in the future using mobile devices, and whether they had any design suggestions which could aid the current situation.

6. Method

Participants were recruited via advertisements placed on online message groups relating to screen reader usage. Depending on the settings adopted by each user, messages could be sent directly to the user's email accounts, reducing the accessibility challenges which can be experienced when viewing web-based forums with a screen reader. The 'snowball effect' was applied, where we asked participants to contact their peers to inform them about our project. This enabled us to also capture data from individuals were less 'tech-savvy' when using a mobile phone with screen reader. The interview consisted of both open and close ended questions, lasting for

[7] Eyes Free – http://eyes-free.blogspot.com

approximately 45 minutes. The questions were divided into various sections including demographic information, current mobile screen reader usage, overview, navigation and orientation using a screen reader, and their use of screen reader with other applications. Depending on their experience with technologies, separate sections were presented on smart phone capabilities, magnification used alongside a screen reader, and Braille-based technologies. If a section was not applicable to the participants, questions relating to the section were not asked.

7. Participant Demographics

A total of 32 participants (20 male, 16 female) were interviewed from multiple countries including the United States, Canada, India, and the United Kingdom. All had heard about our studies through mailing lists, or through references from their peers who had read the recruitment advert. The participants varied in age. A majority of the participants interviewed, 28, were between the age of 20 and 59.

26 of the participants who described themselves as legally blind, and 6 described themselves as partially-sighted where they were unable to rely completely on their residual vision. From the participants who described themselves as legally blind, 23 were congenitally blind, and 3 became blind in later life. 5 partially-sighted participants described their condition as congenital, while the 1 other participant stated that his level of vision reduced gradually in later life.

28 out of the 32 participants were able to read Braille and 26 of them able to read tactile diagrams. Of the 32 participants interviewed, 2 made use of a magnifier on their phone alongside their screen reader, and 2 had accessed mobile Braille devices in the past. Although all had previous experience of using screen readers, only thirty participants currently used them. 5 of the 26 legally blind participants using assistive technologies were currently using touch screen mobile devices (including the Apple iPhone[8], HTC TouchPro2[9] and HTC XV6800[10]). No participants were found using devices developed specifically for the blind community (e.g. Braille based devices or screenless phones).

When asked to rate their mobile screen reader skill level as beginner, intermediate, or advanced, participants rated themselves as follows: 9 at beginner level where basic functionality was accessed or they were learning how to use screen readers, 12 participants as intermediate, and 11 as expert users where advanced features of screen readers were often used. The 5 touch screen phone users rated themselves as intermediate or advanced users. One participant who categorized himself as an advanced user, stated that learning a mobile screen reader is as difficult as you make it. He suggested that it was possible for people new to technology, to learn how to access basic features quickly, but additional commands could take time to learn. He suggested that novice users should take complete advantage of the manuals provided online, and blogs from other blind users who have experienced challenges or workarounds for certain solutions. A second participant suggested that using a new phone or screen reader is typically overwhelming for novice users. She continued stating that in their experience, older adult users have a harder time remembering all the keystrokes and commands needed, when they are learning to use a mobile screen reader for the first time.

The majority of participants interviewed used either MobileSpeak (11 participants) or Talks (12 participants) as their primary screen reader. Reasons for their selection depended on the following factors: recommendations received from other blind users, compatibility of the screen reader with their existing mobile device, the cost of screen reading software, and whether any level of training would be offered. Other participants were using other third party or inbuilt screen readers.

8. Results

8.1 Inaccessible Features

Responses tended to vary depending on the make of screen reader, and the users' experience interacting with the software. 2 of the novice users described the cognitive burden managing the content from the interface, and listening to commands from the screen reader itself. One example of the cognitive burden faced was when accessing text messages longer than 160 characters. On some key-press mobile devices, longer text messages sent to the recipient would be split into multiple messages. To gain an overview of content, the user would need to target the first message, remember the content while navigating towards the next message, and then play next message. Piecing the information together over multiple messages could pose a challenge, especially when commands for the screen reader were unfamiliar.

Novice users also reported experiencing challenges accessing the calendar functionality, using the on-screen help and accessing the camera to take photos for sighted family and friends. Problems were attributed to the inappropriate presentation of speech-based feedback, making it challenging to identify changes to system state and system events.

6 intermediate/expert users stated that they found that third party applications (e.g. games, mobile TV and FM radio) were typically difficult to interact with, as screen reading solutions (e.g. Talks) were unable to effectively translate graphically-oriented cues (e.g. controls) into speech. One participant voiced his displeasure in carrying a separate accessible MP3 player around, when he knew his phone offered the same music playing functionality.

[8] Apple iPhone – http://www.apple.com/iphone

[9] HTC - http://www.htc.com/www/product/touchpro2

[10] HTC – http://www.htc.com/us/support/verizon-xv6800

However, this was the only method he could think of, to play music or listen to the radio when on-the-go.

One participant described issues viewing PDF documents using Talks on a Nokia N82 handset. He favored accessing QuickOffice[11] documents as a workaround, but this could be difficult if documents were unavailable in this format. Other participants described carrying a laptop around with them, as they felt they could not rely on their mobile device and screen reader to perform work-based tasks, such as viewing and writing documents, while on-the-go. Although it was a burden to transport a secondary device with them, it provided an effective backup if it was impossible to access content using a mobile screen reader.

4 intermediate users described specific difficulties associated with web browsing. These included gaining overviews of lengthy text-heavy web pages, and changing system modes to explore online forms and enter information into form boxes, using the virtual cursor. Participants specifically highlighted that distracters (e.g. repeated information and unlabeled images) could cause annoyance due to time being wasted when performing tasks. Although some sites were slow to access, participants suggested that some mobile sites were easier to navigate and contained less extraneous information compared with their PC equivalents (e.g. Facebook Mobile[12]). As a result, these mobile sites would be accessed on the PC, as a way to interact with less clutter on the page.

In order to gain overviews more effectively, intermediate and advanced users were found to have manipulated verbosity settings, and the speed of speech output. This would often depend on the context of use. For example, the speed would be decreased when reading materials where concentration was required, but increased for leisurely reading of text-heavy pages or screens. However, novice users suggested that they were less likely to customize verbosity, favoring the longer speech-based output, anxious that key content would be missed, if speech output was condensed. Suggestions included the presentation of summaries of content, to help users identify whether the page or application was useful to read in its entirety. Participants also described the need for customization of mobile interfaces for key-press phones, to vary the layout of content, so time would not be wasted in the targeting process, particularly for frequently accessed objects or functions.

8.2 Navigation and Orientation

One theme that arose from the data was the amount of information that needed to be committed to memory to interact with mobile devices (e.g. menu structures and location of main content on the interface). Participants knew that they needed to press a particular button a set number of times to locate a specific feature. Some of the novice users suggested that they preferred to select tried-and-tested menu options, rather than attempting to try new options, which could potentially result in errors. There was an underlying anxiety detected amongst these users that they would not be able to recover from the error, as the feedback would be presented visually. The same participants highlighted that time would be spent traversing a hierarchical menu on their mobile devices, so opted to perform simple tasks which could be accessed within a matter of key presses.

Only 2 of the participants said they needed to externalize any information when using a mobile device with screen reader, either by using a voice recorder or Braille notetaker. The rare instance would be when triggering a function they were unfamiliar with, which they would record for future use.

8.3 Processing Multiple Streams of Audio

11 participants reported experiencing conflicts between audio presented by software on the phone (e.g. media player) and the mobile screen reading solution used. Participants would ordinarily lower audio from the mobile applications to make screen reader output audible, but this was not always possible. Another participant commented that when a phone call was received while reading a web page, once the call had ended, the screen reader cursor would jump to the beginning of the web page. This could cause confusion, particularly if the user had read part of the page already. A need was identified for providing more awareness of spatial position on the page, and bookmarking areas on the interface for future access.

8.4 Usage Scenarios

One of the overarching issues cited by the majority of participants related to problems accessing interface content in a discrete manner. For example, tasks which sighted users take for granted (e.g. glancing at the phone to check the time and battery indicator, and visually monitor the number of missed calls and unread incoming text messages) would be difficult for blind users to perform when in a meeting or when speaking with others, without drawing attention to themselves. Blind users would need to excuse themselves from the proceedings, to listen to content using the screen reader. This had led to 2 participants switching off mobile devices while in meetings, rather than silencing or placing on vibrate mode, as they 'served little purpose for notifying users without causing distraction'.

8.5 Touch Screen Devices

The participants who had not previously experienced touch screens felt that they did not provide enough feedback for purposes of interaction. Participants were

[11] QuickOffice - http://www.quickoffice.com/

[12] Facebook – http://m.facebook.com

aware of tactile overlays and tactile adhesive bumps (also described by [7]) which could be used to structurally map the layout of objects on the interface. However, the underlying anxiety of making an error deterred many of these participants to training how to use touch screen devices.

5 advanced users had previous experience of using touch screens. When asked about their strategies for locating objects on the interface, it appeared that the participants had tried to simplify the process by arranging icons in order of common usage, or using different navigational styles to traverse content. For example, one participant who had used a Nokia touch screen device with MobileSpeak used the 'joystick' mode to quickly scan content, by keeping his finger depressed on a section of the touch screen interface which corresponded to the direction of movement (termed a 'virtual key'). This would enable the participant to bypass extraneous information. While this offered an alternative to using gestures (e.g. a sliding movement), the participant stated that this workaround was not perfect, as he would sometimes overshoot important information by positioning his finger on the 'virtual key' for long periods of time.

Many of advanced users questioned praised the universal accessibility of the iPhone. Gestures were found to be learnable, enabling participants to gain specific information such as system status, and battery strength without moving through a menu. However, some of these gestures were thought to be more complex, compared to the gestures made by sighted users when interacting with the phone (e.g. two or three fingers used). However, participants were pleased that they could transfer their knowledge to other Apple products, where similar gestures could be made to interact with Voiceover (e.g. sweeping motions to move through content, or rotation gestures). The 4x4 layout of icons was found to be learnable, through the sound effects made when highlighting a button, reinforcing the grid metaphor. Similar to findings reported by Rana and Rana [14], errors were reported when using the virtual keyboard to compose text messages and emails. Participants relied upon the spell correction tool, as a method of ensuring that composed messages made sense.

Participants were generally excited about the development of applications which could aid users gain an overview of the wider environment (e.g. the Siri[13] application, where the user voices a question about his/her location or places within close reach). Although there were worries that background noise from real-world environments may impact perception of the results. A need was expressed to integrate location finding applications with more accessible mapping tools. While existing GPS functionality provides text based directions to particular destinations, one participant suggested routes should be provided in an accessible diagrammatic format, which can help them to conceptualize directions in a more effective manner.

8.6 Multitasking and Inhospitable Environments

While participants suggested that it was possible to use a key-press phone while in motion, the case would be different using a touch screen phone. Two-handed interaction would be needed (e.g. one hand to hold phone, while the other hand makes gestures). As many blind users have one hand occupied using a long cane, it would be difficult to remain ambulatory while using the phone and perceiving environmental cues (e.g. obstacles in the street). A general theme was identified where participants wanted to gain the same perceptual experience as sighted users when using a mobile device, along with the benefits it offers (e.g. the ability to be walk while using the phone).

In terms of usage scenarios, 18 participants stated that they could use their phones in loud environments (e.g. shopping malls). However, under more inhospitable conditions, such as when riding public transport, the intelligibility of the speech could be impacted when using a mobile device. Many had resorted to wearing Bluetooth earpieces when outside quiet controlled environments, to ensure they could gain the gist of content from the screen. To foster a sense of privacy in public settings, two participants reported modifying the presentation of speech output to make any sounds overheard by third parties 'unintelligible'. This action would put both participants at ease, enabling them to continue with their task.

Similar to Kane et al. [10], participants suggested the idea of a system which was aware of the environment and context of use. For example, when in a noisy environment, shorter salient speech cues would be presented, or potentially through the presentation of other forms of feedback to reduce the speech burden (e.g. tactile and non-speech audio cues). The volume of speech-based presentation could also be automatically adjusted accordingly.

8.7 Other Factors

A study by Rana [13] has shown that 90% of problems interacting with interfaces using assistive technologies can be addressed by using advanced hardware technologies and through training or professional coaching. In our study, concerns were highlighted regarding keeping up new releases of screen reading software, due to the set-up time of transferring software from the PC to the phone. To alleviate challenges with cost, one participant interviewed, used a demonstration version of Talks. The user was forced to reboot the phone every ten minutes to use the software, which although not ideal was necessary to interact with the assistive technology. A general theme of frustration was detected

[13] Siri - http://www.apple.com/iphone/features/siri.html

due to the limited choice in accessible mobile devices, and that third party screen readers were only compatible with certain handsets, which may not be available within the user's local area.

Only 4 of the 32 participants received any training to use their mobile devices with their respective screen readers. Most participants stated that they preferred to teach themselves how to use their phone through manuals, tutorials, and trial and error. Certain providers were found to be more training-friendly than others. One particular example cited was Apple, where blind iPhone users could receive free training on Voiceover offered at the Apple store. Conversely, some of the customer service agents at other stores where phones were purchased, were unable to provide any additional assistance due to their limited knowledge concerning screen readers. Participants would often opt to contact other blind mobile users via online user groups. This would have the added advantage of the terms and methods of performing tasks 'explained in a [non-visual] way that can be understood by blind users'.

For several participants, installing the screen reader itself proved to be a difficult task. Although some stated that their handset came with an inbuilt screen reader which they had tried out, most had chosen to install third party software. Eight reported that assistance was commonly needed from sighted users during the set-up process. One participant described the problems she faced due to issues of compatibility between the screen readers and different mobile models. This caused her considerable confusion, as she reported that settings were changed on her phone due to installation, which she could not access through speech-based cues. She suggested that the phone settings would be reset when removing the application, erasing all the settings and contacts. One participant that set-up the screen reader independently, suggested that from time-to-time, he would call upon sighted peers to aid him when setting the time and date, as this was difficult to perform alone. Participants favored performing tasks independently, rather than relying on sighted users for help.

8.8 Requests for Additional Functionality

In terms of requirements, 24 participants described the needs for more feedback for receiving messages (both SMS and system-related messages), as they did not want to miss important information. More salient cues were requested, to gain the user's attention, especially within inhospitable environments or when walking and vibrations could not be detected. 24 participants additionally suggested that caller details should be presented more effectively, where the privacy of the caller would not be compromised (e.g. presented in an alternative format to speech). 18 participants suggested that a system which enabled them to navigate unfamiliar environments would be very helpful to gain independence. A solution developed offering instructions about the user's local environment, landmarks within it, and more subtle information which can cause difficulties for blind individuals (e.g. long drop downs on sidewalks, obstructions within the street) was also described as being very helpful.

Only one participant mentioned the need for integrating Braille with more mobile phones. However, this could be explained by Braille not being the preferred medium of all users [2, 12]. Additionally, a recommendation was made by one novice user to retain the same commands as the desktop solution when using a mobile screen reader with slider keyboard. This would reduce time and effort spent learning the system. However, we recognize that, due to the limitations in the size and form factor of mobile devices, and the lack of a full sized keyboard, ensuring that commands are identical between a PC and a phone is impractical.

Participants were also asked how they thought mobile screen readers could be improved. Most participants expressed concern regarding pricing of the assistive technologies. Cost plays a big role in participant's decision on which cell phone and screen reader they purchase. Participants also made comments that a wider variety of phones should be available for the blind community. Currently only select phones are compatible with screen readers such as Talks and MobileSpeak. Inbuilt screen readers were not rated highly, as their functionality was not thought to parallel third party products. Increased flexibility with mobile operating systems was the intention of this suggested improvement.

9. Considerations for Non-Visual Mobile Interface Design

The findings from the study can be used to support the design of mobile applications.

- Design for discretion. Similar to sighted users, blind users are faced with scenarios where they need to discretely obtain information from the mobile interface (e.g. number of missed calls and unread texts) without drawing undue attention to themselves.
- Reduce levels of overload by controlling the amount of speech present on the interface. While advanced users were able to modify levels of verbosity, anxieties were detected among novice users, who were both unfamiliar with commands, and experienced worries on how to recover from errors.
- Provide effective methods of gaining overviews of complex content (e.g. long web pages, information-heavy mobile application screens). While workarounds have been developed, summaries of content, or structured sets of keywords can enable users to make a decision to spend time accessing the current application to read all the content, or return at a later point when more time is available.

- The ability to bookmark the position of information on the page would enable users to target a particular area of interest, without having to move through the entire interface content.
- Limit the breadth and depth of hierarchical menu structures, to ensure that novice users are able to target items for commonly-performed mobile tasks. For advanced users, the ability to customize items in the menu structure, would benefit users of key-press mobile phones. This would enable faster targeting of commonly accessed items.
- Test accessible mobile applications under realistic conditions, rather than solely conducting usability studies within controlled laboratory-based environments. For example, screen readers may be used in inhospitable environments, where speech output may not be audible. Similarly, if using a touch screen while in motion, while one hand is occupied, it would be impractical to use multi-finger gestures to perform mobile tasks.

10. Conclusions and Future Work

This paper has presented the findings from an empirical study, identifying the experiences of blind mobile screen reader users. While difficulties continue to be faced with inaccessible content, processing multiple streams of audio and remembering interface layout, participants were able to overcome specific challenges using workarounds. The findings from the study, provide a first step into developing inclusive mobile applications to bridge the ‘disability divide’.

In terms of future work, we aim to perform a set of observational studies to identify challenges when using mobile technologies under more realistic conditions (e.g. when riding a bumpy train, or when using the phone in a noisy environment). We then aim to examine whether other modalities such as spatial audio and tactile feedback integrated within mobile interfaces, may play some role reducing the cognitive burden faced when using mobile screen readers.

Acknowledgement

We thank James Fetter for his contributions to this work.

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