NavTap: a Long Term Study with Excluded Blind Users

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ABSTRACT

NavTap is a navigational method that enables blind users to input text in a mobile device by reducing the associated cognitive load. In this paper, we present studies that go beyond a laboratorial setting, exploring the methods' effectiveness and learnability as well as its influence in the users' daily lives. Eight blind users participated in the prototype's design (3 weeks) while five took part in the studies along 16 more weeks. All were unable to input text before. Results gathered in controlled weekly sessions and real life interaction logs enabled us to better understand NavTap's advantages and limitations. The method revealed itself as easy to learn and improve, as the users were able to fully control their mobile devices in the first contact within a real life scenario. The users' individual profiles play an important role determining their evolution and, even less capable users (with age-induced impairments or cognitive difficulties), were able to perform the required tasks, both in and out of the laboratory, with continuous improvements. NavTap dramatically changed the users' relation with mobile devices and improved their social interaction capabilities.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces—*Evaluation/methodology,Input devices and strategies,Interaction styles,User-centered design,Voice I/O*

General Terms

Design, Human Factors, Experimentation, Performance

Keywords

Blind, Evaluation, Mobile Accessibility, Text-Entry

1. INTRODUCTION

Mobile phones have become an important part of our daily life. These are no longer mere communication devices: they now allow us to store and manage important data, like contacts, personal notes or scheduled tasks. From the early simple devices with basic communication capabilities to the recent stylish devices and applications that are each day more similar to those for desktop computers, they have transcended their original purpose and became leisure and productivity tools.

Even though mobile device interaction has evolved from the first commercial devices, they are still (and if not increasingly) too restrictive. Particularly, blind users face several difficulties operating mobile devices as both the devices' input and output are highly visually demanding. Nevertheless, a great percentage of blind users has a mobile device and is able to operate it at a basic level (receive and perform a call). On the other hand, the majority of the interaction processes present in these devices are not suitable for a blind user and can hinder interaction. The text-entry task is transversal to a great number of mobile applications and when no assistive technology is available, it is just not feasbile for a blind user.

There are several hardware-based approaches trying to tackle this issue by using braille keyboards and screens, but they are too expensive, heavy, big and definitely not mobile. On the other hand, screen readers are software-based adaptations that replace the visual information with its auditory synthesis (e.g. Mobile Speak[1], Nuance Talks[2]). These solutions enable blind users to operate a device as they are able to receive feedback through an available channel. However, the interaction is not adjusted to the users' needs. Indeed, they receive feedback on the screen status but, for example, no information is offered on the keypad layout, thus leading to errors and reducing, or eliminating, the chance for him to learn and improve performance.

This problem gains additional relevance when considering older blind users that are likely to face several difficulties when having to memorize the letter displacement on the keypad and dealing with a trial and error approach. Existent solutions assume a user with good orientation, memorization capabilities, or even good finger sensitivity and Braille knowledge (the blind user stereotype), but the reality is that *more than 82% of all people who are blind are 50 years of age and older* [6] and a great part has lost sight in an advanced stage of their life.

With these problems in mind we have developed methods focused on the users' needs and capabilities that enables them to fully operate mobile devices. Our focus is mainly on text-entry methods, although several considerations were

[1]http://www.codefactory.es/
[2]http://www.nuance.com/talks/

Figure 1: Blind person inputting text with NavTap

made on navigational and event-based tasks. In particular, the NavTap [1] text-entry method allows the user to navigate through the alphabet using the mobile phone keypad.

The approach was previously evaluated with the target population in a controlled environment and results showed that a novice user is able to use a mobile device and input text with a few minutes training. Those evaluations were mainly targeted at users that were not able to perform more than simple communication tasks with their mobile devices. As we have stated, the learning process with traditional interaction mechanisms (even with audio feedback) is very hard, leading blind users to give up and restrict their task to placing and receiving phone calls. The trials were performed in a controlled environment and users were able to input text and overcome their performance when compared with traditional methods (the users were instructed and helped to learn how to use traditional MultiTap approaches). Although these results have pointed the advantages of navigation approaches over traditional multitap ones for blind users, we still had no results on the evolution and performance improvement on a long-term usage scenario. Indeed, only by assessing the users' performance, evolution in uncontrolled settings, and the impact on their daily lives, will we be able to understand the benefits and limitations of our approach. Moreover, the flaws in current mobile interfaces can only be justified by the lack of follow-up studies with the target population. We propose to go further and present a richer characterization of our method and its advantages.

In this paper, we describe a long-term evaluation of the NavTap prototype, a mobile device system for the blind with a navigation text-entry method as its main component. This evaluation was performed during 19 weeks with 5 users (and 3 extra users during an iterative design phase) and, besides uncontrolled (but logged) daily usage, featured regular controlled experiments to observe the users' evolution (Figure 1). With these experiments we were able to collect data on mobile device performance usage, particularly text-entry, but also to observe how the improvements influenced the users' habits and interactions.

Results showed that the users were able to use NavTap in their daily lives and that it had positively influenced their social interactions. Moreover, long term device usage analysis suggested that, although the biggest performance improvements occur in the first experience stages, the users kept improving. Even users with cognitive difficulties (low alphabetization or weak alphabet mental mapping) or age-induced disabilities (weak memorization, disorientation, low finger sensitivity, among others) were able to effectively write text both in the controlled weekly sessions as in their daily scenarios. Furthermore, we were able to understand the limits of our approach. Indeed, the results achieved with these users are highly important for them as they were unable to write text before, but are still far from the traditional MultiTap approaches rates (considering the presence of visual feedback) [9]. However, to our knowledge there have not been performed studies with MultiTap and blind users so the comparison remains unanswered.

2. RELATED WORK

Text input on mobile phones is commonly achieved through a MultiTap system where groups of 3 or 4 letters are assigned to each key; pressing consecutively the same key allows the user to go through all the letters available on it (Figure 2). Other text-entry methods were developed to improve text-entry but like the MultiTap system, have a high visual and cognitive load. Also, predictive methods like t9[3] are even more difficult or impossible to use when no visual feedback is offered. Existent approaches rely on the ability to see both the sentence evolution and keypad. With experience, a user can be able to achieve some success without looking to the keypad, but this is only achieved after months or years of successful and feedback-rich usage and even an expert requires occasional confirmation. Although MultiTap system is a very practical method for most users, those with visual impairments face several difficulties using it. No information about letter displacement on the keypad is available and no feedback is offered on input evolution.

Special mobile devices were developed to overcome the difficulties arising from visual impairments. As examples are the Braillino or the Alva Mobile Phone Organizer, among many others very similar between each other. These devices, which typically work as a Personal Digital Assistant (PDA), use a Braille keyboard for text input, a Braille screen for output information, and provide functionalities like the ones provided in regular mobile phones. Yet, they all share the same flaws: their cost is prohibitive and they are not as portable as a mobile phone is, being too big and heavy.

Nowadays, the most common solution resorts to traditional MultiTap approach along with a screen reader, replacing the visual feedback by its auditory representation (e.g., Mobile Speak or Nuance Talks). However, the offered feedback is restricted to the output as no information is obtained on letter displacement. This approach forces the user to try to find the desired letter, committing several errors in the process, and possibly leading to situations where he simply quits trying. A person that acquires blindness in an advanced stage of life, along with the reduction of other capabilities like tactile sensitivity, is likely to face difficulties in the first contact with this approach, rejecting it before gaining the experience that enables its use [1].

The NavTap text-entry method [1] tries to overcome the lack of visual feedback by transforming letter selection into a navigation procedure. This method presents a low cognitive load as any navigation action can be undone before performing an error. The users receive audio feedback and, unlike MultiTap approaches, are able to continue the navigation or accept the letter.

Focusing on a particular set of blind users, the ones that read Braille, BrailleTap [1] enables the users to input text by using some of the keys on the keypad as Braille cells. Thus,

[3]http://www.nuance.com

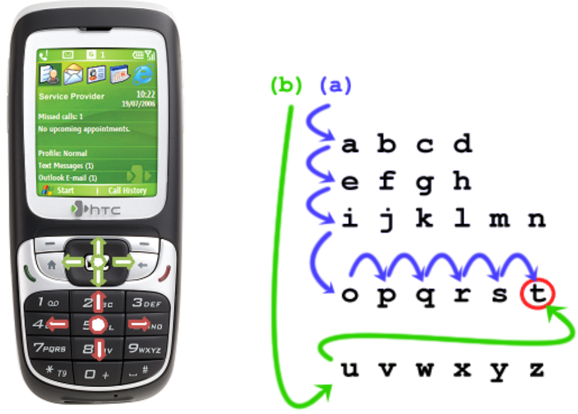
the user is able to select a letter by selecting the cells correspondent to the letter graphical representation, the Braille character. Although this method has achieved satisfactory results, the solution is restricted to a small percentage of the blind population. Moreover, it is not accessible to the aforementioned older blind users that were unable to develop compensation mechanisms like good tact sensitivity or Braille knowledge.

Recently, touch screen mobile devices, like the iPhone, have had a great impact in the mobile communications market and, due to the absence of tactile cues (i.e., keys), some researchers have struggled to make these devices accessible to blind users. There have been projects to improve the navigation between and within applications [3] but also to input text [10, 2] by performing gestures on the screen. These approaches also rely on audio feedback as a replacement for the visual channel. Indeed, as touch screen devices are becoming more common among non-visually disabled people, a great deal of attention has also been dedicated to their accessibility and to answering the challenges imposed by devices that are the exponent of graphical user interfaces (visually rich).

Nowadays, the majority of blind people possess a keypad-based device and, regarding those, the alternatives, namely text-input ones, are almost inexistent. This suggests that the actual interfaces are effective and easy to use but this is hardly true as it can be very difficult for some users to input text with their mobile phones [4]. Besides the lack of alternatives for the ones that are unable to use the adaptations provided, namely MultiTap with a screen reader, there is also a lack of knowledge and understanding on the real effectiveness and evolution of the methods in the users' lives. We try to overcome this issue not only by presenting a method that eases the first contact and enables learning by reducing the cognitive load and stressful situations but, particularly, by studying the users' evolution on the long run. With these follow-up studies we are able to understand the users' evolution with the designed methods, the influence of the methods in the users' daily lives as well as its advantages, disadvantages, benefits and limits. Particularly, in a mobile setting, where the user is subject to several interferences (e.g. situationally-induced disabilities [8]) it is relevant to understand if the interfaces' advantages can still be called so. Only by understanding the interfaces, its values and flaws, will we be able to provide real mobile accessibility.

3. ITERATIVE NAVTAP (RE-)DESIGN

NavTap [1] is a navigational text-entry method designed to reduce the cognitive load while inputting text with no visual feedback. To this end, the alphabet was divided in five lines, each starting with a different vowel, as these are easy to recall. This alphabet representation can be navigated with a set of keys that act like a joystick. Both navigations (vertical and horizontal) are cyclical, which means that the user can go, for instance, from the letter 'z' to the letter 'a', and from the vowel 'u' to 'a' (Figure 2(a)). The users are able to navigate the alphabet and receive audio feedback on the current letter before accepting it (in opposite to MultiTap approaches where a key press can automatically lead to an error). This method drastically reduces memorizing requirements, therefore reducing the cognitive load. In a worst case scenario, where the user does not have a good alphabet mental mapping, he can simply navigate straight forward until he hears the desired letter. There are no wrong buttons, just



(a) Mobile device (b) Navigation scenarios

Figure 2: NavTap text-entry method

shorter paths. Blind users can rely on audio feedback before accepting any letter, increasing the text-entry task success and the motivation to improve writing skills. As depicted in Figure 2(b), different navigation scenarios and expertise levels can be achieved: 1) in the 1-way approach the user restricts the navigation to a single direction (straight forward), which can be classified as a naive approach; 2) in the 2-way approach the user is able to navigate through the vowels and, using them as reference points, get to the desired letter (scenario a)); and in the 4-way approach the user is able to use all 4 directions to perform the shortest paths to the desired letter (scenario b) in Figure 2(b)).

This text-entry method has been evaluated with blind users with reduced mobile device acquaintance (only dialing and getting calls) to assess the first contact with the method and the short term learning curve. The results were compared with traditional MultiTap approaches showing that NavTap, in opposite to MultiTap, enables unexperienced users to input text effectively and enables a fast performance improvement [1]. Similar results were achieved with a touch screen based version where the navigation was performed with directional gestures on the screen[2]. While we have showed that NavTap reduced the barriers imposed by traditional text-entry approaches to blind users, no results were gathered on the evolution and impact of the methods in the users' daily lives. Indeed, we believe that this follow-up studies are essential to go beyond the superficial controlled laboratorial evaluations and understand the limits, advantages and disadvantages of the proposed methods. Particularly, in a mobile setting, where several contextual variables can affect interaction [8], it is important to understand the user's difficulties to further improve the designed approaches.

To be able to evaluate NavTap on a long term basis, we have gone beyond the text-entry task, and created a full prototype system with a simple set of applications (the ones the users revealed as essential and mostly used, in our preliminary studies). This set included contact management, messages, call management, alarm, calculator, notifications (e.g., battery), date and time. All the menu navigation and event reception (messages, calls) mechanisms were redesigned to match the absence of visual feedback and presence of auditory one (text-to-speech). Text-entry was achieved resorting to NavTap using the keys '2','4','6' and '8' to navigate and key '5' to input a space (or punctuation if pressed more than once). Characters and punctuation acceptance were timeout-based. Key '7' erased the last character.

The prototype was developed in the Windows Mobile platform and the mobile phone used was the HTC S310 smartphone (Figure 2). The speech synthesis package used was provided by Loquendo. The first version of the prototype was developed accordingly to guidelines gathered in previous studies with the target population [4, 1].

The user studies herein presented started with a preliminary (re)-design phase following a user-centered design approach. Eight blind users were selected from a group of 14 candidates at a formation center for blind people. The participants were selected accordingly to their proficiency with mobile devices: the aim of these studies was to evaluate the impact of a new text-entry method and the ideal users were those unable to perform text-based tasks before, using NavTap. They had ages comprehended between 49 and 64 years old, all had a mobile device and none was able to input text. The re-design phase lasted for three weeks and was divided in modules (3 sessions per week): Navigation, Event Reception and Text-Entry. Each session with each user consisted in a 30 minute tutorial on particular aspects of the module being presented. With these sessions two goals were accomplished: 1) we were able to detect inconsistencies and adapt the prototype to better suit the users' needs and capabilities (re-design); and 2) the users were able to get some familiarity with the prototype, learning its most important concepts (training). In the iterative re-design, the prototype was modified in different aspects: missing functionalities, screen reading parametrization, input keys, sounds and earcons, among others.

In particular, and considering these studies' main scope, NavTap also featured important adaptations: **1) Keypad Layout -** Prior design of NavTap linked numerical keys to directions (red arrows over the keypad in Figure 2) and a central key to input spaces and special characters. This design aimed at a full coverage of keypad-based devices as they all have a numerical keypad. However, the proximity and lack of distinction between the keys could be erroneous or slow if the users lacked sharp tactile capabilities (which is also a disadvantage of traditional MultiTap approaches). What is also true is that the majority of the keypad-based mobile devices now feature a navigation set of keys (joystick alike) (green arrows over the keypad in Figure 2) with closer buttons which are probably also wider and with better tactile characteristics. Thus, we have enabled their use to operate NavTap. The central key is also closer and easier to detect. This approach also enabled the remaining part of the keypad to be used as a special function repository. Once again, to ease the finding process we have placed the special functions in the corner and reference positions ('1', '3', '5', '*', '#',); **2) Letter Acceptance -** Timeouts are normally hazardous and have been criticized in the Human-computer interaction field [7], although they have been commonly used in mobile text-entry interfaces due to the inherent lack of space. We identified two major problems with our previous timeout-based character acceptance mechanism. Firstly, considering a mobile context, the user is subject to interferences that can lead him to interruptions while navigating, thus leading to an error. Secondly, timeouts pressure the user, damaging confidence and the overall learning process. This was clear in the first contact with the users. An alternative was obligatory. Thus, the central key, while navigating the letter matrix, functioned as an acceptance key. If the central key is pressed after accepting a character (before entering another navigation step), a space is inputed. The erase character, besides deleting the last letter, also disables an unwanted navigation and returns the system to a non-navigation state.

At the end of the iterative re-design and training phase, the users were able to effectively operate the device.

4. EVALUATION

There has been prior evidence to suggest that NavTap can be effectively used by novices with very little training. Five users with no prior experience with NavTap were able to learn the vowel navigation method and perform text-entry tasks on a mobile device in a controlled environment [1]. However, this method was never evaluated in a real life scenario outside the laboratory.

Our primary focus in this investigation is to assess the users' learning experience with NavTap in a real life scenario. This is particularly important since our system is targeted for individuals with visual impairments, who may not have many alternatives to fully control their mobile devices. Thus, an easy and autonomous learning process is crucial to the system's adoption. Therefore, our method should be both immediately effective for novice users and still offer a high degree of improvement as the users become more experienced. Moreover, this learning process should be easy and natural.

Another focus of our study is on the daily usage of our system, particularly on the most used functionalities and communication habits. We want to investigate how our system influences their habits and overall mobile and social interaction.

Although our investigation is focused in the real life scenario, we also want to assess the users' improvement through controlled sessions. Additionally, we are interested in understanding each participant's problems and difficulties, so we can identify the source of the issue and find the best way to address it in the future.

Therefore, we propose to answer the following questions:
1) Can the users effectively operate NavTap?
2) Do users reach an *expert* performance level on NavTap?
3) Does NavTap support the participants' social needs?
4) What issues related to NavTap and its usability are discovered in a long term analysis that otherwise were unrevealed?

4.1 Procedure

To assess the users' learning experience with NavTap we have developed a functional prototype, which comprises the most common cell phone functionalities, already described in section 3. After the initial learning and design period, we left the mobile devices with the users, so they could use them in their daily lives.

The evaluation was based on the analysis of the overall usage experience, which is captured through a logger (the user's privacy is totally safeguarded as no understandable personal data is collected). Apart from this, we performed weekly evaluation sessions in a controlled environment. This gave us a comparison baseline and deeper insights about

NavTap. In those sessions, the participants were asked to input 3 different sentences (different across sessions). Those sentences had 3 difficulty levels based on their length and keystrokes per character for the best (KSPC) theoretical case. The chosen sentences lengths were fixed for the short (6), medium (11) and long (17) difficulty, as well as the interval of theoretical best case scenario keystrokes per character (KSPC) values, to allow evolution analysis through sessions.

The evaluation sessions took place in a training center for blind people over a period of sixteen weeks (thirteen sessions). Moreover, in order to compare the participant's performance before and after the daily usage experience, we performed two evaluation sessions still during the training period.

4.2 Participants

All the initial eight volunteers for our long term study were students at the training center in which our controlled evaluation sessions took place. However, three participants had to drop out from our study because their courses at the training center ended. Table 1 illustrates basic characteristics about the remaining participants. The target group was composed by five participants (2 males and 3 females) with ages between 44 and 61 years old. All participants used their mobile devices on a daily basis but, typically, they could only place and receive calls. All participants used screen readers as their primary means of accessing a personal computer or mobile device. However, only three participants of our target group (P01, P03 and P04) used this kind of technology regularly.

User	Gender	Age	Education	Time with impairment
P01	Male	49	BSc	46 years
P02	Female	44	4th Grade	1 Year
P03	Female	51	4th Grade	10 years
P04	Female	59	4th Grade	12 years
P05	Male	61	9th Grade	11 years

Table 1: Study participants' basic characterization

P01 is blind since the age of 3 and has learned the Braille alphabet at the age of 8. The participant works with personal computers and speech synthesizers for sixteen years. Also, he has a degree on Psychology and good reasoning capabilities. However, he could only place and receive calls, as his cell phone did not have a screen reader.

P02 is the youngest participant, with forty four years old, and started to lose her sight a year ago. This progressive process of blindness has revealed to be very painful and stressful, reflecting on the participant's behaviors and moods. She has the fourth grade and, according to the formation center's psychologist, the participant had some learning and memory difficulties.

P03 had recently bought a screen reader for her cell phone but she could only hear text messages, place and receive calls. Until the time of the experiment, she was unable to learn the available text-entry method (i.e. Multitap) and perform more advanced tasks, such as contact managing.

P04 was blind for twelve years, and has never learned the Braille alphabet. She used a screen reader on her cell phone, for the past three years, but could only perform the most common tasks. Although she was able to hear SMSs, the participant was not able to reply.

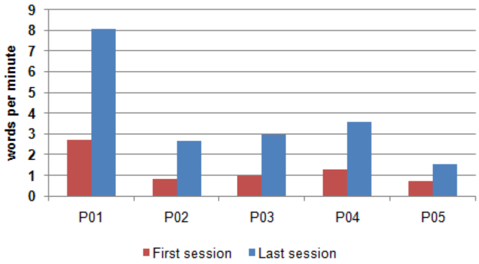


Figure 3: WPM on the first and last session.

P05 started to lose his sight eleven years ago, with fifty years old, due to diabetes, which is affecting both his nervous system and tactile capabilities. The loss of his tactile capabilities has already begun to affect his interaction with several devices, particularly those with less salient buttons.

Overall, our target group has a great diversity of sensory, memory and learning capabilities, mostly due to their age, diseases and impairments. Moreover, some of the participants are rapidly losing their residual vision or tactile capabilities, which is reflected in their behaviors, concentration, mood, and consequentially in the obtained results.

4.3 Results

In the following sections, we present some of the key results regarding our by our weekly controlled sessions, participants' daily usage, and how the latter influences their performance on text-entry tasks. Moreover, due to the limited number of participants, our goal is not to statistically analyze the data, but rather try to understand each user difficulties and issues. In the final section we highlight some key observations about each participant to better understand specific behaviors and results.

4.3.1 Weekly Controlled Results

To observe the participants learning process, in a controlled environment, we weekly recalled them for 3 sentences over a period of 13 sessions.

Figure 3 shows the words per minute (WPM) achieved on both the first and last session for each participant. Overall, participants demonstrated a great improvement in their performance. Among the target group, the words per minute on the first session ranged from 0.7 to 2.7. Over the 13-session (16 weeks) period, the participants reached, at least, twice the initial performance with values ranging from 1.6 to 8.46 WPM. P01 had the highest improvement from 2.7 to 8.46 WPM, indicating that the other participants still have margin to improve.

Keystrokes per character is the number of keystrokes, on average, to generate each character of a text in a given language using a given text entry technique [5]. Figure 4 shows the KSPC on the first and last sessions for each participant. Although some participants follow a naïve approach on the first session, as their mental map becomes clearer they begin to follow a 2-way or 4-way approach. Comparing the improvement rates of KSPC and WPM, the latter is much greater, indicating that participants begin to memorize paths and executing them faster, as they feel more comfortable and confident using NavTap. The impact of times between key presses is greater than the one resultant

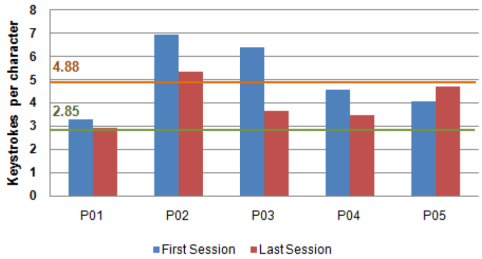


Figure 4: KSPC on the first and last session for each participant. The bottom (2.85) and top (4.88) lines correspond to the 4-way and 2-way theoretical approaches for the last session, respectively.

from a better navigation. However, participants do learn new paths and the ones that started with a naïve approach rapidly enrich their mental model outperforming the theoretical 2-Way scenario (excepting P02). Moreover, three participants almost reach the best case scenario, which indicates that NavTap is easy to use in a first contact and shows a good learning curve.

Figure 5 shows the improvement (%) in average preparation, navigation and acceptance times between the first and the last session for each participant. Overall, participants demonstrated a good improvement in all times, with exception to acceptance time. The acceptance time corresponds to the time between hearing a letter and accepting it, by pressing the joystick central button. On the final session the average acceptance time ranged from 0.78 and 1.69 seconds.

Like we have mentioned before, as participants become more familiar with NavTap and the vowel navigation method, their navigation times between characters improved and is also reflected in the WPM chart (Figure 3). The navigation time between letters, when they were in the same direction had an average improvement ranging from 45% to 66% (average time on final session was 0.74 seconds). On the other hand, the average improvement in navigation time between letters on different row/column was smaller, ranging from 13% to 62%.

Moreover, an interesting fact is that preparation time had the greatest overall improvement from the first to the last session. Although participants improved their KSPC that did not affect their preparation time (i.e. spent time to begin the navigation). Indeed, one could argue that improving the paths to letters did not affect the participants' mental load, as they would discover new paths naturally.

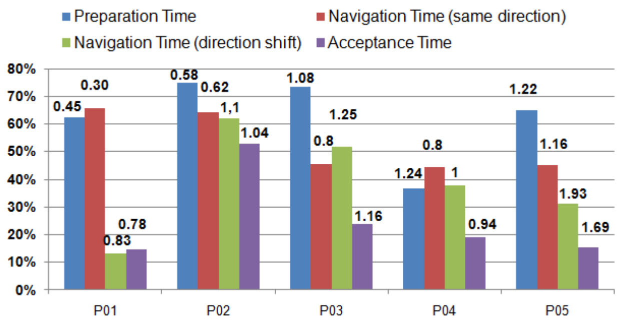


Figure 5: Improvement (%) in average preparation, navigation and acceptance times between the first and the last session for each participant. Numbers above the bars indicate the value in the last session.

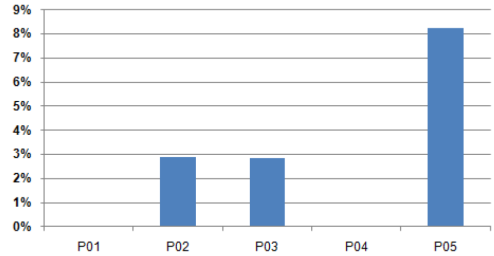


Figure 6: Average MSD error rate.

The error rate (i.e. number of times a participant deletes a character) across sessions ranged between 1% and 4%, which indicates that participants usually did not make errors. To better understand the quality of the transcribed sentences, Figure 6 shows the Minimum String Distance (MSD) error rate [5]. Both P01 and P04 transcribed sentences are exactly the same as the proposed sentences for all 13 sessions. Moreover, P02 and P03 had an average MSD error rate of 3%, which is not significant, typically one error per session. P05 had the highest MSD error rate with only 8%, though. This indicates that NavTap is indeed easy to use and aids the users in their text-entry tasks, by preventing errors and consequently minimizing frustration.

Following the experiment, we performed a questionnaire to subjectively assess NavTap. The participants specified their agreement with a set of statements using a 5-point Likert scale (1 = Disagree strongly, 5 = Agree strongly). The gathered results are here present in the form of "statement (median, interquartile-range)": easy to use (5, 0), fast to use (4, 0), easy to learn (5, 0), felt in control (5, 0), improved with practice (4, 2), and makes the cell phone accessible (5, 0), increase communication (5, 0). Overall, the values are very high and consistent with exception to the statement "improved with practice." This can be explained because P01 did not felt that he had significantly improved, since he was already very good in the first session. On the other hand, P05 had a very limited usage of text messages and consequently was not able to improve.

4.3.2 Daily Results

As aforementioned, although participants used their (old) mobile devices in a daily basis, their usage was very limited prior to the herein presented system. Most participants could only receive and place calls to a limited number of contacts, even those with a screen reader. Because they were not able to learn the traditional text-entry method (i.e. Multitap), they could not perform more advanced tasks such as contact managing (add, delete, edit or search contact) or sending text messages.

The results presented in this section and the system's usage may be influenced by a great number of factors, some of which are beyond our control, such as social and economic factors. Therefore, during this investigation we aimed at understanding the reasons for each usage pattern.

Overall, participants liked our system since day one and

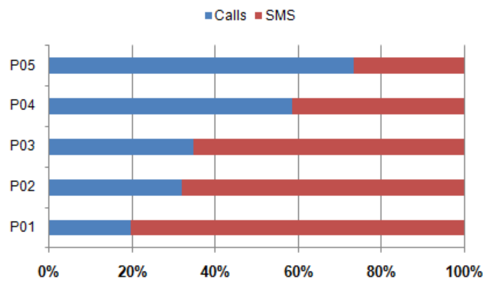


Figure 7: Participants' communication rate

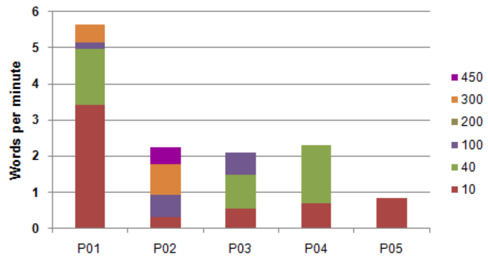


Figure 9: Sent text messages influence on WPM.

were very enthusiastic in using it. Our target group, with five participants, received and placed 678 and 797 calls, respectively, over a period of 16 weeks. Although this is a great result we cannot compare it to previous call usage. However, regarding text messages we know that none of the participants was able to send SMSs before they used our system. The achieved results were surprising and impressive; overall, participants received and sent a total of 1200 and 1825 text messages, respectively.

Figure 7 shows the percentage of communication method used over a period of 16 weeks. Overall, SMS usage was over 20% and 3 of the participants in our target group prefered text messaging to voice calls. This indicates not only that text messages are indeed needed by older visually impaired people to communicate with friends and family, but also that our method was able to support this need. It is noteworthy that none of the participants was able to send SMSs with their old cell phones.

Relatively to contact managing, participants added a total of 133 contacts and deleted 26. The search contact task was the most used (Figure 8), which can be easily explained as this task is a sub-part of other tasks, such as placing a call, sending a text message or deleting a contact. However it also indicates that participants could easily input text and perform more advanced tasks.

Concluding, before participants began to use our system they had a very restrictive usage of their mobile devices. Indeed, they were only able to receive and place calls. NavTap allowed our target group to make a more efficient use of mobile devices, augmenting social inclusion and assisting them in their daily tasks.

4.3.3 Usage Influence

In our previous studies, we evaluated NavTap's learnability over a period of 3 laboratorial sessions, meaning that the participants' improvement could be somehow restricted. In this investigation we wanted to observe if their daily usage influences the method's learnability. Figure 9 shows the progress in words per minute (in controlled sessions) of our target group according to the number of text messages sent. Notice that the first 40 sent SMSs had the biggest influence in the participants' performance (exception has to be made to P02, which had the highest social activity but her improvement was very slow when compared to the remaining participants).

Moreover, Figure 9 also illustrates the diversity of our target group, both in social activity and performance improvement. P02, P03, and P04 reached the same WPM performance degree, although the number of sent text messages is very different.

Figure 10 shows the influence of sent text messages KSPC improvement. Overall, participants demonstrated the highest improvement in the first 40 SMSs. Again, exception is made to P02 that had a different learning curve, but a high number of sent text messages, though. P05 is not represented in Figure 10 because he did not improve his KSPC value(Figure 4). However, his performance was better than the theoretical 2-Way scenario, indicating that even with a small amount of experience (i.e. less than 15 text messages), NavTap is easily understandable and usable.

4.3.4 Observing Each Visual Impaired Participant

To better understand specific behaviors that may affect our target group, particularly their results, we highlight some key observations about specific participants.

Since day one, P01 had a good understanding of our system, particularly the text-entry method, NavTap. This specific participant had a very good mental model of the alphabet and a high literacy level. Therefore, it was easy for him to use a 4-Way approach since the training session (Figure

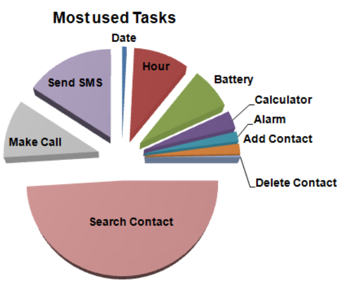


Figure 8: Most used tasks.

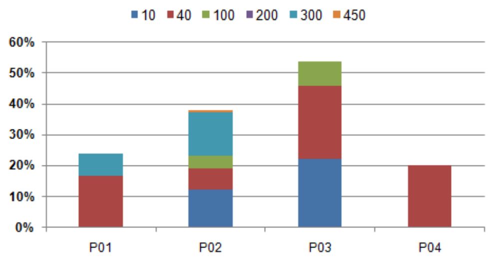


Figure 10: Sent text messages influence on KSPC.

4). On the other hand, that did give him a very low margin of improvement, mostly on KSPC. His main improvements were in both navigation and preparation times, reaching 0.3 and 0.45 seconds, respectively. In our understanding, this participant is near from reaching the theoretical limit on both WPM and KSPC metrics.

On the other hand, P02, accordingly to the training center psychologist, had severe learning difficulties. On the first training session this participant stated that she would never be able to learn how to input text with a mobile device. However, after a few minutes of practice she was able to navigate through the alphabet, even if using a naïve approach, and write a full sentence. Her interest in our text-entry method has only grown and this participant is currently near a perfect 2-way approach. Moreover, P02 was able to improve her preparation, navigation and acceptance times (Figure 5), indicating a comfortable usage of our system. The social inclusion of this participant was enormous, even with all her difficulties. She sent 625 text messages (half of total group) over a period of 16 weeks, and continually insisted in using NavTap on a daily basis after this research. Because this was the only text-entry method she was able to learn, it became, without a doubt, a success story.

P05 did not improve his KSPC from the first to the last session (Figure 4), suggesting that our method is hard to learn. However, this happened because he did not practice and marginally used text-entry tasks. This was influenced by social and economic factors, which we could not control or anticipate. Indeed, this participant had a very low usage of his mobile device, as he only called his wife once or twice a day. Therefore, he maintained his navigation skills, reflected on KSPC, since the first session, which was already better than the 2-Way theoretical scenario, and also improved his performance. This suggests that NavTap is easily usable since the first contact and natural, even without practice.

5. CONCLUSIONS

Mobile devices play an important role in our daily lives. However, most of the times, they are inaccessible to blind users, due to their visually demanding interfaces. Moreover, current approaches, like screen readers, lack the adequacy to users' needs, especially for those with that face greater difficulties. NavTap is a solution to this problem, allowing users to easily control their mobile devices. Our main goal in this research was to assess the users' learning experience with NavTap in a real life scenario. We also wanted to see if users were able to use their mobile devices in a daily basis and what influence could it have on their performance.

All participants in this study were able to understand and use our text-entry method after a few minutes of practice, although with different performances. The higher improvement was seen on the first two weeks of daily usage, indicating that indeed, participants felt in control and comfortable interacting with their mobile devices.

In this research we also assessed participants' communication patterns and even though these were influenced by several factors (mostly economic and social), text messaging reveled to be an important communication method to blind users. Indeed, some participants adopt it has their primary communication method, due to context restrictions. Moreover, all participants are still using NavTap in a daily basis, indicating that is indeed useful. Even those with screen readers preferred NavTap, due to its ease of use.

Despite the participants' diversity of learning and memory capabilities, NavTap revealed to be accessible to all. Moreover, results suggest that those with higher education level could perform better on a first approach with the system, but still improve with experience. On the other hand, participants with more difficulties, although with less efficiency, could also control their devices.

Concluding, in order to fully evaluate a text-entry method or other communication solution we need to deploy it in real life scenarios with the target population. Only then we will be able to assess the users' true learning experience and impact in their social inclusion.

As future work, we will study Multitap's learnability and improvement on real life scenarios, as we did with NavTap, and compare both approaches. Also, we intend to evaluate both text-entry methods with target users with different levels of experience. Finally, we will explore the users' diversity and maximize their performance and learning experience taking into account their specific capabilities.

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