Getting Smartphones to Talkback: Understanding the Smartphone Adoption Process of Blind Users

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ABSTRACT
The advent of system-wide accessibility services on mainstream touch-based smartphones has been a major point of inclusion for blind and visually impaired people. Ever since, researchers aimed to improve the accessibility of specific tasks, such text-entry and gestural interaction. However, little work aimed to understand and improve the overall accessibility of these devices in real world settings. In this paper, we present an eight-week long study with five novice blind participants where we seek to understand major concerns, expectations, challenges, barriers, and experiences with smartphones. The study included pre-adoption and weekly interviews, weekly controlled task assessments, and in-the wild system-wide usage. Our results show that mastering these devices is an arduous and long task, confirming the users' initial concerns. We report on accessibility barriers experienced throughout the study, which could not be encountered in task-based laboratorial settings. Finally, we discuss how smartphones are being integrated in everyday activities and highlight the need for better adoption support tools.

Categories and Subject Descriptors
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous; K4.2 [Computers and Society]: Social Issues – Assistive technologies for persons with disabilities.

General Terms
Performance, Experimentation, Human Factors.

Keywords
Blind, Novice, Smartphone, Adoption, Touchscreen, Challenges.

1. INTRODUCTION
Mobile phones have evolved from single-purposed communication devices into "Swiss Army"-like tools that support a wide range of tasks, including navigating, listening to music, texting, shopping, and so forth. Smartphones enable people to access a wealth of information and services through their extensive connectivity; they have the potential to empower people in everyday tasks.

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Since the inclusion of screen reading software, such as *Talkback* or *VoiceOver*, modern touchscreen smartphones have become more popular amongst blind and visually impaired people. Upon the emergence of these services, research on mobile accessibility has been mostly focused on specific tasks, mainly text-entry [2, 4, 13, 14], but assuming that the device and operating system are accessible. This research has also been limited to laboratory experiments where users engage in artificially created tasks for short periods of time.

However, anecdotally, we have observed that several blind people continue to use their older feature phones and see a keyless future as a daunting one [6]. For many other users, interacting with these devices is still confusing and challenging to master. Little is known about the daily experiences of blind people with these devices, or how they are integrated into their everyday activities. Moreover, even less attention has been paid to novice smartphone users and their learning experiences, particularly during the adoption process, i.e. transition from an older phone to a touch-based smartphone.

In this paper, we investigate smartphone adoption and usage by novice users with visual impairments through a combination of longitudinal device usage, weekly interviews, and interaction observations. We focus our attention on the concerns and expectations of 5 novice blind users before owning a smartphone, the learning and usage over an 8-week period, and how they feel about their initial concerns and expectations.

Results show that users delay the adoption of a smartphone due to several reasons, including a concern of not being able to master the device as desired and failing to communicate with family and friends. The first contact with these devices is challenging as users are confronted with both a lack of support and a set of inconsistencies in how the device/accessibility services behave. At the end of the study, participants still experience their initial concerns, and lack proficiency in interacting with their devices. Nevertheless, despite their inefficiency and inefficacy in comparison to their feature phones, participants value the benefits of using current technologies, such as smartphones. Moreover, they show resilience and willingness to continue exploring and improving their ability to use these devices.

These results reveal the shortcomings of current accessibility tools for mainstream mobile devices as felt by novice blind users, shedding light on improvements needed in the support tools provided (e.g. usage tutorials) and in solving the inconsistencies users face every day.

2. RELATED WORK
Our research is informed by prior work on touchscreen accessibility for blind and visually impaired users and the real-world usage of mobile technologies.

2.1 Non-visual interaction with smartphones

Mainstream touchscreen device manufacturers have recognized that an increasingly number of blind people want to use touchscreen mobile devices. Therefore, these platforms come preloaded with a range of accessibility tools and services, some of which are designed specifically for non-visual interactions. Android's *Talkback* and iOS' *VoiceOver* enable visually impaired users to explore the interface elements by either dragging their finger around or performing a sequence of swipe and tap gestures while receiving audio feedback - similar to the techniques proposed by Kane and collegues [8]. While these accessibility services allow blind users to interact with the technology, they can result in much slower interactions than those of sighted users [13]. One particular task that has been vastly explored is text input, where alternative gesture-based [7], multiple selection- [4] and Braille-based [3, 13, 14] methods have been devised.

Difficulties in operating a touch-based phone without visual feedback have also been acknowledged by other researchers working on haptic feedback [5] or even on how to teach touch gestures to blind people [12]. On a more general note, the number of options and novel interaction paradigms is also likely to disable users to adopt this technology. This gave space to the release and maintenance of commercial alternatives that, using a touch-based phone, support a more structured interaction, similar to the one seen on older phones (e.g., Mobile Accessibility[1]).

While non-visual operation of a touch-based smartphone seems to be a concern, there are, to our knowledge, no reports on the very first contact and daily usage of these devices by blind users. In this paper, we look at the challenges faced by novice blind participants since their first experience with an unknown smartphone. We then report a set of barriers, concerns, and experiences that enrich the knowledge base on how to improve the accessibility of such devices.

2.2 Real-world Usage and Adoption

Prior studies have investigated real-world technology adoption and usage by people with disabilities. Using interviews and participant diaries, Kane et al. [9] explored the accessibility challenges faced by people with visual and motor impairments when using mobile devices. More recently, Anthony et al. [1] analyzed YouTube videos of people with physical disabilities interacting with touchscreen devices, which were supported with online surveys on technology usage. This approach captured the unique and interesting ways in which people have augmented or crafted solutions to support their interactions with touchscreen devices. Furthermore, the study highlights real-world usage scenarios and interaction contexts from individuals with motor impairments. Similarly, Naftali et al. [11] conducted in-the-wild case studies with four people with motor impairments to explore the impact of environmental context on their mobile interactions using a combination of interviews, participant diaries, and contextual session observations.

While previous studies offer novel insights about real-world technology usage by individuals with disabilities, data is still limited to a particular time-window through reflective participant diaries. Commonly in-the-wild user studies do not allow the researchers to obtain objective performance measurements of device interactions, as previously seen within laboratory evaluations. One exception is the work by Montague et al. [10] who conducted a four-week in-the-wild user study involving participants with motor-impairments, using a custom built game to capture touchscreen interaction performance measurements. However, this approach was limited to collecting interaction data within the custom built game - overlooking the interactions that participants were making with other device applications.

In the current study, we go beyond the state of the art on understanding technology usage and adoption by resorting to a combined approach of data collection comprising qualitative weekly data, quantitative weekly controlled assessments, and in-situ device usage data. This information enables us to better understand how users learn and evolve, their usage patterns, and limitations.

3. METHODOLOGY

This paper focuses on uncovering and understanding the smartphone adoption experiences of blind users. We used a combination of coded interviews and observations, alongside with an analysis of device usage from a two-month in-the-wild user study with five participants.

3.1 Research Questions

We aim to answer the following research questions:

- What are the main concerns and expectations of novice smartphone blind users?
- How well current systems support the novice user in a first contact?
- When are these devices integrated on everyday activities?
- What are the barriers to smartphone adoption by novice blind people?
- What role did external influences play in the adoption process?
- How different is their smartphone usage from their previous device?

3.2 Participants

Five participants with visual impairments, four males and one female, took part in our user study. Participants' age ranged from 23 to 55 (M=37.2, SD=15.2) years old. They were recruited from a local social institution, and all participants were legally blind as defined within our IRB approved recruitment. None of the participants owned or used smartphone devices; however, they were all experienced desktop screenreader users Table 1 provides further information about participants, including their technology usage and experience.

Table 1 . Participant profile, where YB (Years of Blindness) UD (Use per Day)

ID	Age	Sex	YB	Old device	UD	Features
P1	55	M	52	Nokia C5	5-7	Calls, SMS
P2	34	F	11	Nokia E52/ Nokia 3230	>10	Alarm, Calls, SMS
P3	51	M	25	Nokia N70	2-4	Alarm,Calendar, Calls, SMS
P4	23	M	9	Nokia E66	>10	Alarm,Calendar, Calls, SMS
P5	23	M	5	Nokia C5 / Nokia E65	>10	Calls, SMS

[1] http://codefactoryglobal.com/app-store/mobile-accessibility/

3.3 Apparatus

Participants were each provided with *Samsung S3 mini* touchscreen smartphones running the Android 4.1 operating system. We enabled the *Talkback*[2] screenreader and pre-installed our data collection service, TinyBlackBox (TBB). The TBB service was designed to run constantly in the background, capturing the users' interactions with any and all applications within the device. User interactions are encrypted and stored locally on the device, alongside the interface DOM tree from which the interactions took place. On a daily basis the device would attempt to communicate with the Google Cloud services to securely transfer an outstanding set of log files using an available Wi-Fi network connection.

3.4 Procedure

The user study spanned for two months (8 weeks), and consisted of the following components; 1) pre-adoption interviews and background data, 2) introduction session with *Talkback* tutorial, 3) in-the-wild device usage, 4) weekly sessions with researchers 5) post-study interview.

3.4.1 Pre-adoption Interview and Background Data

We met with the participants at a local social institution for blind people. All sessions were audio recorded to maintain fluid conversation flow, and to allow for data analysis afterwards. Participants first completed a background questionnaire, provided details of their existing mobile phone, device usage, and prior experience with touchscreen interfaces. All participants owned and used feature phones, as shown in Table 1. Moreover, none had previously used a touchscreen smartphone. During the pre-adoption interview, participants were asked to discuss in more detail their current mobile device, particularly what they liked or disliked about it; how they felt about smartphones and touchscreens; what were their expectations, i.e. things they would like to do with the device, how long they thought it would take to learn how to use the device, and challenges or concerns with using smartphones; and finally, they were asked about their existing support network, i.e. friends or family that could assist them with learning to use the smartphone. To capture a quantitative baseline of mobile device usage, we collected data from the participants performing a set of basic tasks on their former phones (check the time; add a contact; call a contact; call a number; answer a call; read a new SMS; reply to an SMS (no text); create a new SMS conversation; open target app, and complete text-entry trials).

3.4.2 Talkback Tutorial and Basic Tasks

Participants were first introduced to the smartphone, including its physical buttons and features - i.e. how to turn it on and off, the volume controls, and touchscreen. We then enabled the *Talkback* accessibility service on the device and started the Android *Talkback* tutorial application. Participants were then given the device back and asked to follow the tutorial instructions and complete the *Talkback* introductory training. Whenever they had any doubts, they could ask the researcher present. The researcher would then explain verbally how the user could accomplish the given task. The *Talkback* tutorial in Android 4.1 is composed of 4 lessons each introducing at least one new gesture to users. The lessons are Explore the Screen, Scrolling through Lists, Context Menus and Reading Granularities. Afterwards, participants were guided through all basic phone tasks: lock/unlock, check battery, check time, make/receive SMS/calls, explore app menu and add a new contact. During these tasks, we asked participants to think aloud and talk about their experiences while learning to use *Talkback* and the device. The tutorial sessions were video recorded and the TBB framework captured device interactions.

3.4.3 In-the-Wild Device Usage

To capture the participants' adoption experiences, we asked each participant to replace their existing feature phone and use the provided smartphone as their primary device. We assisted the participants with installing their carrier SIM cards, and transferring their device contacts onto the new device. Participants were informed of the TBB data collection service, and provided examples of the data that would be collected. The in-the-wild usage of the adoption phase was scheduled to run for two months. While it was not expected to cover the participants' full learning experience, i.e. from novice to expert, , it allowed sufficient time to trace the adoption process and conduct additional controlled assessments of key behaviours through weekly sessions.

3.4.4 Weekly Sessions

We met with the participants for 30-60 minutes on a weekly basis to collect performance measures of the aforementioned basic tasks and conduct small interviews. We asked participants to discuss their experiences with the device on that week, describing any challenges or concerns they may have had; informing us of new installed applications or activities they tried that week with the device; and finally, we allowed them to request assistance with using the device - as they would with family or friends. We would then attempt to answer the participants' questions; where possible we would provide the participants with verbal responses only, to avoid training them on device interactions and usage.

3.4.5 Post-Study Interview

After the eight-week period, we conducted the post-study interview with the same procedure as the pre-adoption. Interviews lasted from 15-30 minutes. We asked questions related with their answers in the pre-adoption interview such as *did their concerns and expectations come to fruition? Did their personal opinions change? Would they make the transition again? What would they do differently? Would they recommend the device to others? What advice would they give to novice users?* Finally, *what are the challenges looking forward?*

3.5 Data and Analysis

A total of 50 interviews were conducted: 5 pre-adoption, 40 weekly and 5 post-study interviews. We followed an iterative coding process where two researchers independently created codebooks. Each researcher coded the same two adoption interviews and two weekly interviews, after which the codebooks were refined and merged. Using the merged codebook, the researchers proceeded to analyse five weekly and two adoption interviews which lead to further refinement of the codebook and finally a Cohen's kappa agreement of k=.85 (SD=.08) was achieved.

The results from the thematic analysis were complement with observations and log data from the weekly tasks and log data collected in the wild. We gathered a total 7175 in-the-wild

[2]https://play.google.com/store/apps/details?id=com.google.android.marvin.talkback

sessions from the five participants. A session starts with an activation of the screen and ends when the device goes to standby.

4. FINDINGS

In this section, we present our findings structured by the phases explained in the procedure: Pre-Adoption, First Contact, Weekly Evolution, and Post-Factum. Weekly Evolution comprises the data collected from the weekly session tasks, interview, and in-the-wild data.

4.1 Pre Adoption: Concerns and Desires

4.1.1 The need to adapt.

Feature phones are slowly disappearing from the marketplace - forcing blind users to, sooner or later, make the transition to smartphones. These devices are now mainstream and having one is seen as a gateway to social inclusion.

> *"I have nothing against my current phones, but I would be more inserted into society and in today's technology". (Participant 5 – P5)*

4.1.2 More than a phone.

One of the many benefits of smartphones is their ability to provide richer communication channels (e.g. email, *Whatsapp*, *Facebook*). Smartphones can also be the solution to some of the current inaccessibility problems users face every day with standard out of the box technology.

> *"[With a smartphone] I can have access to the Internet, email… and to be able to listen to music, I like my MP3 player but it is extremely hard to control I have to keep asking for help" (P2)*

4.1.3 Concerns.

While the participants were usually aware of the benefits of owning a smartphone, they were considered too expensive and viewed as a luxury item. Participants associated it with the use of Internet and therefore attribute its cost to the retail price plus the hidden costs of internet data usage.

Moreover, participants showed some concerns with using such "luxurious devices in public, stating that simply carrying them around, poses additional security risk in public transports.

Finally, how to manipulate and interact with a touch-based smartphone is still a mystery to many people. This lack of knowledge triggered several sentiments of self-doubt. Participants were afraid they would perform actions unwillingly and they would have to rely on their spatial ability.

> *"I will need to target where I know something is rather than feeling where it is" (P5)*
>
> *"I mean, I cannot see the keys, so how am I going to be able to select the letters? How will I be able to tell where they are?" (P2)*

The lack of tactile feedback and screen size on touchscreens are fundamental characteristics that lead blind users to feel smartphones were never intended for them. They believe smartphones were adapted to fit their needs after development and, therefore, will inherently have accessibility problems. They show conflicting views of the device, even the same participant. Expecting to have problems while enabling them to use new features such as the music player as previously stated. They are simply unaware of what to expect:

> *"I don't know how accessible touchscreen applications are" (P2)*

4.1.4 Expectations.

Doubts on the interaction method and thoughts on the inaccessibility of the device resulted in participants expecting a difficult transition that required the assistance of others. However, expectations on adoption time highly depended on individual needs. While one user expected to take months to feel comfortable with the device others believed it would take only a few days or weeks. One participant was committed to the changed and needed to make the transition in a day:

> *"I have to learn it the day I get it. People will keep messaging and calling me. If I don't answer people will start to think I am dead [smiling]. I have to at least answer my mother!" (P2)*

Most smartphones come out of the box with a screenreader available. Thus participants had higher expectations for it as opposed to their feature phones where the screenreader was an external software that had to be installed. They expected applications to be inherently more accessible.

4.2 The Daunting First Contact

Talkback tutorial revealed to be a problematic task for all users, only 1 out of 5 successfully completed all the lessons. The tutorial disables the interactive area while explaining what users need to do next. This explanation is triggered whenever users accomplish a task or take too long to finish. The latter triggers even while people are interacting with the screen interrupting the task and forcing them to listen to a long explanation again. Users felt frustrated since they weren't in control of the flow of the lesson and their learning experience.

Overall, the tutorial application was unable to recognize successful and unsuccessful tasks several times. As an example, let us consider the Explore Screen lesson; users were asked to perform a slide from left to right to navigate to the next option. While they were trying to perform the gesture, their fingers would end up touching an icon on the screen and the tutorial assumed they had performed the correct gesture when in fact they just dragged over a random option. As a result, none of the participants understood they could use the slide gesture to go to next focusable option.

Moreover most of the tasks did not have an intended target, yet they rely on affecting the interface (e.g. focus a target, scroll the list), the users are only aware that they performed the intended gesture but have little knowledge how they affected the interface. As an example the list lesson asks users to select an option, users would simply tap anywhere on the screen and went to the next

Figure 1. Samsung S3 Mini with capacitive buttons at the bottom of the device.

step of the lesson having no idea what they just did other than they taped the screen.

4.2.1 Gestures.

Lesson 3 and 4 from the *Talkback* tutorial required users to perform an L based gesture to open the special *Talkback* menus. Four out of five participants were unable to consistently open the menus even after 15 tries. They struggled with performing the gesture fast enough, in the correct area, with the correct shape, and even when they successfully did so they struggled with the following menu. As a result, these users skipped one or both of the last two lessons. When they opened these menus the interaction method changed. They now had to focus an item by dragging the finger around a circular area, which is completely different from the previous grid/list layouts, and lift their finger to select the intended option. The participants were confused as to why the interaction method suddenly changed.

4.2.2 Capacitive buttons.

The back and settings buttons have no physical cues and are activated on touch. Participants struggled with distinguishing between the bounds of the screen and capacitive buttons (Figure 1). This is especially challenging given that no audio feedback is provided for either the back or the settings buttons. This issue was exacerbated when they did not press them intentionally.

4.2.3 Physical cues.

Touchscreens lack physical cues, as such participants attempted to use whatever they could to facilitate screen exploration. P4 *noticed that the basic apps basic (i.e. shortcuts to Phone, Messages, App Drawer, etc) were located in the bottom of the home screen above the physical home button of the device*. Consistently throughout the session whenever he had to select one of these apps, he would first locate the home button to start the exploration from there. The lack of physical cues made impossible for participants to distinguish between the touchscreen and the capacitive buttons. Participants ended up inadvertently pressing the back button when using the edge of the device as a physical cue.

4.2.4 Text-Entry

Even though text-entry was one concerns exposed in the pre-adoption interview participants were able to use input text after a brief explanation of the interaction method of virtual keyboards. Analysis of the text-entry performance is outside the scope of this paper.

Table 2. Weekly task table per participant where it's represented the first week from which participants started to consistently be able to perform the task.

Task	P1	P2	P3	P4	P5
Check time	W1	W1	W1	W1	W1
Add Contact	W6	W4	-	W6	-
Call Contact	W2	W4	W3	W4	W8
Call number	W2	W3	W1	W1	W1
Answer Call	W1	W1	W1	W1	W1
Receive Text Message	W6	W1	W1	W1	W5
Send Message	W1	W1	W5	W1	W3
Send new Message	W7	W5	W6	W3	W7
Go to <App>	W1	W1	W2	W3	W3

4.2.5 Interaction Method

Participants were introduced to two different exploration methods and three different selection methods in less than two hours. The three selection methods are associated to different features. On lift is used to input text and to select options on the contexts menus of *Talkback*. Double tap is the default method to select any focused option. On press is used on the physical home button and the two capacitive buttons on each side (back and settings). During the session participants were mixing some of these methods, double tapping to input text or trying to select options using on lift. Some of them asked why would there be different selection methods between functionalities.

After the *Talkback* tutorial participants relied solely on explore by touch by dragging their fingers rather than directional gestures. Only when participants felt the need to navigate through all options on the screen and asked how they could achieve it, the researcher explained once again both methods. This illustrates how ineffective *Talkback*'s tutorial was, even in explaining essential features.

4.3 Learning and Evolution

Guided by the thematic analysis of the weekly interviews we present the following themes: Barriers, Concerns & Insecurities, Influences, Positive Experiences and Attitude. Each theme provides an insight into the adoption process supported by observations, data from weekly tasks, and in-the-wild device logs.

4.3.1 Barriers

During the study the amount of barriers referred-to never subsided, they only changed in form. Participants were constantly tackling new challenges as they overcame the previous ones.

Gestures. Difficulties with performing intended gestures directly affected participants' ability to operate the device, especially in the first week. They struggled even with simplest gestures (e.g. double tapping). The underlying causes varied from accidental touches, timing issues, and unrecognized taps. While P5 *used his fingernail to double tap*, P2 *performed it too slow and end up focusing a different target*. P1 *holding hand would inadvertently touch the screen, preventing the target to be selected*. As the weeks went by the basic gestures problems were observed in less frequency during the weekly sessions and were far less mentioned during the interviews.

Unlock. The unlock mechanism was unnecessary complex; it was composed of a double tap followed by a slide. Participants struggled with these gestures even without the time constraint required by the unlocking mechanism. Thus, during the first three weeks, we observed participants performing several attempts to unlock their devices. In most severe case, P1 was *unable to consistently unlock in the first 3 attempts* throughout the study from week one to week eight.

Interaction Method. Most participants kept the same interaction method throughout the study. Those that initially struggled with gestures ended up solely using explore by touch. While most used both methods, P5 *used almost exclusively gestures to navigate around the interface avoiding explore by touch*.

Capacitive Buttons. The capacitive buttons continued to be a problem during the firsts three weeks. Participants would inadvertently press them and struggle to recover the previous state. Confused by the different interaction methods they would sometimes double tap the buttons as if they were interface elements selecting the action twice.

Navigation Inconsistencies. Applications keep the previous state depending on how they were closed and how they were implemented to resume when reopened. These inconsistencies made it challenging for participants to learn how interface elemnts are displayed and build a mental model of the application in order to repeat previous interactions.

> *"One thing I noticed is every time I try something I always find things different and since I can't find regularities I cannot learn [how to do it]" (P1)*

Scrolling. Without recurring to *Talkback* gestures, scrolling lists becomes a challenging task. Users have to perform a two-finger slide inside the list's bounds to drag it. Participants faced several challenges on: 1) where to position their fingers, and 2) understand how finger movement affected the scrolling. For instance, some participants inadvertently opened the status bar on the top of the screen while trying to scroll through the contacts. As a result, tasks involving the contact list (e.g. call a contact and send new text message) were the most problematic as seen in Table 2**.** Participants tended to rely on the dial phone in the first weeks while learning to manipulate lists.

> *"I never know how much I move when I slide, I don't know if I skipped a few options or not" (P1)*

Paradigm Shift. The applications on the smartphone are quite different from the ones in feature phones. Many of the initial barriers can be attributed to the mismatch between participants' expectations (i.e. mental model) and the actual interfaces. *P1 was expecting to have the different folders of Inbox/Sent/Drafts in the SMS app rather than a conversation paradigm where all messages are grouped by contact*.

Accessibility Compliance. After the first four weeks, barriers started to shift to a more feature- or application-driven. As participants delve into new applications they started to face accessibility issues not so commonly found in the out of the box essential apps. They found many buttons without a description, forcing them to create coping strategies around it.

> *"I found that the send button is always changing number, I have to remember that it is the button next to the text box" (P2)*

Assistance of Others. Although relying on others is probably one of the most effective coping mechanisms, help may not be always available. In a similar situation the same participant stated:

> *"I still can't use Endomondo, because instead of start and end, the buttons are numbers and I don't know which is which" (P2)*

This demonstrates that some barriers are hard to surpass without the assistance of others, which can have dramatic consequences. P3 and P4 mistakenly changed the language of the device and from that point onwards were unable to recover. P3's family was not able to solve the issue; therefore he did not use the device for the remaining part of the week. Sighted people are not familiar with *Talkback* and may not be able to assist screen reader users. When this happens, users and helpers engage in collaborative tasks to tackle the issue. P1 was struggled with inserting the password on his home network and his daughter was not able to navigate the device with *Talkback*:

> *"I went into the Wi-Fi configuration screen just like I learned, and then I asked my daughter to select the network and insert the password". (P1)*

Feedback. Smartphone interactions are accompanied by specific audio feedback. During the initial weeks users had no understanding of what this audio cues meant and therefore struggled to understand interface states. P5 *In forms kept pressing the edit box over and over again to get to the keyboard and it took him a while to realize the sound he was hearing meant the keyboard was already opened in the bottom side of the screen*.

Audio feedback sometimes does not respond as users would expect and therefore break their trust in the accessibility service. The TTS sometimes would not immediately respond to user interactions due to buffering effects that led to users only receiving the audio cues from the option focus being shifted but not to what.

> *"We are searching for the buttons and we just hear poc, poc, poc, but it doesn't say anything" (P3)*

This mistrust in the system led users to not realize their gesture simply were not being recognized and instead thought the system was simply slow. The delay between interaction and feedback caused users to take action and adapt to it. P3 and P4 sped up the *Talkback* voice while P2 *simply started waiting for the feedback before interacting*.

Coping. When confronted with a barrier, users tended to have one of four approaches. First they would ask for help, if help was available. If they felt it was an interface or application they would simply reboot the device. If possible they would rely on other devices to search for a solution or simply accomplish the desired task on a secondary device.

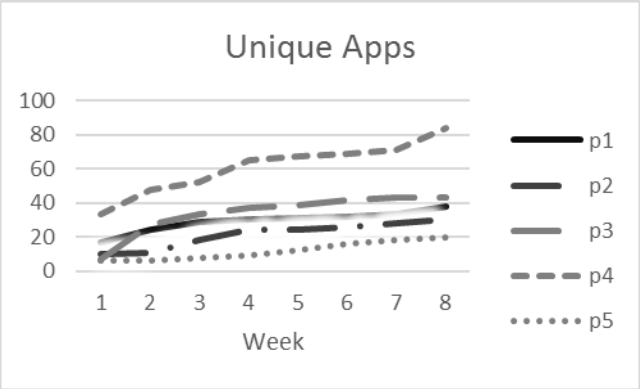

Figure 2. Cumulative number of unique applications visit during the eight weeks by each participant.

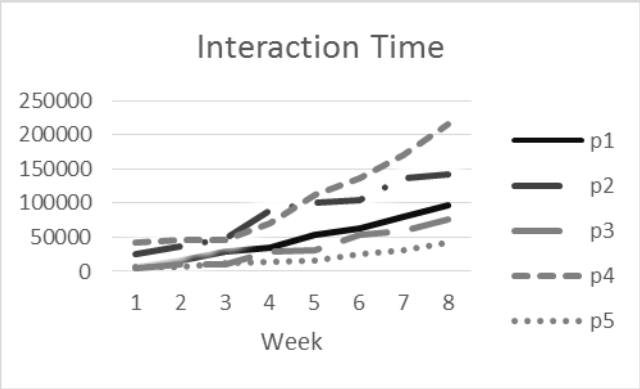

Figure 3. Cumulative interaction time during the eight weeks by each participant in seconds.

4.3.2 Concerns & Insecurities

This theme aggregates all the reports of the users concerns when using the device including their reported insecurities and privacy issues.

During the first three weeks users had difficulties controlling the screen reader and felt uncomfortable while doing so. Users stressed how insecure they felt in public transportation. This caused users to avoid using the device in public places some even after the eight-week period.

> *"What I like the least is the fact that I feel like a complete idiot looking for the options and then not being able to use them" (P2)*

Users showed some resistance with sharing information due to the lack of knowledge of how it would be shared. They were afraid that by sharing their location, or having their calendar synchronize somehow others would be able to tell their location/schedule without their permission. As newcomers to the smartphone paradigm they were not familiar with registering in apps through their Google or Facebook accounts - When they opened applications for the first time that warranted for a registration, the participants were left weary and some did not proceed with the registration before confirming with a friend that they had the correct app installed.

4.3.3 Influences

This theme gathers the collected information on how users were influenced by outside sources in their exploration and usage; and how they influenced others.

Other smartphone users can directly affected the way users interacted with their device by sharing their experiences. Most will undoubtedly help but when users are misguided it can have a negative effect on their learning process. P3 was told about a gesture he could do from a iPhone user. During the following weekly session P3 tried to do a gesture he learned to no success due to that gesture being specific to iPhone.

Sharing experiences can also be exactly what the users need to bootstrap their device usage. P4 in the first weekend with the device explored the it with a friend. P4 was by far the most adventurous explorer in the first week alone he used 33 unique applications (Figure 2). Knowing other smartphone users greatly promoted the discoverability of new applications.

Some participants were also impacting how others perceived smartphones.

> *"My mother never liked new technologies, she got used to phones really slowly. She found my device funny and enjoyed playing with it. She is even considering buying one of this for herself. Its funny how the device is gathering fans." (P2)*

4.3.4 Positive Experiences

In this theme we gathered reports of users success stories. Through them we can have a glimpse into their evolution.

Users find positive experiences wherever they can and accordingly to their proficiency with the device. Users had very different experiences as one can assess looking at the weekly tasks in Table 2. Users who struggled the most reported positive experiences associated with basic tasks or exploration. P5 was one of the users that used the device the least and struggled the most as seen in Figure 3 by the eighth week the user positive experiences were still related to basic tasks.

As more weeks went by the positive experiences shifted to being app related or more complex tasks. P1 complement his pc use with the device and now checks for emails on the phone before reading them on the pc. To P4 the smartphone was becoming much more than a phone he kept installing TV apps, games and educational applications, he was particularly happy with social apps. P3 found great joy in utilities apps such as *CamFind* which directly affected their feelings towards the device.

> *"CamFind is very useful around the house. With 2 blind people is great. I like the device more with each passing day" (P3)*

Users found joy when they accomplish something without any external help even if it was simple phone features as setting the phone on vibrate.

4.3.5 Attitude

This theme gathers the attitudes of the participants about the device usefulness and their ability to handle it during the study.

When users struggle they avoid situations where they have no control like avoiding to use the device in public. In extreme cases they go as far as warn their families about their inability to control

the device in order to avoid misunderstandings if they aren't able to answer/call:

"Pretend that I don't have a phone" (P1)

Motivated by their need to adapt they pushed through their difficulties. Users felt compelled to adopt the device no matter what in order to fit in with their surroundings. When users were neglect of successful experiences they started to report frustration and self-doubt. When they finally broke through everything changed.

"After I was able to send the message I think I stopped thinking I couldn't do it" (P1)

Users believe their performance would never reach the one with their old phones due to things being inherently harder. From week four onward users started feeling more comfortable and recognized they could do more with the devices. As they started to explore the device it was becoming evident this was more than a phone to them.

During the study users clearly set self-goals. With each passing week users tried to address their previous barriers and sometimes came back with success stories.

"It's hard to handle the post navigation in Facebook" (P1 Week4)
"I can now navigate between the posts but I still can't read the full text I still have to learn" (P1 Week5)

4.4 Post-factum: Perceive Challenges and Benefits

In the post-interview we were interested in understanding how they perceived their adoption and how they would improve it. Did their concerns come to fruition? Were their expectations met? What was important and what would advise others to do? What are the next goals?

4.4.1 Concerns

The participants that expressed concerns on using the device in public continue to feel this way. Two participants (P1, P3) felt that this device was worse as a phone, it was more difficult to use and slower than their previous device. Not all users shared this consensus, P2 and P4 saw smartphones has being better even for the most common tasks:

"In my old one the only thing I'm faster is searching for contact, even writing a text I am faster here". (P4)

P5 was the user who struggle the most and in his pre-adoption interview thought he was learning a device not design for him, the experience with the device changed his view on smartphones:

"My opinion has changed. They aren't that hard, as everything else we just need to learn to use them" (P5)

4.4.2 Expectations

Most underestimated how much time it would take for them to get used to the device and how much of a challenge it would be. Some felt that they were used to the device after two weeks (P4), while others state they still are not completely comfortable (P3). P2 has met her initial expectations and was happy she able to send messages in the first week. User's ability with one of the basic tasks did not translate quickly into the other. In P2 case her prowess with the messages did result in a quick adoption of all features as seen in Table 2.

4.4.3 Looking back

Dedication can be the key to the adoption as most users felt they should have spent more time exploring the device. A gradual transition by relying in a second phone can help users keep their spirits up making the adoption smoother. However, it can also slow the process P5 felt he might benefit from a forceful transition

"I know that if I was forced to use just one I would have done things quicker" (P5)

Having someone to rely on was crucial in the early adoption stages not only as an aid, but also as an assurance that if something went wrong they had someone to go to.

Users regretted not being able to share their experiences with others or not have it done sooner. They believed cooperative exploration would have quickened the learning process.

To improve the learning process one common request was the creation of a manual with a step-by-step guide on how to accomplish the basic tasks.

Participants felt that the device is still not accessible to all blind users. While they would recommend the device, they wouldn't recommend it to everyone

4.4.4 More than a phone

To the participants their device became so much more than a communication device. The new applications and features are becoming part of their daily life and playing a role in supporting their independence:

"Just the other day I had difficulties seeing my medication, I took a photo with CamFind it told me what the medication was." (P4)

To some users the added functionalities came at a cost. Two users believe they made a trade-off between more features and easiness of use.

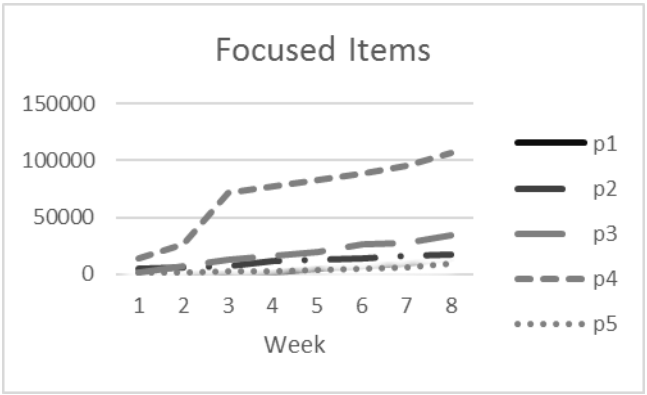

Figure 4. Cumulative number of items that were focused during exploration throughout the eight weeks per participant.

They don't believe they will ever be quicker with smartphones. Yet, they clearly see the advantages.

> *"It allows you so much more than a regular phone wont, we can use it almost as good as our old ones. I believe it's a trade off in favor of the smartphone" (P1)*

4.4.5 Looking forward

Participants were keen to continue to improve their device usage even if only motivated by the inherent need to adapt:

> *"Someday there will only be smartphones, we have to live with it" (P3)*

Most set their goals as they had been doing week by week, each had one particular application or feature within an application that they wanted to master. One user saw the smartphone as an opportunity to learn something he even struggles to do on a pc.

> *"I would like to browse the Internet, it's something I even struggle with the computer" (P5)*

One user was particularly interested in the navigation capabilities of the device; he was determined to be able to use them.

Lastly, one user felt he had reached full adoption and believed he could do whatever is possible to do with the device. This confidence is not surprising given the amount of exploration he had with the device far surpasses other participants, as shown by the total number of items focused during the weeks in Figure 4.

5. DISCUSSION

Based on our findings we are now in a position to answer our research questions.

What are the main concerns and expectations of novice smartphone blind users?

Pre-smartphone adoption blind users had two major concerns safety and fear of the unknown. They perceive having a smartphone as an additional security risk due to the unwarranted attention it brings. This insecurity was deeply felt in the initial weeks where even users that used their previous phone on a public setting did not anymore. Only when participants felt in control their attitude changed. Since they had yet to interact with the device they feared they would be unable to use it due to not having any physical cues and fearing they would have to rely on their spatial abilities. Their fears were exacerbated by thinking smartphones were inherently not designed for them, and as such they would have to adapt to an inaccessible device, an opinion they no longer share. Most expected a much faster and easier adoption, they struggled more than they anticipated. From the starting point most believed they would never perform better than with their current phone, but felt they add to adapt mainly due to the market pressure.

How well current systems support the novice user in a first contact?

The *Talkback* tutorial simply was not enough for users to even get started. They struggled with some of the gestures presented and even after eight weeks we still see no reports or data where they use complex gestures. During the tutorial they were even misguided into thinking they had performed the correct gesture when in fact they didn't. The gesture to go to the next option was not learned during the tutorial, which caused users to struggle during the tutorial and in the following weeks with the exploring of applications. Using just explore by touch is a demanding task that heavily relies on the users memory and spatial ability, to explore new applications. It is crucial to improve the tutorial session in order to reinforce how, when and which gesture is more appropriated to the task. The tutorial presents users with the basic gestures but makes no effort in providing feedback on how they affect the underlying interface. We complemented the tutorial with a guided session through the basic tasks. Although users were able to perform all the tasks, most felt they learned too much in a short space of a time. From just basic tasks users had to learn three different selection methods (lift, press and double tap) and learn where to apply each. Moreover, they had a multitude of new interfaces to learn. As such, when looking back many users had the desire for a manual that they could rely on. There is a need to provide better learning mechanism for blind users on mobile devices.

When are these devices integrated on everyday activities?

Given the opportunity users will quickly integrate smartphone in their daily activities to improve their independence or simply as a source of entertainment even if they are yet to fully control the device.

What are the barriers to smartphone adoption by novice blind people?

Throughout the weeks we saw how the different barriers evolved. In the initial weeks users mainly faced gestures related issues. The biggest hurdle was understanding the new paradigm they were in. Suddenly users couldn't find any consistency in the applications. They no longer have one single path between point A and B, but any number of ways to do the same thing. Applications now have states, depending on whether you back or home they close or go to the background and resume in different ways. This mixed in with every application behaving differently to the back button led to users struggling to learn to interfaces and repeat tasks. We need better methods to convey this new paradigm to users. From all interface elements, lists were with no doubt the harder ones to grasp, we believe this begins with a poor tutorial and gets worse when they reach the contact list. Applications had elements with no descriptions or simply not reachable through a non-visual exploration. Application developers need to start respecting basic accessibility guidelines and strive to make their application friendly to a non-visual exploration.

What role did external influences play in the adoption process?

Users felt that without someone who they could rely on to help them they would possibly have an insurmountable barrier. During the firsts weeks users relied on their friends and family to help them with configurations, app installments or simply understanding the basic interfaces. The primary coping strategy for users throughout was asking others for help. Looking back users wished they knew people that were using the device so they could share experiences and help each other.

How different is their smartphone usage from their previous device?

Most had their previous phone for more than a couple of years, it comes as no surprise that in eight short weeks most feel they are slower. The smartphone is much more than a phone. It is allowing

them to be more socially active through Internet communication and social apps such as *Whatsapp*, *Facebook*. It is becoming an educational tool for them to study and learn languages. It's becoming a means towards independency and a solution to problems using utilities apps such as *CamFind* (e.g. identify medicines). At the very least for all it is a mobile entertainment device, to listen to music, play games, read a book or simply watch TV.

6. CONCLUSIONS

We conducted an eight-week study with five novice blind participants. We observed their adoption process through a combination of interviews, weekly assessments, observations and in-the-wild data. We present a detailed understanding of the adoption process of a blind user moving from a feature phone to a touchscreen smartphone. We uncovered theirs struggles, motivations and accessibility issues from the very first contact with the device and throughout the initial eight weeks of usage. The accessibility issues raised and their evolution should be taken into account. Others can play a huge role in the adoption process. They can be the propellers for application exploration or simply someone to share an experience with. Users will not always be able to resort to others for assistance. We saw that the current tools in place are not enough and can even provide the wrong stimuli to novice users. There is a need for better adoption support tools that take into account the evolving needs of participants for assistance. Given the opportunity users will quickly integrate smartphones in their daily lives, even if at first it is not a full-fledged phone. They will take advantage of its capabilities for entertainment, education, social activities and even to improve their independency through utility apps. Finally, these results were only possible due to the variety, quality and amount of usage data and opinions collected during the eight-week period. In order to uncover and improve the accessibility of these devices future research should seek to have similar in depth approaches enriching the quality of their data from multiple sources.

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