Touchscreen Mobile Phones Virtual Keyboarding for People with Visual Disabilities

Agebson Rocha Façanha[1], Windson Viana[2], Mauro Cavalcante Pequeno[2], Márcia de Borba Campos[3], and Jaime Sánchez[4]

[1] Instituto Federal de Educação, Ciência e Tecnologia do Ceará, Brasil
agebson@ifce.edu.br
[2] Universidade Federal do Ceará, Brasil
{windson,mauro}@virtual.ufc.br
[3] Pontifícia Universidade Católica do Rio Grande do Sul, Brasil
marcia.campos@pucrs.br
[4] Universidad de Chile, Chile
jsanchez@dcc.uchile.cl

Abstract. This paper presents the design and initial evaluation of a Braille virtual keyboard which allows text input on touchscreen devices such as smartphones and tablets. The virtual keyboard, called LêBraille, is a metaphor of the Braille writing system that uses audio and vibration feedbacks to promote accessibility for people with visual disabilities. We integrated this keyboard into two mobile applications and implemented an initial usability evaluation with nine people with visual disabilities. The evaluation comprised activities including a comparison of text input in three types of keyboards (physical keyboard, alpha numeric virtual keyboard, and LêBraille). Initial results indicates that writing activities can be as fast as a virtual keyboard depending on the Braille expertise of the user and the degree of blindness, however, the writing pace with a virtual keyboard is lower than the writing pace with a physical keyboard.

Keywords: Accessibility, Mobile Computing, and Braille.

1 Introduction

Touchscreen interfaces on smartphones and tablets have brought a new interaction challenge for users with visual disabilities [9,11]. After all, these devices have a glassy surface with several visual elements accessed through capturing the movements and gestures on the screen. Also, these interfaces have fewer points of reference and low tactile feedback to guide the interaction. Third-party applications developed for these platforms are more demanding from a visual perspective; they are based on gesture navigation and possess an adaptive layout, which changes the interface according to the device position (i.e., device screen rotation). In addition, physical keyboards are replaced by virtual versions. These characteristics make the interaction with these devices more complex for people with visual disabilities and often require strong cognitive efforts from them, such as the memorization of the positions of

M. Kurosu (Ed.): Human-Computer Interaction, Part III, HCII 2014, LNCS 8512, pp. 134–145, 2014.

virtual keyboard keys [9,10,11,12]. Therefore, there is a growing demand for visual accessibility of these devices, since people with visual disabilities claim for adaptations that allow them to have access to such technological innovations [10,12].

A very well-known layout by people with visual disabilities is that of the six cells in the Braille system. Braille is one of the main resources available for communication and social inclusion for people with disabilities into society. However, it is noted that currently there is a trend towards less use of Braille in digital technologies, when compared with the use of haptics and sound technologies 1.

In this context, our research is focused on the design of a software application, the LêBraille virtual keyboard, which allows writing on touchscreen devices using a Braille metaphor. We aimed at examining this layout as alternative for QWERTY and Perkins based keyboards [14], and also to promote a much wider use of Braille in digital technologies. In this paper, in particular, we present the design and development of the LêBraille virtual keyboard, its integration into two mobile applications (SMS and Twitter clients), and an initial usability evaluation with nine users with visual disabilities. The final version of the LêBraille virtual keyboard and its evaluation are the main contribution of this paper.

The remainder of this paper is organized as follows: Section 2 presents related work on text input on mobile devices. The LêBraille Virtual keyboard, and its design and development processes are described in Section 3. Section 4 presents the usability evaluation of the mobile applications. Finally, we conclude the paper with final considerations and future work in Section 5.

2 Related Work

Research on the development of assistive technologies for mobile devices is relatively recent. In fact, the presence of audio, communication, and sensor features on these mobile devices offer a unique and personal platform to the development of new services (e.g., entertainment, navigation, and communication) aimed at people with visual disabilities which have attracted the attention of many researchers [1,8].

The challenge of text input on such devices has been one of the research objects [1,9]. Examples of such researches are: Eyes-Free Text Entry [9], NavTouch [11], No-Look Notes [10], NavTilt [12], BrailleType [1], BrailleTouch [14], Mobile Messenger for the Blind [8], and TypeInBraille [15].

NavTouch [11], NavTilt [12], and BrailleType [1] have been developed by researchers at the University of Lisbon, Portugal. NavTouch, for example, is software used for text entry that interacts with the user through directional movements (right, left, up and down) and sound features. NavTilt differs from traditional approaches of text input based multitapping by having a gesture-based 3D interaction and a new organization of the alphabet; the aim is to allow text input using only one hand. BrailleType is an evolution of these previous experiences. It proposes a method of text input through the touch-based graphical representation of the Braille alphabet. The system was developed for Android in which the letters are encoded in a matrix of six points with audible feedback through the SVOX voice synthesizer.

In our approach, we propose to reuse the well-known layout of six cells of the Braille system. Eyes-free [9] NavTouch [11], No-Look Notes [10], NavTilt [12], however, they are applications more centered on the production of new keyboard layouts. In fact, our proposal for text input resembles in some principles to the project BrailleType 1, which was designed concurrently with our project. We use the same keyboard metaphor, both applications execute on Android platform, and our target device is the smartphone. In this paper, we go one step further by including the development of two applications that promote the use of our Braille-based keyboard.

3 The LÊBRAILLE Virtual Keyboard

LêBraille is a mobile service for the Android platform that aims to include the use of Braille on new technologies. It uses gestures on the screen, gestures using the device, audio feedback, and nuances of Braille to facilitate text input on touchscreen devices. Besides to propose an alternative data entry on touchscreen devices, we expect that our research can also be used for practical training of the Braille alphabet. For the development of the virtual keyboard and the mobile applications we adopted an extension of the co-design methodology proposed by Millard et al. [13]. This methodology integrates techniques of software engineering, agile development methodologies, and methods for the design of graphical user interfaces in order to compose an iterative development process. Fig. 1. illustrates the general stages of the methodology. We decided to adopt a development in three sprints described below.

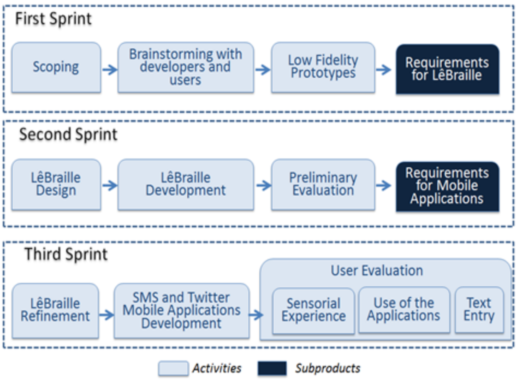


Fig. 1. Sprint-based process for the development of our approach

The first stages of the methodology include the study and design of applications made during the discussion meetings with a small group of users. These early stages were included in the **first two sprints**. At first, we held storyboarding meetings with three developers on mobile systems, which had notions of accessibility, and two persons who are blind[1]. The main objective was to understand the needs and expectations in the interaction with these interfaces. Based on these observations, we developed a

[1] They were two men, one aged 25 and another aged 43. Both were blind from birth, possess advanced knowledge on Braille, intermediate knowledge on computers, and had little or no experience in the use of touchscreen interfaces.

low-fidelity prototype virtual keyboard based on the Braille System. During the meeting, a discussion on the choice of prototype platform was initiated. We opted for the Android platform, since it is a more open platform, despite being, at that time, a fledgling operating system regarding accessibility compared to Apple's iOS.

Following the methodology mentioned, we developed a high-fidelity prototype of the virtual keyboard. We conducted a brainstorming process with a group of 5 people with visual disabilities, who had heterogeneous profiles (knowledge of Braille, age, gender). This experience was important for structuring the research and allowed for a better definition of the scope and the limitations of the study. This very preliminary research pilot study including practical activities is reported in a previous study [2].

Taking this initial evaluation and considering other experiments described in the literature [3,4,5,8], we have identified some key requirements to improve visual accessibility in applications that run on touchscreen devices [1]. Some of these requirements were applied in the design of mobile applications in this study, such as:

- Always provide feedback for all actions in the interaction elements.
- Preferably, use motion-based interaction, because the actions performed through gestures reduce the barriers imposed by the interface.
- When using the interaction elements, the application must include an exploration mode of the screen, since the interaction elements must be identifiable with both tactile and audio feedbacks.
- The elements of interaction including the interfaces should be presented in a list layout or in a two columns layout, avoiding table layouts. Then, the device sides can be used as reference points.
- Alert messages and pop-ups must fulfill the entire screen with options to exit and return to the previous screen.
- Use of timeout in an element selection should be avoided. It can confuse users, especially novice users who need more time to interact with the application.
- If it is not possible to design an interface adapted to the screen rotation, it is better to set a layout orientation (preferably vertical, top to bottom).
- The use of colors that provide a minimum contrast between background and foreground is required.

Based on the requirements to improve visual accessibility and the feedback from the usability of the initial experiment [2], we redesigned a more complete version of the virtual keyboard LêBraille. The virtual keyboard LêBraille was based on the operation of the Braille system. The arrangement of interface elements follows the structure of a Braille cell; the buttons correspond to the formation of Braille points. Once touched, the device emits a sound corresponding to the selected cell.

During the interface design, we chose to merge the use of buttons and gestures. Thus, the system can be used by people who are blind, by people with low vision, and sighted people that understand the Braille system. The keyboard LêBraille interacts with speech synthesis software configured as standard on the mobile device (e.g., Pico, SVOX, eSpeak). For this study, we used a native function of the Android platform (android.speech.tts.TextToSpeech). The language used by the TTS software is automatically configured by device operational system. LêBraille can be invoked by any other text application using inter-process communication based on Intents. Fig. 2 presents an overview of the system commands.

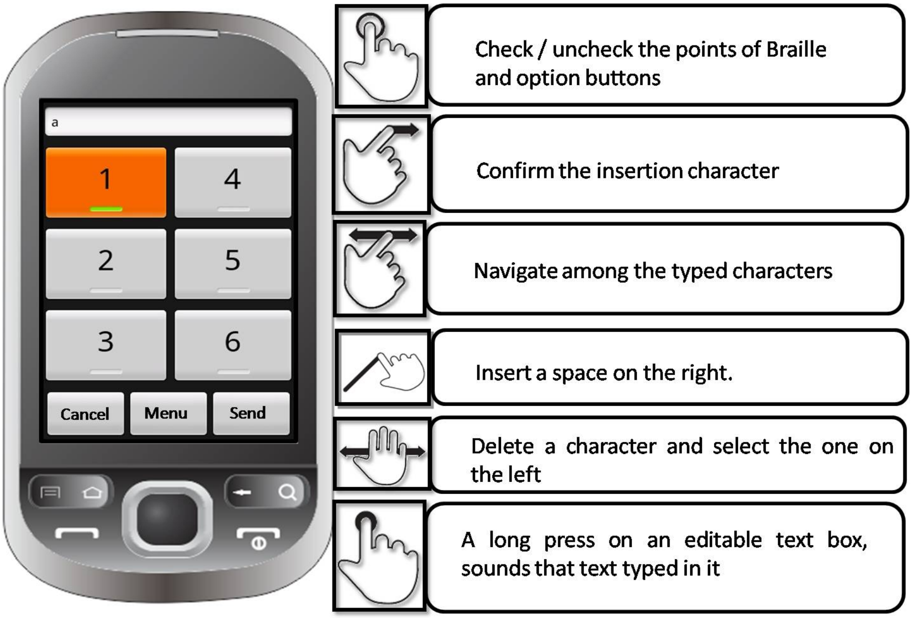


Fig. 2. LêBraille commands and recognized gestures

We developed two mobile applications to encourage interaction and communication between people with visual disabilities through services that provide the tasks of sending and receiving messages. These applications offer access to the social networking platform Twitter (LêBrailleTWT) and to the SMS messaging service (LêBrailleSMS). Both applications use the virtual keyboard LêBraille to allow for writing messages on a touchscreen device. The mobile applications developed are illustrated in Fig. 3 and Fig. 4. They have universal design of their graphic interfaces. Thus, non-blind people (e.g., special education teachers) can also practice the Braille by using text-based communication services provided by these applications.

Fig. 3. Twitter mobile client screenshots

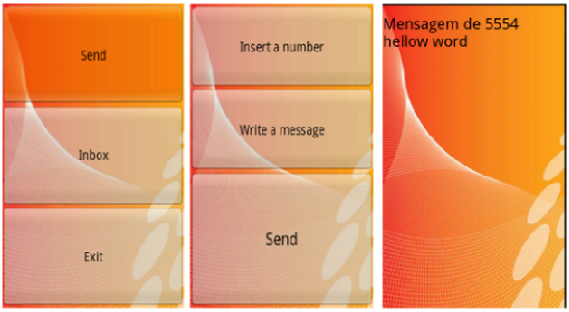


Fig. 4. SMS mobile client screenshots

Both applications access the device accelerometer to recognize some gestures. They also communicate with the Internet and the mobile phone network to perform its functions. For example, LêBrailleTWT performs a REST request to the Twitter Web-Service in order to make communication (e.g., list and read the 20 most recent posts and tweet a message). LêBrailleSMS, in turn, invokes a method of sending text messages via the Android SDK. The virtual keyboard is also used to enter the recipients' phone number and maintain the same interface, since it is possible to enter numbers using Braille. LêBrailleSMS provides both the sending and receiving messages in an accessible way, having a structure comprising navigability, gestures and commands similar to LêBrailleTWT application. A video illustrating the use of LêBrailleTWT is available in http://www.youtube.com/watch?v=IY8cgd-jh8g. It shows one user that is reading his Tweets and is writing a message with the LêBraille virtual keyboard. He writes the phrase "Web Accessibility" in Portuguese.

4 Usability Evaluation

After designing and developing the mobile applications, a usability evaluation was performed and also the speed of writing using LêBraille was measured.

4.1 Sample

For the usability evaluation, we use the focus groups methodology[2] [6], in order to obtain an initial validation of the mobile systems with a test group of nine users. Four different sessions were implemented: i) a test knowledge of Braille, ii) an analysis of the Twitter client and the writing speed of the virtual keyboard, iii) an analysis of the interface for sending and receiving SMS messages from the application, and finally, iv) a comparative writing test with other types of keyboards.

Each session had an average duration of two hours. The sessions were held in the period from March 2012 to April 2013. The sample was non-probabilistic, selected for convenience according to [7]. Users with visual disabilities were older than 18 years, with prior knowledge of Braille and computer practice. The detailed profile of each participant is shown in Table 1.

---

2 Focal group methodology is sampling process that seeks to obtain qualitative information given the perceptions reported by participants during discussion meetings.

Table 1. Profile of the users sample for the usability evaluation

	User 1	User 2	User 3	User 4	User 5	User 6	User 7	User 8	User 9
Age	27	25	34	26	22	45	41	28	26
Gender	M	M	M	M	F	M	M	F	M
Degree of Blindness	Blind	Blind	Blind	Low Vision	Blind	Blind	Blind	Blind	Blind
Cause of Blindness	Acquired (8 years)	Birth	Acquired (6 years)	Birth	Birth	Birth	Birth	Birth	Birth
Knowledge of Braille	Intermediate	Advanced	Intermediate	Intermediate	Advanced	Advanced	Intermediate	Intermediate	Advanced
Computing Skills	Advanced	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Advanced

4.2 Materials

We developed wood model prototypes that simulate some interfaces of the mobile applications. The goal was to familiarize users with the systems layout, through the appropriation of their repertoire of commands, gestures and actions. A wood prototype example is illustrated in Fig. 5. During the experiments with LêBraille we used a Galaxy 5 I5500B device including a 2.8 inch screen and the Android 2.2 system.

Fig. 5. Sensorial experimentation with wood prototype models of the virtual keyboard

The session aiming to compare speed of writing was implemented with a Nokia E5 device and the Galaxy 5 I5500B device. Nokia E5 possesses a physical QWERTY keyboard. A virtual QWERTY keyboard with audio feedback was installed on the Android device since we were unable to use the default virtual keyboard of the platform. All sections were recorded by videotaping and at end of each session we asked users to fill out a questionnaire.

4.3 Instruments

A questionnaire was administered in order to discover, analyze and validate, through observations of the user group, requirements for improving the mobile applications. The questionnaire was created guided by the following metrics:

I. *Organization and Presentation*. Indicate levels of user´s acceptance. This is determined by the way of presenting the technology being tested. Therefore, involves the overall organization, structure, presentation strategy, consistency and completeness.
II. *Motivation*. Measures the ability of technology to impact, motivate and arouse interest. It is also related to user´s acceptance
III. *Design*. Measures the quality of the design presented in the application interface.

IV. *Audio Style.* Refers to the understanding, quality, and style of the audio provided by the application.
V. *Navigation.* Measures the easiness of the user in browsing pages and its content.
VI. *Content.* Relates to the subject matter covered by the technology being tested.
VII. *Speed.* Determines the speed of access to the page or application contents.
VIII. *Objectives.* Quantifies if the approach achieves its purposes and goals.
IX. *Special Education.* Measures whether the technology can be applied in the education of people with visual disabilities.

4.4 Procedure

Before the initial interaction with the mobile applications users had undergone practical tests to prove their skills with the Braille system. They transcribed the same phrases used during testing with the mobile applications. The time for writing these phrases was measured. During session II and III three activities were proposed with increasing levels of difficulty. They aim to achieve better quantitative results of validation and acceptance of the virtual keyboard and mobile applications.

For activity I, we asked users to navigate in the Twitter client application, to read tweets and re-send some tweets (retweet). Then, a practical challenge was proposed for each participant. The challenge was to tweet the complete alphabet through the text input interface. The goal of this challenge was to evaluate the writing pace using LêBraille which so far had not been evaluated by Braille literate users.

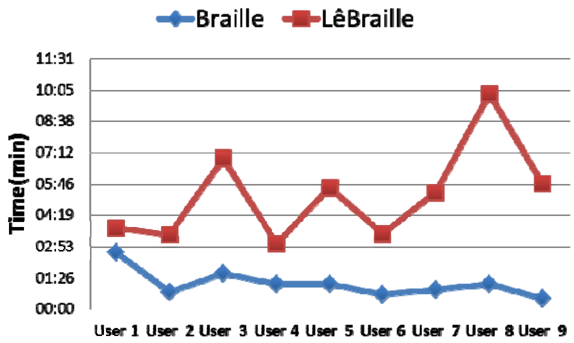
Activity II was to post a message to Twitter. This message followed the reports of Socialmediatoday[3], which cite the average words per tweet. Thus, we proposed writing (via LêBrailleTWT) a proverb[4] that fits the specifications mentioned. Each user had a time period to conduct a random posting to remember the steps of submission. After this time, the activity began.One of the objectives of the activity II was to evaluate the average writing time with the virtual keyboard LêBraille. In the fourth section, we asked users to write the same sentence of the activity II using two other types of keyboards: a QWERTY virtual keyboard and a physical QWERTY keyboard. The comparative results of these interactions are described in the next section. Activity III consisted in sending a SMS (via LêBrailleSMS). The user could select the message, but it should contain at least 10 words and the last word should be the user name as message identification. This message was sent to the mobile phone number of one researcher. The main objective of this activity was to obtain qualitative information from the perceptions reported by participants during the performance tests using the SMS application.

4.5 Results

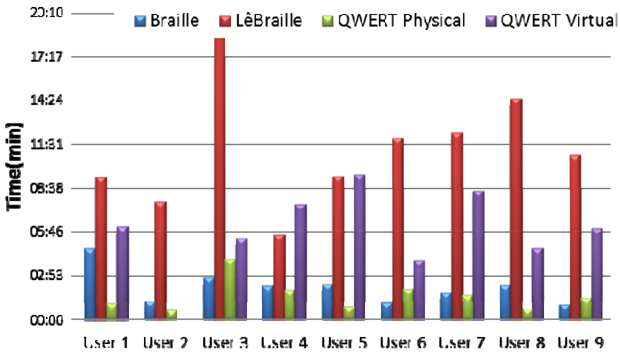
Graphic 1 shows the results of the writing challenge in the activity I. The graphic presents the time results of each participant to conclude the challenge using LêBraille, slate and stylus. When using LêBraille, the average time to writing and posting of

[3] `Socialmediatoday.com/joshgordon/253668/content-marketing-lessons-top-10-retweets-2010`
[4] "Antes de dar comida a um mendigo, da a ele uma vara e o ensina a pescar".

messages was 05 min and 23 sec. The coefficient of variation was 39.26. The comparison with the writing time using the slate and stylus indicate speed difference between the two approaches, which may be explained by navigational difficulties due to lack of experience of the user with the application and the challenge to use touchscreen interfaces to write text. Some users showed better results (3 min and 20 s), such as the user 4 that has low vision and users 5 and 6 that had advanced skills on Braille.



Graphic 1. Time for writing the alphabet using LêBraille with the slate and stylus

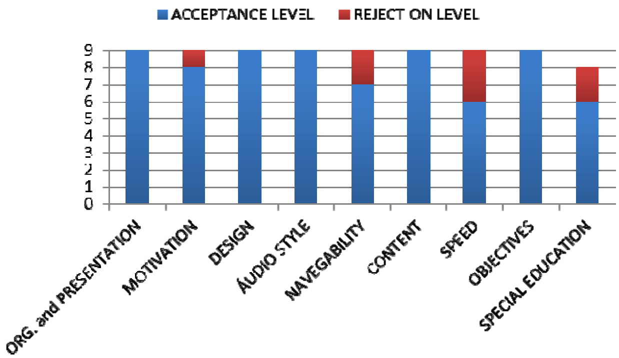


Graphic 2. Time to writing the proverb on the four systems

Graphic 2 illustrate the writing time of the proverb on the four systems experimented: Braille, LêBraille, a QWERTY virtual keyboard, and a QWERTY physical keyboard. The average time for writing and posting on Twitter with LêBrailleTWT was 11 min and 36 sec and the coefficient of variation was 33.99. This suggests a relatively high time. Regarding the comparison between the writing approaches, it is clear the better performance of data input using physical returns as Braille and QWERTY keyboard with physical buttons. Even for some users using the physical keyboard had a better performance compared to the use of Braille. This makes us believe the increasing use of computers as a means of communication to the detriment of Braille.

Of the nine users who conducted the experiment, three of them had better performances using the LêBraille than using the QWERTY virtual keyboard. User 2, although trying for three times on different days, could not finalize the proposed activity with the QWERTY virtual keyboard. According to him, the task was not completed because of failing to adapt to the interface, since there was a lot of information on the screen and it requires much effort and precision for locating the keys. The user 4 with low vision also excelled in the experiment. He had the best performance using LêBraille. According to him, this occurs because of the contrast provided by the interface. Regarding user 5, which practically had equivalent performance between the two virtual solutions, we noticed that he is a user with advanced skills in Braille and good notions on computer uses.

For some users, such as users 3 and 8, the intermediate domain of Braille and computer use had influences on the inefficient performance in relation to the use of Virtual Qwert. It is important to note that the use of the physical QWERTY keyboard in the same section may have helped them to remind and tie the QWERTY layout. Despite this fact, it should be said that through the evaluation criteria used in the questionnaire administered, all members approved the Twitter application and the virtual keyboard in the categories described in section 3.3.



Graphic 3. Results of the Evaluation Questionnaire for the SMS application

Graphic 3 show the results of the application of the same questionnaire for the SMS application. The results were obtained after completion of the third activity (i.e., access the inbox messages and send an SMS message to a specific mobile phone). Most users, 88.8%, confirmed that the proposed technology is interesting, has an impact and motivates them. Also, 77.7% of users reported the ease of browsing the pages and content, and 66.6% of users considered acceptable the speed to access the content. Over 66.6% accepted the idea of combining SMS with LêBraille to be used as a tool to support Braille learning (one user chose not to answer).

5 Discussion and Conclusions

Mobile devices have a major role in today's information society. If the trend of the ubiquity of touchscreen devices without physical keyboard is confirmed, the research for new ways to allow text input and the design of mobile applications with multimodal interfaces (i.e., haptics, gesture, audio recognition) should be encouraged to avoid interaction issues with these devices by people with disabilities.

In this paper, we present an initiative in this context, focused on the issue of text input on touchscreen devices. Different from other studies more centered on the production of new keyboard layouts, we propose to reuse the layout of six cells of the Braille system. People with visual disabilities were able to accomplish the writing activities with both the LêBraille virtual keyboard and the mobile applications developed in this study. All three activities implemented were able to be performed by the users: tweet the alphabet, tweet a proverb, and send SMS with a phrase the user's choice. In some cases, the writing pace was as quick as or faster than with an alpha numeric virtual keyboard. However, for all users, the speed of writing in both virtual keyboards approaches (a QWERTY virtual keyboard, and the LêBraille) was much slower than the activity with a physical keyboard.

When analyzing the results of writing paces we should also take into consideration that the users had contact with the applications only during the experimentation sessions. This occurred since the Android system in its version 2.3, even with the use of screen reader TalkBack, did not provide full autonomy to the user with visual disabilities to operate the device. Thus, it is essential to implement a long term usability evaluation considering a bigger sample and diverse contexts of use in order to monitoring whether there is a significant time reduction to write and send messages or tweets.

Furthermore, in the field of education, touchscreen devices are being inserted into learning environments to facilitate interaction between the student and the content to be learned. Researchers are increasingly and actively exploring ways to integrate touchscreens devices in m-learning environments. The study presented here, as well as in [1,9,10,11], show the need for further research leading to the development of new mobile accessible technologies. Therefore, these new studies should promote the inclusion of students with visual disabilities in these new classrooms practices.

As future work, we envision developing educational games that use the LêBraille virtual keyboard to serve as a tool to stimulate student writing. These games can be used in non-formal school literacy activities of people with visual disabilities, or even, for training sighted people who want to learn or practice Braille in a playful way.

References

1. Oliveira, J., Guerreiro, T., Nicolau, H., Jorge, J., Gonçalves, D.: BrailleType: Unleashing Braille over Touch Screen Mobile Phones. In: Campos, P., Graham, N., Jorge, J., Nunes, N., Palanque, P., Winckler, M. (eds.) INTERACT 2011, Part I. LNCS, vol. 6946, pp. 100–107. Springer, Heidelberg (2011)
2. Façanha, A.R., Viana, W., Pequeno, M.C.: Estudo de interfaces acessíveis para usuários com deficiência visual em dispositivos móveis touch screen. In: XVI Congreso Internacional de Informática Educativa (TISE 2011), Santiago Chile (2011)
3. Kane, S.K., Wobbrock, J.O., Ladner, R.E.: Usable gestures for blind people: understanding preference and performance. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI 2011), pp. 413–422. ACM, New York (2011)
4. Kane, S.K., et al.: Access overlays: improving non-visual access to large touch screens for blind users. In: Proc. of the ACM Symposium on User Interface Software and Technology (UIST 2011), pp. 273–282. ACM, New York (2011)
5. WCAG. Web Content Accessibility Guidelines (WCAG) 2.0. (2008), `http://www.w3.org/TR/WCAG/`

6. Lunt, P., Livingstone, S.: Rethinking the focus group in media and communications research. Journal of Communication 46(2), 79–98 (1996)
7. Levy, P.S., Lemeshow, S.: Sampling of Populations: Methods and Applications, 4th edn. Wiley Series in Survey Methodology (2008)
8. Sánchez, J., Aguayo, F.: Mobile Messenger for the Blind. In: Stephanidis, C., Pieper, M. (eds.) ERCIM Ws UI4ALL 2006. LNCS, vol. 4397, pp. 369–385. Springer, Heidelberg (2007)
9. Tinwala, H., MacKenzie, I.S.: Eyes-free text entry on a touchscreen phone. In: Proceedings of the IEEE Toronto International Conference – Science and Technology for Humanity – TIC-STH 2009, pp. 83–89. IEEE, New York (2009)
10. Bonner, M.N., Brudvik, J.T., Abowd, G.D., Edwards, W.K.: No-look notes: accessible eyes-free multi-touch text entry. In: Floréen, P., Krüger, A., Spasojevic, M. (eds.) Pervasive 2010. LNCS, vol. 6030, pp. 409–426. Springer, Heidelberg (2010)
11. Guerreiro, T., Lagoá, P., Nicolau, H., Gonçalves, D., Jorge, J.A.: From Tapping to Touching: Making Touch Screens Accessible to Blind Users. IEEE MultiMedia 15(4), 48–50 (2008)
12. Lucas, D., Nicolau, H., Guerreiro, T., Jorge, J.A.: NavTilt: Interface Gestual para Cegos. In: Proceedings of the 4th National Conference on Human-Computer Interaction (Interacção 2010), Aveiro, Portugal (2010)
13. Millard, D., Howard, Y., Gilbert, L., Wills, G.: Co-design and Codeployment Methodologies for Innovative m-Learning Systems. In: Multiplatform E-Learning Systems and Technologies: Mobile Devices for Ubiquitous ICT-Based Education. IGI Global (2009)
14. Frey, B., Southern, C., Romero, M.: Brailletouch: Mobile Texting for the Visually Impaired. In: Stephanidis, C. (ed.) Universal Access in HCI, Part III, HCII 2011. LNCS, vol. 6767, pp. 19–25. Springer, Heidelberg (2011)
15. Mascetti, S., Bernareggi, C., Belotti, M.: TypeInBraille: a braille-based typing application for touchscreen devices. In: The Proceedings of the 13th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS 2011), pp. 295–296. ACM, New York (2011)