

Developing Apps for Visually Impaired People: Lessons Learned from Practice

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Abstract

Innovation is a challenge because it must meet the characteristics of an entire population. This includes visual impairment, which is the focus of this paper. Considering the interaction capabilities offered by mobile devices, especially smartphones, we asked ourselves this question: what kinds of interaction make it easier for visually impaired people to use mobile apps? To answer this question, we first researched into these persons' smartphone usage habits. Then we developed a prototype for an electronic calendar that provides interaction via voice commands, keyboard and touch. An electronic calendar is a very useful tool especially in business, since it can be used for managing people, resources and events, having a positive impact on productivity. This prototype was analyzed with potential users and we collected their initial impressions about the benefits of using various forms of interaction. The lessons learned with this work are presented and categorized using some of the best-known usability heuristics.

1. Introduction

According to data from the World Health Organization (WHO)¹, from August 2014, there are about 285 million visually impaired people in the world, of which 246 million have low vision and 39 million are blind. In Brazil, the country where this research is being conducted, according to IBGE (Brazilian Institute of Geography and Statistics), from the 2010 Census survey, 35,791,488 persons reported to have some type of visual impairment. Of these people, 528,624 stated that they do not see, 6,056,684

declared great difficulty to see and 29,206,180 reported having some difficulty.

In a WebAIM survey² about the usage of screen readers, 72% of the 1465 users answered that they used a screen reader with their mobile devices. A comparison drawn between this and previous surveys showed that mobile device adoption has been increasing in the last years, which demonstrates the importance of developing apps for this audience.

In this scenario, we are challenged to help people with disabilities use smartphones, not only by improving the access mode to reduce difficulties in interacting with a touchscreen [1], but also by motivating this use. Besides contributing towards their digital inclusion, the use of a smartphone and its numerous apps can also allow their inclusion in the business environment. Email, calendar, cloud storage and document editors are some simple examples of smartphone apps used in the workplace.

In this context, it must be taken into account that most smartphones have several ways of interaction, including multitouch screens, voice command capabilities and the traditional keyboard. Thus, our research question emerges: what kinds of interaction make it easier for visually impaired people to use mobile apps? Bearing this question in mind, we conducted exploratory descriptive investigations [11], including interviews and user observations. We also focused on electronic calendar apps, which are very useful tools especially in the business environment, since it can be used to manage people, resources and events, having a positive impact on productivity. Considering this context, we adopted the following methodological steps: (1) literature review, (2) formative interviews, (3) prototype design and development, and (4) user study about the implemented techniques.

¹ Available at <http://www.who.int/mediacentre/factsheets/fs282/en/>

² Available at <http://webaim.org/projects/screenreadersurvey5/>

The remainder of this paper is organized as follows. We briefly describe some related works presented in the literature in Section 2. We describe the formative interviews in Section 3. After the analysis of these interviews and of distinct calendar applications, we identified the main functionalities that a calendar should have. Then, we developed a prototype for an application to replace the native calendar and we present it in Section 4. Afterwards, we conducted a user study to observe and compare the usage of the developed prototype and the native calendar application, as we describe in Section 5. Finally, we present our conclusions and goals for future research in Section 6.

2. Related Works

A literature review showed that accessibility in touchscreen devices and the use of speech input technology for visually impaired users have already been subjects of research [2][3][4][5]. Several studies propose an accessible User Interface (UI) or evaluate the existing options or interaction modes available for blind mobile phone users, and some of them are presented here.

Azenkot and Lee [3] conducted a study to explore the options present in Android and iPhone keyboards for text entry using speech. The study comprised two phases: one to determine the frequency and context of use and the impressions about the technology, including users with and without visual impairments; and a second phase to observe blind users making use of speech input and keyboard text entry. The reason for also including sighted users was to compare their experiences. Eight users were observed composing paragraphs using speech input and an accessible on-screen keyboard. The results showed that the entry rate with speech input was considerably higher than with typing. However, editing and reviewing text took longer when speech input technology was used. Users also noticed some problems with the screen reader response, such as lack of punctuation, extra spaces and misspelled words (that were easily identified by sighted users with an underline).

In an attempt to improve the efficiency and decrease the time required to edit and review the sentences provided by the speech recognizer, Kumar et al. [6] proposed a new model to interact with this technology. Voice Typing is a model that allows users to review and edit words in real time, rather than doing so for entire sentences. After a user speaks a word or a short phrase, a menu is shown with some options: a list of possible words (including the word capitalized), an option to speak again and a list with punctuation

choices. This model was submitted to a test with 24 users. In this test, they should use the Voice Typing and Dictation methods to compose three e-mails. The results demonstrated that the number of mistakes and the time to review decreased with Voice Typing, compared to Dictation mode. The users noticed that they felt more comfortable with Voice Typing and that it required less effort to edit and review sentences.

Oliveira et al. [7] tested four methods for text entry using keyboard in touchscreen mobile devices, which are: QWERTY, MultiTap, NavTouch [8] and BrailleType. Thirteen participants tested these methods. The results showed that QWERTY was the fastest method (average of 2.1 words per minute), followed by MultiTap (average of 2.0 words per minute). The slowest one was BrailleType (average of 1.49 words per minute), and NavTouch was slightly faster (average of 1.72 words per minute). Although NavTouch and BrailleType were deemed easier to comprehend and to use, they are the slowest methods considering the Word per Minute (WPM) metric. As for the error rate among these methods, BrailleType had the best result, followed by NavTouch, QWERTY and MultiTap. This is probably because QWERTY and MultiTap have a large number of elements on screen, which demands more attention and spatial abilities.

There are also some keyboard prototypes in the literature, such as EasyTap [8] and SlideType [10]. EasyTap, based on MultiTap, lets users choose the desired letter using a 4-way selector (up, down, left and right with letter options, and a button in the middle to select the letter). The EasyTap method had better results than MultiTap, both on WPM and Error Rate evaluations. Xiong and Sanford [10] proposed a keyboard based on a universal design with SlideType. This keyboard's layout has a slider with all letters in alphabetical order. Users can choose the letter by tapping on it or sliding their finger. On the left side, there is a button to delete the last letter and on the right side there is a button to add a space. At the top of the slider, there is a box with the currently selected letter, and two buttons (left and right arrows), which add yet another option for letter selection. Nine users with different disabilities (5 with vision impairments, 3 with mild cognitive impairment and 1 with dexterity impairment) tested this keyboard. According to their feedback, they considered it to be easy and intuitive to use. The participants also remarked that they liked the slide gesture to choose the letter.

Buzzi et al. [4] developed a component to improve user feedback on touchscreen devices. Initially, some usability issues were listed. The authors (one of whom is blind) identified the issues by interacting with Android and iPhone devices using the screen reader feature. The main issues listed were: the lack of

navigational order between the elements, the lack of UI orientation and problems related to focusing text-editing components. To address these issues, the authors proposed a component based on the use of haptic technology. They created some customized components that allowed developers to add helpful cues for users. It is possible to add a vibration pattern, a spoken message and a sound to the component. These components were applied in an open-source e-mail client that was tested by two users and received good feedback. However, they proposed carrying out the test with more users in order to evaluate their performance and obtain qualitative data for future improvements.

Even though there are works that attempt to improve the quality of mobile device use for visually impaired people, there are still several challenges to be overcome. With constant updates and the creation of new forms of interaction for mobile devices, sometimes accessibility is disregarded. In this context, we can find some works that seek to verify whether or not some technologies are accessible for users [3][7]. Others are focused on improving the existing forms of interaction [6][8], or even on creating new ones [10]. Tests were made in all works presented in this section. Some of them, listed as future work, performed tests with more users [4][10]. Azenkot and Lee [3] tested the speech technology with a large numbers of users. They were able to find some related problems and with this information they listed some obstacles for researchers who are interested in non-visual text input. These obstacles could be incorporated into both text input methods (speech or keyboard). They consist of improving the text selection method, cursor positioning, error detection (such as spelling mistakes or letter case errors) and a study about the use of autocorrect by sightless users.

3. Formative Interviews

In order to understand the most common ways visually impaired users interact with smartphones, together with the ease and the difficulties associated with this interaction, we chose to go deep but not broad [11], using direct conversations in interviews.

We surveyed six participants with visual impairments, with ages between 22 and 51 years (average age 35), chosen by convenience sampling. Table 1 shows the demographics of the participants. For data collection, we used semi-structured interviews, conducted individually in a previously established location. We investigated the way the interviewees operated the calendar application on their

smartphones, and what changes they believed this kind of application needed.

Table 1. Participants' demographics.

| Id | Age | Gender | Impairment |
|-----------|------------|---------------|-------------------|
| P1 | 22 | Male | Total Blindness |
| P2 | 27 | Female | Reduced Vision |
| P3 | 29 | Male | Total Blindness |
| P4 | 35 | Male | Total Blindness |
| P5 | 44 | Female | Total Blindness |
| P6 | 51 | Female | Total Blindness |

With the content analysis [11] of the participants' replies, we initially created two categories: 'computer usage' and 'smartphone usage'. These categories describe the form of interaction and the problems encountered in the participants' daily lives. After that, we identified a new category named 'calendar application', which was subdivided into 'used functionalities' and 'suggested functionalities'. Thus, it was possible to identify existing positive aspects of appointment calendars and discover functionalities that can improve user experience. Result categorization is presented in Table 2.

4. Prototype Design and Development

Considering the results of previous steps, we designed and developed a prototype for an application called All Appointments, to be used in new exploratory investigations.

Our goal was to create an accessible mobile application that was capable of interaction through voice commands and multi-touch for visually impaired users. We designed the interface by using high-contrast background and foreground colors, allowing low-vision users to better identify components on the screen. We developed the application so it could be used along with the screen reader, by adding a brief description of the components that could interact with users. It was developed for Android devices (4.0 and later).

The application works as a replacement for the native calendar app and lets users manage appointments from any existing calendar on the device. To do this, the calendar must implement the Calendar Provider API [12], which allows another application to create, update, delete and read the appointments of this calendar.

Table 2. Result categorization.

| Category | Registration Unit |
|----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Computer Use | Form of Interaction Screen Reader. Audible feedback. Navigation through keyboard. |
| | Related Problems Interaction with software via a graphical interface. Websites lacking accessibility. Not use of high contrast configuration. Software containing visual resources, without description. Lack of communication while an operation is running. |
| | Form of Interaction Screen Reader. Audible feedback. Navigation through keyboard (when available). Voice commands. Multi-Touch interaction. |
| Smartphone Use | Related Problems Applications without accessibility. Not knowing the current status of ongoing operations. Applications with voice commands that do not ask for confirmation for a received instruction. |
| | Used Functionalities Create, edit and delete entries. Reminders using the alarm. View appointments for the day. |
| Calendar Application | Suggested Functionalities Search Filter. Interaction through voice commands. Appointment classification by type (e.g. birthday, meeting). Schedule conflict warnings. |

After the analysis of distinct calendar applications on Google Play Store and the results of the formative interviews, we obtained the main functionalities that a calendar should have, according to the users. The functionalities listed and developed were: creating, deleting, editing and reading appointments, filtering for easy appointment search and the possibility to use voice commands for creation and editing. We also implemented the ‘Suggested Functionalities’ (Table 2), except classification by type due to an API limitation. Concerning the ‘Smartphone Use’ category (Table 2),

we implemented all forms of interaction except navigation through keyboard due to our focus on touch interaction. Figure 1a shows the app's home screen.

To create a new appointment, users should tap on the “New” button (Figure 1a). The fields (Figure 1b) for title, date, hour and frequency (whether the appointment is daily, weekly, monthly or yearly) are mandatory. Users can fill them out by using a keyboard or voice commands. To use voice commands, they must to tap on the button at the bottom of the form. The voice command must comply with a format: the user must say the name and the value of the field, for all fields. For example: “Title: Dentist; Date: Today; Hour: 18:00” (Figure 2). However, no particular order is required, e.g. users could state the date before the title.

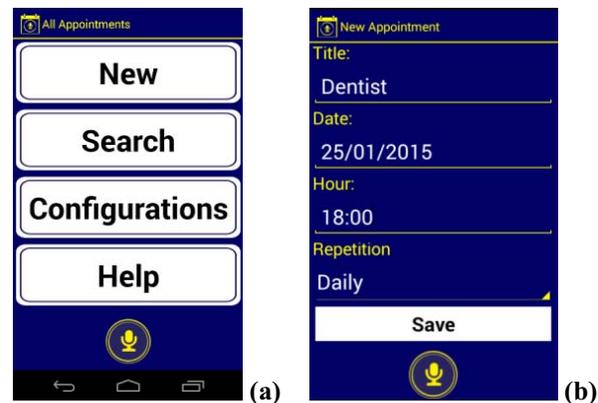


Figure 1. All Appointments: (a) home screen and (b) creation/editing screen.

To edit and delete an appointment, users must first make a search by using the filter screen illustrated in Figure 3a. This option is available via the "Search" button on the home screen. After tapping on this button, users are redirected to another screen with three options, which are “Filter” (to use the filter functionality), “Today” (to see the appointments for the current day) and “This Week” (to see the appointments for the current week). The filter acts upon the title and the initial and final date fields. The dates are mandatory (if the final date is not informed, the app suggests the current date). As with the creation of a new appointment, users can also use voice commands to fill out the filtered fields, but it is also mandatory to respect the format (name of the field followed by its value, for each field on the screen). Once again, no order is required.



Figure 2. All Appointments: new appointment creation with voice command

The result of applying a filter is presented to users on a list, which we called “Paginated List” (Figure 3b). Unlike the standard way of displaying items on a list with which users should interact by sliding their finger up or down, this list shows only one item on the screen. Users can navigate between items by tapping on the “Previous” and “Next” buttons, which are at the bottom of the page. We also provide options for editing and deleting appointments. By default, the options for an item are provided using a context menu and if the “Today” or “This Week” option was chosen, users can navigate between days or weeks by sliding their finger left or right.



Figure 3. All Appointments: (a) filter screen and (b) paginated list.

Another way to present appointments, which was implemented in this application, was to use some of Android's UI patterns. To enable this, users should choose it in the application's configurations. Then, they can navigate through three tabs: Filter, Day and Week. These tabs can be seen at the top of Figure 4a. If the Day tab is selected, the appointments are presented in a standard list and a context menu is enabled with a long press gesture to display the edit and delete options.

Figure 4a illustrates the list, as well as the long press gesture, whose result is shown on Figure 4b.



Figure 4. All Appointments: (a) appointment list by day, with long press gesture and (b) options in a context menu.

If the Week tab is selected, the screen shows the days of the week paired with their appointment count in a grid layout. When the user selects an item, the list of appointments for that day is shown (Figure 4a). Users can navigate through the weeks using swipe gestures, similar to the ones for the day list. The Filter tab contains the form screen, and after the user confirms the filter, the list of results is shown. Figure 5 presents the week view and the swipe gesture.

All components have an appropriate description. Before saving a modification or an insertion, and before deletion, it is necessary to confirm the operation by tapping on the “Yes” button in a confirmation dialog. Also, users are alerted about errors and validations by a dialog with the suitable message.

When users navigate through the app's screens, in addition to the voice message, it produces a small vibration in an attempt to help users know when a new screen is available.



Figure 5. All Appointments: week view with swipe gesture.

Voice commands are also available in the home screen and in the “Search” option. Users can tap on the button at the bottom of the screen and speak the option. There is a range of accepted commands for each option. For example, for the option “New”, the commands “New”, “New Appointment”, “Add” and “Create” are valid. When users want to learn the correct structure of a command, they can say the word “Example”, which will provide them with a small explanation of the voice command and an example. This option is available in all screens that support voice commands.

5. User Study

In order to get first impressions about the implemented techniques, we conducted a study with visually impaired users to observe the usage of both the prototype and the native calendar application. We decided to observe native calendar usage to get an initial comparative analysis between them, according to the user’s experience. For this, users received tasks to be performed with the prototype and the native calendar app.

Four visually impaired users took part in this phase, with ages between 29 and 51 years (average age 37.5), chosen by convenience sampling (Table 3). We recruited two participants who also had been part of the formative interviews (P3 and P6), and two participants that did not, referred herein as P7 and P8.

Firstly, when asked which accessibility resource they usually used, all of them answered that they only used the screen reader. When asked how they used to learn a new application on their smartphones, they all answered that first they tried to explore the application. P7 said that, if necessary, she would ask another person

to help her, and P6 said that sometimes she would search the Internet.

Table 3. Participants’ demographics.

| Id | Age | Gender | Impairment |
|----|-----|--------|-----------------|
| P3 | 29 | Male | Total Blindness |
| P6 | 51 | Female | Total Blindness |
| P7 | 30 | Female | Total Blindness |
| P8 | 40 | Male | Total Blindness |

Regarding the use of calendar applications, only P3 reported he used this kind of software, along with the voice recognition system of his iPhone device. P3 commented about the use of voice commands to create a calendar entry in his iPhone: “*it is very practical, but there are many improvements to make, mainly because I can only use it in English or Spanish*”.

Lastly, none of the participants, except for P3, was accustomed to using voice commands. P7 reported she had already used voice commands on an iPhone device, but it was just once. She said it was very easy and practical to use.

5.1. Procedure

Tests were executed individually in places chosen according to the participants’ preference, and were recorded with their consent. Each participant performed the task of creating an appointment once in the native Android calendar and twice in All Appointments: first using voice commands and then using the keyboard. This was done so as to evaluate the accessibility of both ways of interacting with the proposed app (by exploring the screen and using voice commands). To avoid exhausting the participants, only one of the existing layouts for filter results presentation was used: the paginated list. The rationale behind this choice is the fact that it presents results in a new fashion, not based on any existing pattern.

We created two test scripts: one containing tasks for the native Android calendar and another containing tasks for All Appointments. We alternated which script would come first to prevent the order from influencing the results. Tasks created for the tests were:

1. Open the native Android calendar.
2. Create two entries in the native Android calendar.
3. Search for one of the created entries in the native Android calendar.
4. Edit an entry in the native Android calendar.

5. Delete an entry from the native Android calendar.
6. Exit the native Android calendar.
7. Open All Appointments.
8. Create an entry in All Appointments using voice commands.
9. Create an entry in All Appointments using the keyboard.
10. Search for the first entry created in All Appointments, using voice commands.
11. Edit the returned entry.
12. Search for the second entry created in All Appointments, using the keyboard.
13. Delete the returned entry.
14. Exit All Appointments.

During all the tests, Android's accessibility resources³ were enabled. Firstly, we explained to each participant how to interact with an Android device. After that, we let them use it for a few minutes, to become familiar with the form of interaction.

Initially, we conducted a pilot test to verify if, given what we planned, we would be able to obtain the expected results. After verifying the adequacy of our test planning, we continued conducting tests with others users (it should be noted that no changes were needed in the created script after the pilot test).

Tests lasted about 2 hours for each participant. We timed the tests from the beginning until the end of the task (the end was marked by the task being completed or the user giving up trying to execute it). Furthermore, sometimes during the execution of a task, users made comments or suggestions. Time spent with comments and suggestions was computed together with task execution time.

5.1.1. Using the Native Android Calendar. For the task of creating a new appointment in the native calendar, we could notice that the users did not receive any spoken feedback about several items on the screen. The main screen of the native calendar shows the days of the month in a grid form (Figure 6a). Users are able to create and check the appointments for a specific day. However, none of the participants succeeded in using this resource because, when they tried, the app did not give any spoken feedback. The main actions of the app are available through a Popup Menu activated with a button located on the upper right corner of the screen, as shown in Figure 6a. One of the participants was unable to find this button, and the others spent a long

time to find it, due to its reduced size and inconvenient location.

The task of creating a new appointment was partially completed by only one of the participants. Because of the lack of spoken feedback, the user mistakenly saved the appointment, while trying to correct the typed data. Besides, he could not correctly interact with the hour component, asking for help to fill it out. Other participants could not complete this task, because they did not find the button to save the appointment. They, too, reported problems regarding the hour component. Figure 6b shows the hour component of Android's native calendar

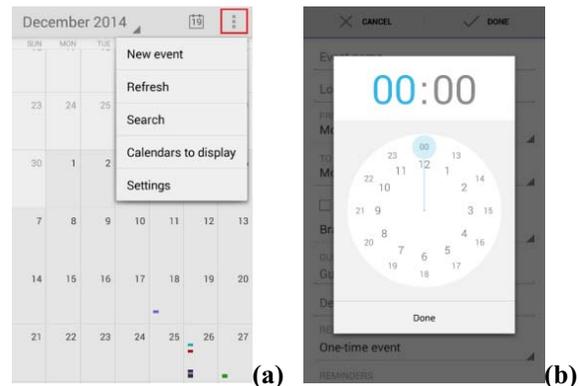


Figure 6. Android's native calendar: popup menu options and (b) hour component.

During the task of searching for a registered appointment, users remembered that this option was in the same menu as the create option. Nonetheless, the absence of a sound response to warn the user that there was a field for typing made the task more difficult. In some cases, users asked for help with using the search field. Considering the tasks of editing and excluding an appointment, only P3 managed to complete them as requested; the others were unable to find the “Edit” and “Delete” buttons.

5.1.2 Using the Prototype. All test participants successfully carried out the task of adding a new appointment without using voice commands, solely interacting with All Appointments’ graphical interface. We noticed that users occasionally selected the title field's description and, having received sound feedback, inferred they were activating the title input field. The same occurred for the other fields. Using Android's standard keyboard turned out to be the greatest obstacle (also observed when using the native calendar) for participants when executing the first appointment creation task in All Appointments. In

³ TalkBack, the standard Android screen reader, and Explore by Touch, a feature that allows users to explore interfaces and hear the contents of the screen.

some cases, at the participant's request, it was necessary for researchers to aid in typing data.

At the start of an appointment creation task using voice commands, it was necessary to explain their format to the participants. They listened to the example given but required more time to comprehend the structure, and as soon as they did, they managed to register a new appointment with ease. Some users found it hard to locate the voice command activation button, occasionally causing them to tap beside it.

For the search for an existing appointment using voice commands to fill out the date interval fields, we needed to clarify the expected format, since it is different from the one used for creating an appointment. After performing the search, some participants took some time to locate the buttons for navigating through the results. We observed the same difficulty when they were asked to edit and delete an appointment through a search.

5.2. Results

After performing the tests, users were asked about the experience perceived when carrying out the proposed tasks.

When asked about the native calendar, users reported various issues. Concerning the process of registering a new appointment, user P3 said he missed having the option to save in a more convenient location. According to him, *"when we want to use a calendar app, most of the time we want to use it to create events, but the feature is too hard to find in the way it was made"*. P3 also said that the creation screen had many unnecessary fields, mentioning the time zone as an example: *"it should be an app-wise configuration."*

Users considered searching for appointments in the native calendar simple and practical. However, they expressed problems regarding the lack of adequate audible feedback.

When surveyed about the appointment editing and deleting procedures in the native calendar, users reported problems with respect to field size and arrangement, which made it impossible for some to fulfill their tasks. P3, who managed to find the options, answered that he disliked the fact that he had to open the appointment in order to execute the operations: *"it is unintuitive"*.

The main difficulty brought up about Android's native calendar was the absence of adequate audible feedback, which at times confused the user. Interaction with the hour selection component also posed a challenge. Users' general opinion regarding this

calendar was that it is unintuitive and very hard to use. P6 added: *"I would need a lot of training to use it. It doesn't give feedback when being used. You would have to set a sequence of steps for us to use it. However, it is unfeasible to come up with a sequence of steps for everything we have to do."*

Interaction with All Appointments' graphical interface was considered to be significantly friendlier when compared to the native calendar.

Users deemed the event creation procedure to be much easier, especially for having fewer fields on the screen. Users P3 and P8 accounted the use of masks for the date and hour fields to be better than the one in the native calendar. In contrast, user P7 preferred the form of date interaction presented by the native calendar, considering it to be easier than typing. Furthermore, P7 and P3 both recommended adding another text field for additional information to be input.

Voice commands were viewed as a positive feature, although some argued that they needed to memorize the correct terms. When asked about using voice commands to add and filter appointments, P6 said: *"it seemed very easy to me."* Moreover, P6 commented on voice commands: *"we [blind persons], when moving on the street, for instance, need our walking stick, but sometimes we have to carry other things, such as a handbag. Using voice commands facilitates matters a lot because, when typing, we have to enter the letter and wait for the response, which does not happen with voice commands, since you can say it just once and the information is there. This allows us to save on sound feedback and time."*

The audible feedback provided by All Appointments was a facilitating factor when using the app, improving the screen exploration experience. The arrangement of screen components and the way in which the application's options are accessed have also been considered to help explore the screen.

Generally, users classified All Appointments as intuitive and practical. According to them, the most pleasing interface was All Appointments'. When asked whether or not he would replace his current calendar with All Appointments, user P3 replied that he would not stop using the standard one, but rather use one alongside the other. The remaining users declared that, should there be a need to use an appointment calendar, they would.

Finally, users also suggested some changes to perfect the interface. The chief changes they suggested were:

- improving the keyboard's sound feedback (especially for cursor position and character erasing);

- removing the need to click the system's message button (error and success);
- creating a text field to add arbitrary information about the appointment;
- removing the confirmation prompt when typing;
- suggesting example voice commands only the first time a command is used;
- having the year in a date field be automatically filled out;
- having the current appointment be described by the screen reader when navigating through items on a paginated list.

5.2.1 Prototype Refinements and First Impressions.

All Appointments passed through a refinement stage based on the studies with users. However, not all enumerated modifications were implemented so far. After the modifications, a test was executed with one extra participant. The participant, who was over 45 years old, had low vision (5%) and experience with touchscreen smartphones. She began executing the tests for the native calendar. In this calendar, she had trouble with the arrangement of the fields on the screen, requiring help to find some of them. Besides, she had great difficulty when interacting with the date and time components. The user did not manage to edit and delete an appointment, for she could not locate the corresponding buttons. The search was done after their location was shown.

In All Appointments, tests had better results. The user liked to use voice commands, even though she initially found the structure hard to understand. Furthermore, the user praised the size of the components, the colors used and the font size. She suggested we provided a way for users to choose background and component colors, and also that a text field be added so additional information could be included.

6. Conclusions

Mobile devices such as smartphones increasingly add functionality to and gain more space in daily life. However, innovation is challenging, for it has to fulfil the individual needs within an entire population, which include disabilities such as blindness. The lack of accessibility to innovation “may have the unintended effect of social exclusion from certain workplace activities, and may lower productivity” [13]. Thus emerges the challenge of bringing greater accessibility, providing easier access and contributing to digital inclusion.

Therefore, the research presented in this work aimed to investigate the following question: what kinds of interaction make it easier for visually impaired people to use smartphones? We think that the methodology used provided indications that interfaces that provide different forms of interaction, such as voice, touch and vibration, do facilitate the use of applications for the visually impaired. The electronic calendar was chosen because it is a very useful tool especially in the business environment.

Table 4 presents a summary of the lessons learned until the current stage of our research. We categorized them using some of the best-known usability heuristics [14], reinforcing their necessity in this particular case (and, of course, not neglecting the need to follow the other known principles). If we pay attention to the two practices related to Feedback and to the need for natural speech language, in User control, we can categorize them together in the Flexibility heuristic, allowing users to interact with the application's interface the way they desire, need, or can.

Table 4 - Lessons learned.

| Usability heuristics | Lessons Learned |
|----------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Appropriate feedback | Spoken feedback is essential. Vibration to inform changes. |
| Aesthetics and minimalist design | Top-to-bottom screen design. Avoid using labels. Avoid hidden components. Keep interaction as simple as possible. |
| User control and freedom | Natural speech language for voice commands. Provide ways to disable spoken feedback. Provide ways to configure the colors of the interface components. |
| Recognition rather than recall | Users should be able to easily identify the features and options provided by the interface. |

As an exploratory descriptive investigation [11], the findings related and discussed in this work are a first step to answer our research question. They helped us identify key research issues in order to formulate our research hypothesis, and now the investigation should be deepened.

One obstacle we had during the investigation was finding subjects that had already used touchscreen smartphones, since the majority of them resorted to physical keyboard smartphones because of the screen reader. Those who owned touchscreen smartphones did not use an Android device, and even amongst them, it was hard to find one who used an appointment

calendar, which raised the concern of spoiling the sample. These complications turned out to restrict the number of users who took part in the study.

As future work, we intend to expand the user sample, incorporating people with decreased ability to see in addition to those who are completely blind. Moreover, we want to implement and test different versions of the application, with different forms of interaction (e.g., natural language speech or keyword-based entry) in order to gather impressions, compare the results and obtain better understanding about problems and preferences of visually impaired users. We are also interested in developing a completely voice-controlled interface to investigate its potentials.

7. References

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