Improving Smartphone Accessibility with Personalizable Static Overlays

André Rodrigues[1], André Santos[1], Kyle Montague[2], Tiago Guerreiro[1]
[1]LASIGE, Faculdade de Ciências, Universidade de Lisboa
[2]Open Lab, Newcastle University
afrodrigues@fc.ul.pt, abranco@lasige.di.fc.ul.pt, kyle.montague@newcastle.ac.uk, tjvg@di.fc.ul.pt

ABSTRACT
The physical keypads that used to dominate our mobile devices provided additional support for non-visual interaction - the keys could be recognized tactually, the interfaces were simpler and consistent. When combined with a screen reader, these devices could be easily operated by blind people. The advent of smartphones, with their rich, feature-filled applications and interfaces, have brought forward additional challenges for blind users. Apps and features are no longer developed by a single entity leading to an overwhelming variety of interfaces. We present an approach that superimposes a virtual overlay to all other interfaces ensuring interface consistency by re-structuring how content is accessed in every screen. To explore the approach, we split the screen, dedicating half to a configurable set of static options mimicking always available physical buttons regardless of context; while the other enables the standard content navigation gestures with the ability to re-order content and apply filters. In a qualitative study with nine visually impaired participants, the virtual overlays were reported as simpler to use, while still providing full-fledged usage of the system and the third party applications, and were seen as effective and useful, particularly for novice users.

CCS Concepts
• **Human Centered Computing →Accessibility**

Keywords
Blind; Smartphone; Accessibility; Personalizable Interface

1. INTRODUCTION
According to WebAim[1] surveys, 69% of the inquired screenreader users in 2015 also rely on a mobile screenreader. From those who do, 20% are still using feature phones or restrictive accessibility services on smartphones. There is a considerable share of the visually impaired population that are yet to fully transition to smartphones. Moreover, with keypads users were able to use a phone without a screenreader but smartphones cannot be operated without one. Many people, particularly less tech-savvy people wish they could continue using their dated feature phones with physical keypad and consistent interfaces [4]. Unfortunately, due to market pressure such devices are being produced less and less.

The default screen readers for today's top mobile operating systems, *VoiceOver* and *Talkback*, have provided basic access to smartphones for blind and visually impaired people. Although smartphones are powerful, they have been reported as challenging to adopt. Rodrigues et al [4] exposed that the barriers go beyond touchscreen accessibility, spawning from the mismatch between users' application mental models and the actual interfaces. Moreover, independent of user expertise, smartphone navigation and interfaces can be construed as inconsistent due to the freedom each developer has in structuring its apps interfaces and navigation (e.g. a confirm button can be in different places both physically and in the navigation hierarchy). This represent a substantial leap from the feature phones with their always available physical keypads with standard behavior's. In an environment where new apps and updates are made available everyday users have to continuously adapt to new interfaces.

Prior approaches have tried to replicate the consistency found in previous systems by replacing the entire operating system - limiting the user to the set of bespoke apps (e.g. *Mobile Accessibility* and *GeorgioPhone* on Google Play Store). Although it guarantees the consistency and accessibility of the apps provided, it negates the benefits of thousands others. Custom and implicitly restrictive assistive technologies can have also have the adverse effect of stigmatizing people that would rather be able to use mainstream applications and devices [5].

Other work on mobile accessibility has been mostly focus on input, namely text-entry [3] and gestures [1]. In recent work, Zhang et al. [6] address the issues found in the particular sub-context of mobile web browsing by adapting all web pages to be provided using a single personalized hierarchical view of the content, thus allowing users to quickly skim through content. At an application level, other approaches [2] have tried to facilitate the learning process of older adults by exposing users first to an interface with reduced functionalities before allowing full control. Zhang et al. [7] introduces the concept of interaction proxy allowing third party developers to augment mobile application accessibility by adapting how a specific application is rendered and accessed by the user.

Currently mobile screen readers allow users to access all the content available, but unlike custom made applications they cannot guarantee a consistent interface or navigation. Targeted application adaptations [7] can improve learnability and accessibility. However, similarly to custom made applications, these require adaptations for each app individually, hindering their scalability.

In an effort to combine the advantages of both paradigms, that is, providing the consistency and personalization of custom solutions,

[1] http://webaim.org/projects/screenreadersurvey6/

ASSETS '17, October 29-November 1, 2017, Baltimore, MD, USA

ACM 978-1-4503-4926-0/17/10…$15.00
https://doi.org/10.1145/3132525.3132558

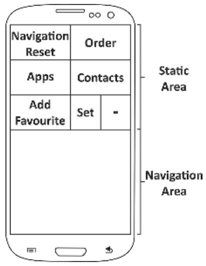

Figure 1 - Default template for PSI.

without sacrificing system wide access to all applications; we propose resorting to virtual layers that adapt and abstract how users access content. In a possible parameterization of such approach, targeted at blind people, we propose a virtual overlay with two main components: 1) a set of static always-available options, mimicking options associated with physical buttons in the old feature phones; and 2) a navigation area, that allows and abstracts access (e.g., ordering elements alphabetically or by usage frequency) to all applications and interface elements underneath. We developed an Android accessibility service that instantiates this approach adapting how it is presented and navigated by its users.

In this paper, we investigate the benefits and shortcomings of a personalizable, static and consistent interface (PSI) on mobile devices for non-visual access, alongside its acceptance by blind people (novice and expert users). In a lab study, we exposed nine smartphone screen reader users to PSI and all its features. Through thematic analysis of the interviews conducted, consistent layers were perceived as simpler to use and held potential benefits when first learning to use a smartphone. Furthermore, for users who struggle with current methods, believed these layers could enable them to take full advantage of their device.

2. PERSONALIZABLE STATIC OVERLAY

Many features were lost with the demise of physical keypads. They provided a consistent interface with multiple shortcuts, from always being a press away from the messaging app or speed dialing a contact. We aimed to provide a consistent and familiar interface to the user regardless of what application was being explored. With PSI, our goal was for users to only need to learn to use one interface in order to interact with all apps. To achieve it, we developed the PSI Android accessibility service, that adapts how content is transverse by the Talkback screen reader. Since PSI only adapts how content is navigated it provides system-wide access while presenting a consistent interface that was only previously available in custom restrictive approaches.

2.1 User Interface

The interface was split in two: the Static Area (SA) and Navigation Area (NA). The static area contains a set of options that are always available on screen and occupies half the screen. The other half contains the navigation area that is used to access all content. PSI adapts every interface as described except for text-entry.

2.1.1 Static Area

In its default state, the SA has seven options, Navigation Reset, Order, Contacts, Applications, Add Favourite, PSI Settings and Minimize. To access these options the user can rely on touch-to-explore (i.e. drag their finger on the screen to focus an element and double tap to select) or swipes when a static element is focused. Whenever a static element is selected it affects the content that is accessible in the navigation area.

2.1.2 Navigation Area

In the NA using the Talkback standard gestures of swiping left/right and double tap to select, users can access the content being displayed on screen. With a dedicated navigation area we intend to reduce focusing errors from swipes that are misinterpreted as touch-to-explore focus actions. Moreover, with the added control over navigation PSI is able to sort and filter elements.

2.1.3 Special Cases

In text-entry, when an edit box is selected the static area is hidden and the NA is displayed on the top half. The keyboard is displayed on the bottom half while allowing users to navigate on the top half, once the keyboard is closed PSI resumes its standard interface.

2.2 Personalizing PSI

When PSI is first launched on a device the default layout template is shown (Figure 1). Through the PSI Settings, users can create and edit the template options (with the exception of the PSI Settings and Minimize buttons which are locked). PSI rows always fill the full width of the screen, and in each row every option occupies the same space with the exception of PSI Settings and Minimize. There are two ways to create a new template: easy or expert mode. In easy mode users select options to be displayed in a layout of rows of three. In expert users are able to add as many options as they see fit in a table structure. When editing a template users are able to add and remove options. When adding, users first select the type of element (i.e. feature or shortcut) and then choose its position. To remove users simply select the unwanted option.

2.3 PSI Featured Options

PSI allow users to personalize their templates with several options. The Navigation Reset focus the navigation area and its first element. Order allows users to sort and filter content in the NA. Applications opens the list of applications installed. Contacts sets a list of contacts in the navigation area that when selected initializes a call. Add to Favorites stores the current focused element as a favorite in that screen. In the PSI Settings menu, the user is able to customize the template including adding shortcuts. Lastly, Minimize pauses PSI, similarly to Talkback, PSI can then be resumed through a sticky notification.

2.3.1 Sorting Elements

Users can sort how content is navigated to quickly reach their intended target. Currently, it can order: default, alphabetically, most used, most recently used, favourites (i.e. favorites displayed first) and interactive (i.e. filters out all non-interactive elements). PSI filters work on a per-screen per-app basis. To do so, PSI counts and locally stores user's interaction with each element in each application screen to provide the filters to order by frequency and recency. The PSI system is designed to ensure easy addition of other filters in future developments.

2.4 PSI Personalized Shortcuts

There are three types of shortcuts that can be added to the static area: app, contact and task. App opens the corresponding app; contact speed dials a contact; and task performs a pre-defined sequence of commands. In the current iteration of PSI we define tasks for a given application and version (e.g. open last email in Inbox, open last text message in Messages).

3. USER EVALUATION

To evaluate our approach we conducted a lab study where nine participants were exposed to PSI. We analyzed the qualitative data collected from the debriefing interview to understand the benefits and shortcomings of our approach.

3.1 Participants

We recruited nine smartphone screen reader users (i.e. four used Android and five had an iPhone). Participants self-reported as being capable of performing basic phone (i.e. making and receiving calls and messaging). Age ranged from 27 to 58

Table 1 - Participants experience in months and list tasks able to perform marked with an Y for yes and N for not.

ID	Months	Tasks						
		Listen music	Receive Email	Send Email	Browse Internet	Social Apps	Install Apps	Assist. Apps
P1	30	Y	N	N	N	N	N	N
P2	72	Y	Y	N	Y	Y	Y	Y
P3	48	Y	Y	N	Y	Y	Y	Y
P4	0,5	Y	N	N	N	Y	N	N
P5	72	Y	Y	Y	Y	Y	Y	Y
P6	36	Y	N	N	Y	N	N	N
P7	48	Y	Y	Y	Y	Y	Y	Y
P8	12	N	Y	Y	Y	Y	N	Y
P9	6	Y	Y	Y	Y	Y	N	Y

(M=43.3, SD=10). Smartphone experience and ability to perform a broad set of tasks varied amongst our participant, as shown in Table 1. The two participants able to perform all tasks in Table 1 are accessibility instructors who provide training for other blind and visually-impaired people on how to use screen readers. Participants were recruited from a local social institution and all were legally blind.

3.2 Apparatus

We used a Samsung Galaxy S3 with Android Nougat 7.0, running our PSI accessibility service. PSI operates as a foreground service acting as a proxy between the content on the screen and the screenreader. Talkback was enabled and used as the default screen reader.

Table 2- Tasks performed by the participants with PSI.

TASK
Explore all the static options on the top half of the screen.
Use the *navigation area* and to find *settings.*
Use the alphabetic filter to find the option *Accessibility* in *Settings.*
Go to Apps and order by *frequency* to find the most used app.
Use the *contacts* shortcut and to call the last most used contact.
Mark *sound* in *settings* as *favourite*. Use the filter *favourites*.
Use PSI *settings* to add a fixed shortcut to the contact john snow.
Use PSI *settings* to add a fixed shortcut to *open last received email*.

3.3 Procedure

Participants were informed the purpose of the study was to explore Personalizable Static Interfaces to identify its benefits and shortcomings. Participants were introduced to PSI and given an overview of all its features. They were then guided through a set of eight tasks. The researcher first gave a short explanation of the feature and the current window content followed by the task to be performed. Participants could ask questions freely and assistance was provided on request. Each participant performed the tasks depicted in Table 2 in the same order, this process took about 30 minutes. Finally, we conducted a debriefing session where we performed a questionnaire and a 10-30 minutes semi-structured interview. Participants were asked for their views regarding PSI consistent and personalizable characteristics.

3.4 Data Analysis

Interviews were recorded and transcribed. Two researchers coded two interviews to inductively create a codebook[2]. The researchers coded the remaining interviews independently with the resulting codebook and reached a Cohen's Kappa agreement of k=0.71.

3.5 Findings

All participants were able to successfully complete the tasks. Five themes emerged from the data analysis, herein we present our findings framed by the themes. In *Challenges to Smartphone Usage* we discuss the participants views on the challenges they faced since first starting to use a device and on its effects. *Personalize, Organize, and Simplify* aggregates the discussion surrounding PSI interface. The main advantages brought forward by PSI are reported in *Learnability & Autonomy*. The remaining two themes are *Concerns & Limitations* and *Improving PSI* where participants expressed the perceived drawbacks of PSI and how PSI could be refined. In this section we will refer to users that reported to be able to do six of the seven tasks in Table 1 as experts.

3.5.1 Challenges to Smartphone Usage

As found in prior work [4] participants reported to have struggled when getting started with their smartphone. When asked to reflect on their own experiences, some participants could not remember the specific origins of the issues (happening up to three years ago), however, vividly described the deep sense of frustration they faced at the time. Accessibility features have improved over the years, however, we haven't reached a point where adopting a device is a streamlined experience. One of the lesser experienced participants explained their initial difficulties and the reliance of peer support to get going when everything was new. "*My first challenges was to not throw it against a wall. I didn't know how to do anything. I tried to explore on my own but my daughter would end up mad at me because I kept modifying stuff without realizing it. With your app I am sure I would be scolded a lot less." (P4)*

Despite P4 having the desire to explore the device alone, they felt it was dangerous to do so, as they were inadvertently editing settings and configurations. From an expert view many of the issues that plague novice and less experienced users spawn from a lack of spatial ability to overcome the challenges presented. Consequently, users often get lost and feel frustrated. *"If we don't have spatial awareness we will navigate left, right, left, right, left, left, right. (...) If we can't visualize the paths in our head it's like trying to find the metro. If I don't know the way I will end up circling a post" (P5)*

Getting started with a screen reader on a smartphone can be overwhelming. Less tech-savvy users struggle to understand what is happening since the interface seems to change completely every time an option is selected. Not only is navigation confusing and seems to change from app to app, but the variety of gestures can be a burden. *"It's Facebook and email and all those troublesome gestures, swipe with two fingers, swipe with one, up and down, blah blah blah it annoys me. I would rather have these. [PSI interface]" (P4)*

Ultimately for novice users this all leads to a lack of autonomy when interacting with their device. Even experienced users are not necessarily experts. In some cases even after years of usage, they can still struggle with navigation to a point where discoverability becomes an issue. For P1 he can still only perform basic tasks and

[2] https://goo.gl/7JzSUi

struggles to find the options he is looking for. *"I often receive messages with bills to pay and I would like to forward them to my wife. Unfortunately I am unable to, I usually end up memorizing the reference codes and write a new message." (P1)*

3.5.2 Personalize, Organize and Simplify

PSI permanent options and dedicated screen areas brought structure to how content can be accessed. *"Everything used to be scattered, but with the options present in the top I will no longer need to search for them, it is easier" (P9)*

By dedicating an area of the screen exclusively to swipe navigation and establishing a clear rule to how content is structure users perceived the interface as simpler. *"For example if I had that navigation area when I was in the Messages application I would probably be able to find the forwarding button" (P1)*

PSI ability to order content on demand was seen by users as a way to facility interaction and promote discoverability. For some users this simply meant they would need to spend less time learning the different gestures for advanced options while for others the adaptability would allow them to have different navigation strategies depending on the app. *"Today I could be using Alphabetic ordering but I could change to Most Use, all depending on the application and on what I intended to do" (P3)*

Participants acknowledged different users have different interaction needs. Moreover, needs can easily change. Thus, the ability to personalize the static area and add the different types of shortcuts was a key feature for some users. *"The ability to add contacts and tasks, it makes it easier because we have an open door to what we want. (...) For example I could be contacting frequently John Snow, but if for whatever reason it stopped happening. Instead of having a lot of fixed buttons I could remove them." (P1)*

3.5.3 Learnability and Autonomy

PSI was seen has a simpler interface to interact with smartphones. Participants believed they would have had less problems if they would have PSI during their adoption period. *"It would have been a lot easier. You see, I had a phone with normal keys, and it suddenly broke down… I bought a smartphone and I couldn't even answer a call. (...) To start with this would have been much better." (P8)*

Furthermore, participants reported that people with additional difficulties either due to being less tech-savvy, or having less spatial abilities could benefit from a consistent interface. *"Some people have a lot difficulties using a smartphone. Why? Because things are never in the same place, buttons move from one place to another. I believe this would help." (P3)*

Two expert participants mentioned how PSI should be incorporated in default screen readers as an "easy mode" that could be a stepping stone before using the de facto screen reader navigation. *"You should sell this to Talkback, we would benefit from it. The user would start with this, when he felt he was familiarized with the system he could start to try the original." (P5)*

However, they also believed people with additional difficulties would never be able to fully adapt to current screen reader navigation thus PSI would be the first and final step. *"They are forced to use a touchscreen screen. A phone without any physical keys. I believe your app is not just for getting started. They would always rely on it." (P5)*

As a side effect PSI consistency users felt an additional sense of security and independence when exploring the system. *"It [Static Area] is something that gives us a bit more confidence when exploring" (P2)*

For some participants PSI was more than a stepping stone. They believed the ability to order and add shortcuts would improve their performance. *"When you get used to that menu (static options) you will do things faster, and the shortcuts facilitate a lot." (P3)*

3.5.4 Concerns and Limitations

For one instructor PSI had the severe limitation of breaking the norms established by the de facto screen readers on smartphones. PSI content navigation does not support touch-to-explore navigation and gestures shortcuts do not affect the content on the navigation area. As such he believed users with good spatial abilities and a high understanding of the interface (i.e. experts) benefit more from the standard screen reader. *"For someone who already know how to use touch-to-explore he will use touch-to-explore. (...) Another issue is when you are dividing the screen in half you are also blocking the standard gestures used in Android" (P7)*

Participants often described scenarios where they had requested sighted assistance to overcome an issue. One participant was concerned if sighted users would be able to provide assistance if PSI was running on the device. *"The applications that make our life easier, make the smartphone difficult to interact for sighted people. People already think Talkback is weird enough. (...) What does a sighted people see when interacting with it?" (P1)*

3.5.5 Improving PSI

When queried about how we could improve PSI all users suggested more customization options. For some that meant having the ability to change the size and position of the dedicated areas. For others that meant a fixed toggle button to order content in a specific way rather than a button with all possible sorting options. Others mentioned the desire to create their own shortcuts to tasks. *"I would like to have more shortcuts to tasks. The type? Well that depends on what people use more often on their phones. Maybe users could be given the chance to create their own tasks." (P6)*

Several participants mentioned PSI should be incorporated natively in screen readers. For one expert user this would mean PSI would not only support standard gestures but it could allow the creation of shortcuts using gestures. *"For example if I want to open Whatsapp I would do a W." (P7)*

The two instructors expressed how physical cues and interfaces can still play a fundamental role both in adoption and navigation. One is still wishing for old physical interfaces to return, suggesting we should provide a physical directional pad on the phone allowing users to navigate as they used to. The other instructor suggested adding a physical tactile line in PSI to reinforce and facilitate learning the distinction between the dedicate areas. *"It could have a physical line to divide it. (...) A line almost imperceptible just so we can tell tactile if we are in one area or the other." (P5)*

4. DISCUSSION

4.1 The Benefits of a Consistent Approach

Smartphones lost the similarities between applications that was once the norm. For screen readers' users this led to having to understand an infinite amount of app structures and navigation approaches to reach the intended elements. With PSI we provide dedicated areas and clear rules to how content is structured and accessed. Having the SA allowed users to have a consistent point of reference which granted a sense of constant awareness. The fixed set of customizable options brought back the quick access, ever present "physical keys" favoured in the feature phone devices. Specifically, the ability to order content established an expectation of which content is going to be transversed. Thus, information was not perceived as scattered or disorganized.

4.2 Same Functionalities, Simpler Interface

Talkback allows full access to the system by modifying how users interact. It provides two navigation methods: swiping for next and previous item; and dragging the finger through the screen until the location of the desired item is found. Both interactions methods have their strengths and weaknesses. We took advantage of each method with a clear divide where to navigate content and where to access permanent static features. Touch-to-explore is particular adequate to deal with quick access and static options. On the other hand swipe navigation allows users to navigate without any previous knowledge. The main disadvantage to sequential navigation is the time required to reach options in cluttered applications. For a system to succeed with it, it must provide opportunities for users to quickly reach content. In Talkback the answer was gesture shortcuts and touch-to-explore. In our approach we provided ordering filters with a single button.

PSI breaks the paradigm of direct manipulation of content in conventional smartphone screenreaders in favor of providing a consistent interface. Currently blind users are required to have strong spatial abilities to quickly interact with their smartphone. PSI was built to adapt all interfaces to a single one by taking advantage of the same DOM tree structure available to Talkback. With PSI users only needed to understand a single screen in order to understand them all, which is particular beneficial for users with less spatial abilities. Therefore, users perceive our consistent interface as simpler, organized and ultimately, easier to learn.

4.3 Personalizing, Customizing and Adapting

When asked what they would improve in PSI most of what was mentioned was further customization options. Users showed interest in continually adapting their interface through the introduction and removal of the different types of shortcuts. In addition to simple contact and application shortcuts the ability to create task oriented ones may prove to be crucial to support more demanding users. Therefore, similar approaches that take advantage of permanent static elements must ensure a straightforward personalization process. Furthermore, every user is different and it expects different things out of his/her device, for a consistent interface to succeed it needs to give users the ability to adjust to their needs.

4.4 Static Overlays from Novice to Expert

Participants unanimously believed a personalizable static overlay provides a simpler interface. One of the referred key benefits was to facilitate the adoption process without having to compromise functionality. For some, consistent interfaces can be just a stepping stone to ease the transition to smartphones. However, for a large segment of users with additional difficulties, it may be the only way to take full control of their smartphone. Static overlays were not seen as a less performant method by some of the more advance users. Users expected the ability to create a wide variety of shortcuts, customizing the interface and adaptive ordering filters could have a positive effect in their current navigation.

However these interfaces provide diminishing returns for users that rely on their spatial abilities and mental capacities to memorize the location of each option in each app. Moreover, advanced users often rely on gestures shortcuts (e.g. first item, next page) that were not supported by PSI. Going forward solutions relying on consistent interfaces should not neglect advance users and support the advanced shortcut gestures.

5. CONCLUSIONS

Today's accessibility services must accommodate the large diversity of mobile apps. They provide access to often conflicting interface paradigms. As such they are not particular designed for any interface; leading to a more complex and less effective interaction. Current screenreaders enable touching to explore, swiping to navigate to next/previous elements, and performing special gestures, all in the same area. The complexity of these interactions together with the complexity of the interfaces disables a large portion of the population to use mobile devices effectively. As such, we are proposing personalized interface layers that allow users to create a consistent presentation experience for themselves, regardless of the application they are interacting with. Recognizing the additional difficulties faced by blind users with dual interaction spaces, we developed a solution that provides clearly separated interaction areas. Providing a simpler navigation area that enables a more flexible, but still complete, access to available interface elements in the applications underneath. This approach is perceived by users as simpler to use and learn, and to enable an easier transition to these devices. Future work should seek to explore the impact PSI could have in the adoption process. There is an opportunity to reconsider mobile accessibility approaches to be more modular and customizable, enabling higher degrees of personalization and thus supporting at all levels of expertise.

6. ACKNOWLEDGEMENTS

We thank the Fundação Raquel e Martin Sain in Lisbon. This work was partially supported by Fundação para a Ciência e a Tecnologia (FCT) through funding of the scholarship and ref. SFRH/BD/103935/2014, LASIGE Research Unit, ref. UID/CEC/00408/2013 and EPSRC award number DERC EP/M023001/1 (Digital Economy Research Centre).

7. REFERENCES

[1] S. K. Kane, J. O. Wobbrock, and R. E. Ladner. 2011. Usable gestures for blind people: understanding preference and performance. In Proc. of the SIGCHI Conference on Human Factors in Computing Systems (CHI '11). ACM, New York, NY, USA, 413-422.

[2] R. Leung, L. Findlater, J. McGrenere, P. Graf, and J. Yang. 2010. Multi-Layered Interfaces to Improve Older Adults' Initial Learnability of Mobile Applications. ACM Trans. Access. Comput. 3, 1.

[3] H. Nicolau, K. Montague, T. Guerreiro, A. Rodrigues, and V. L. Hanson. 2015. Typing Performance of Blind Users: An Analysis of Touch Behaviors, Learning Effect, and In-Situ Usage. In Proc. of the 17th International ACM SIGACCESS Conference on Computers & Accessibility (ASSETS '15).

[4] A. Rodrigues, K. Montague, H. Nicolau, and T. Guerreiro. 2015. Getting Smartphones to Talkback: Understanding the Smartphone Adoption Process of Blind Users. In Proc. of the 17th International ACM SIGACCESS Conference on Computers & Accessibility (ASSETS '15).

[5] K. Shinohara and J. O. Wobbrock. 2011. In the shadow of misperception: assistive technology use and social interactions. In Proc. of the SIGCHI Conference on Human Factors in Computing Systems (CHI '11).

[6] D. Zhang, L. Zhou, J. O. Uchidiuno, and I. Y. Kilic. 2017. Personalized Assistive Web for Improving Mobile Web Browsing and Accessibility for Visually Impaired Users. ACM Trans. Access. Comput. 10, 2.

[7] X. Zhang, A. S. Ross, A. Caspi, J. Fogarty, and J. O. Wobbrock. 2017. Interaction Proxies for Runtime Repair and Enhancement of Mobile Application Accessibility. In Proc. of the 2017 CHI Conference on Human Factors in Computing Systems (CHI '17).