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Abstract

Purpose – *The purpose of this paper is to discuss the issue of tailored text input methods for visually impaired and blind users that are needed on touchscreen devices to support their accessibility. Previous approaches still have issues related to the necessity of searching for characters, slow entry speeds or cumbersome handling.*

Design/methodology/approach – *The authors developed a new Braille-based text input method named EdgeBraille, which allows entering six-point Braille characters by swiping one finger along the edges of the touchscreen in an arbitrary sequence. The approach was compared with the current standard method of a talking keyboard, first in a short-term lab study (14 participants) and then during two weeks of daily training (seven participants).*

Findings – *Overall EdgeBraille was perceived well by the users and possesses favourable handling characteristics. In terms of user performance (words per minute and error rate) the authors found no significant differences between the two methods. However, based on the evaluation results and the feedback of the participants the authors identified possibilities for improvement in terms of a smaller EdgeBraille version allowing the entry of eight-point Braille characters, and conducted a proof-of-concept study (seven participants).*

Originality/value – *In the paper the authors comprehensively reflect on advantages and disadvantages of Braille-based methods in general and EdgeBraille in particular. The authors argue why and how Braille-based methods should serve as complement to current text input paradigms based on talking keyboard and indicate future directions of research.*

Keywords *Accessibility, Braille, Mobile device, Text input, Touchscreen, Visually impaired and blind*

Paper type *Research paper*

1. Introduction

Many visually impaired and blind (VIB) people are intensive technology users and use mobile devices regularly. With the emerging era of smartphones, touchscreen devices without keypads are becoming increasingly common, thus the improvement of touchscreen accessibility is an important issue to address. This is why a variety of methods for making touchscreens accessible for VIB users have been proposed in previous research (e.g. Kane *et al.*, 2008; Sandnes *et al.*, 2011).

An important aspect of interaction with smartphones is the ability to enter text, for example, in order to write short messages or e-mails. The common way of making soft keyboards accessible for VIB users is based on the “talking fingertip technique” (Vanderheiden, 1996). VoiceOver for iOS and TalkBack for Android are commercial products using this technique, which allows the device to read onscreen elements (such as letters of the keyboard) to the users, when they touch them with their fingers.

A disadvantage of using a soft keyboard for entering text on touch devices is that the entire alphabet has to fit on the screen, which hampers the selection process. This is why a number of

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alternative solutions for nonvisual text input have been presented in the scientific literature, aiming to reduce the number of elements on the screen. Some of these solutions used Braille-based text input, which in the basic version uses six dots for one letter and was presented as a promising possibility in accessibility research.

However, previous approaches still have issues related to slow input speed or cumbersome handling. Therefore, in this paper, we present the design of a new Braille-based text input method for touchscreens named EdgeBraille and reflect on Braille-based methods in general as well as possibilities for further improvement of these approaches.

2. Related work

Besides the current standard in commercial products – using a QWERTY-layout soft-keyboard – a number of alternative solutions for nonvisual text input on touchscreen devices have been presented in the scientific literature so far.

Pie-menu-based text input

Pie-menu-based methods have the advantage of requiring fewer screen elements (which therefore can be bigger) in comparison to QWERTY keyboards. However, they are potentially tedious and slow due to the multi-step interaction. For example Yfantidis and Evreinov (2006) present an approach with a rectangle with eight characters surrounding the user's finger. By swiping in one of the eight directions the user can select a character. Other characters are presented after a defined period of time spent dwelling on a position. In Bonner *et al.* (2010) the screen is divided into eight zones, each zone containing three to four letters arranged clockwise. The user can first select one zone, and in a second step select the target letter.

Gesture-based text input

An early gesture-based text input system for touchscreen devices which found broad application is Graffiti from Palm Inc., which is based on Unistroke (Goldberg and Richardson, 1993). Graffiti is a single-stroke alphabet which resembles the Roman alphabet.

A related approach with special relevance for our work is EdgeWrite (Wobbrock *et al.*, 2003). The basic idea of EdgeWrite is to improve accuracy of gesture-entry by utilizing the edges of a small input area. A specialized EdgeWrite alphabet (also based on the Roman alphabet) optimized for edge-based stylus movements was developed. The stabilizing effect of moving the stylus along the edges, allowed for fewer errors and better recognition. Tinwala and MacKenzie (2009) have also suggested the use of gestures derived from the Roman alphabet in the context of eyes-free text input. The results of a user study indicate that the approach is promising for sighted users. However, it is unclear how well visually impaired users can adopt this approach. Results of studies by Kane *et al.* (2011) indicate that these rather complex gestures may be difficult to use for individuals born blind.

Braille-based text input

Previous Braille-based input methods can be differentiated into those who allow entering a Braille letter in one single step, and those who split the entry into several steps, by entering row after row or column after column of a Braille letter.

With TypeInBraille (Mascetti *et al.*, 2011b) three steps are needed to enter one Braille letter. For each row, users can select no (tapping with three fingers), one (tapping with one finger on the left or right area on the screen) or both dots (tapping with two fingers). Perkinput (Azenkot *et al.*, 2012) supports entering a Braille letter in one or two steps, depending on the size of the multi-touch screen. For small screens such as smartphones, characters can be entered in two steps with three fingers. When using two small screens or one larger screen such as a tablet, two hands can be used simultaneously in order to input both columns of a Braille character in a single step. Braille letters can be entered by placing fingers anywhere on a touch surface, a technique the authors call "Input Finger Detection".

Input of Braille letters in one step is used in BrailleType (Oliveira *et al.*, 2011) and BrailleTouch (Southern *et al.*, 2012). Both approaches use six targets on the screen that represent the six dots of a Braille character. In the BrailleType system, target dots can be selected successively by touching them. After the desired dots are selected, a double tap anywhere on the screen confirms the input. BrailleTouch uses a multi-touch paradigm. Therefore the mobile phone is used with the screen facing away from the user, with three fingers of each hand resting over one of the six targets (three on each side). A swipe forward enters a space and a swipe backward deletes the last character.

For comparison Table I provides an overview of evaluation results of the different Braille-based input methods and the values reported for VoiceOver.

Considering previous work related to Braille-based text input, our goal was to create a new Braille-based method, which allows entering a Braille letter fast and in one single step. Furthermore the method should be convenient and usable with one finger, following findings by Paisios (2012), who reports that one-finger interaction was rated best by blind users. Reasons for the users' highest ratings of the one-finger method (compared to two-finger, split-tap, thumb-typing and nine-digit method) were that it was graspable very quickly without training and felt as the most intuitive and natural way of entering Braille.

Inspired by previous research concerning text input with edge-supported Graffiti strokes (Wobbrock *et al.*, 2003), we developed EdgeBraille. We use a screen layout similar to BrailleType (Oliveira *et al.*, 2011) and BrailleTouch (Southern *et al.*, 2012), but the input paradigm differs significantly. BrailleType uses a multi-touch approach, which is indeed fast but requires the users to hold the phone with both hands. With EdgeBraille users can hold the phone with one hand and they only need one finger to enter the Braille letter. BrailleTouch uses tap-based input of each dot at a time, which is not very fast and requires accurate tapping. We expect a swipe-based approach along the display's edges to be faster and easier. Our design approach is described in detail in the following section.

3. Prototype design and development of EdgeBraille

EdgeBraille enables entering a Braille letter in a similar manner to graffiti strokes by following the sequence of the Braille dots with a finger. The structure of the screen relates to the structure of a Braille letter. The top two and bottom two dots (diameter: 12 mm) of the Braille letter are placed in the corners of the display. Two points halfway along the side edges of the screen are used for the two middle dots. Dots are separated 17 mm vertically and 22 mm horizontally.

A letter is entered by sketching an arbitrary sequence of Braille dots. Each dot can be activated by moving the finger on the dot, and revisiting a dot deactivates it. Examples of different strategies to write a letter can be found in Figure 1.

Table I Summary of evaluation results reported by previous work on Braille-based methods

Method	*n*	*#*	*wpm*	*Error rate (%)*
TypeInBraille vs VoiceOver	7	1	6.30	3.00
			5.20	4.00
BrailleType vs VoiceOver	13	1	1.49	7.00
			2.10	14.12
Perkinput vs VoiceOver	8	7	6.05	3.52
			3.99	6.43
BrailleTouch expert performance	6	5	23.20	14.50
BrailleTouch moderate performance	3	5	21.00	33.10
BrailleTouch poor performance	2	5	9.40	39.30

Notes: *n*, the number of participants; #, the number of sessions; wpm, the measured words per minute. BrailleTouch (Southern *et al.*, 2012) reported the performance values captured in the last of five sessions. For the remaining methods the reported value is the average over all sessions conducted. TypeInBraille (Mascetti *et al.*, 2011a) calculated the error rate by dividing all errors through the length of the text. The rest of the methods used metrics proposed by Soukoreff and MacKenzie (2003). BrailleType (Oliveira *et al.*, 2011) reported the old MSD error rate, Perkinput (Azenkot *et al.*, 2012) the uncorrected error rate and BrailleTouch the total error rate

A space is entered by tapping anywhere on the screen but not on a dot. To prevent accidentally deactivating a dot, the zone for deactivation is approximately 1.7 mm smaller than the zone for activation. When activating and deactivating, vibro-tactile feedback is provided and different sound files are played for activation and deactivation. For users with residual vision also visual feedback is provided, as the dots are highlighted green when activated and grey when deactivated. When the finger is lifted, the activated dots are registered and the letter is spoken to the user and displayed on the screen. To prevent accidentally writing a letter, a threshold of 75 milliseconds for lifting the finger was defined.

The edges of the touchscreen are used as guardrails by marking them with a mechanical frame. Thus, we assume that this will ease orientation for the VIB people and speed up the process. This assumption is supported by Kane *et al.* (2011), who reported that blind people preferred gestures that used screen edges and corners. For the short-term lab evaluation we built a cardboard frame to provide physical guidance. For the longer term use evaluation we used a commercial cover (Griffin GB01902 Survivor Cover) as shown in Figure 1.

The prototype was developed using Adobe AIR 3.0. Screen auto orientation was not used to prevent errors according to the auto-orientation feature as reported by Mascetti *et al.* (2011b).

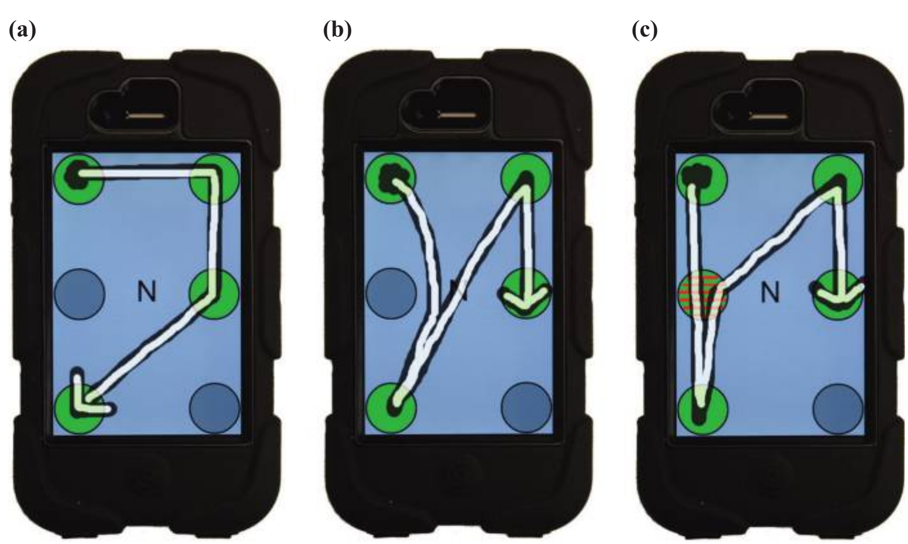
4. Short-term lab evaluation

We conducted a lab study to evaluate how suitable EdgeBraille is for VIB users, when they use it for a short time. We compared the participants' performance and opinion towards EdgeBraille along with Android's talking keyboard method TalkBack. We did this for two reasons: first talking keyboards still are the standard accessible method for text input on touchscreens provided by mobile operating systems and second, the Braille-based approaches presented in the related work were not available for comparison at the time we conducted our research. For the short-term evaluation we used a HTC Desire S with Android 2.2.3.

Participants

For the evaluation 14 VIB participants (nine male, five female) between the age of 16 and 57 years (mean age = 33 years, SD = 12.68) were invited to participate. Seven of the participants were

Figure 1 Possibilities to enter the letter "n" with EdgeBraille



Notes: (a) Selecting the dots using the shortest path; (b) selecting the dots column wise circling around dot No. 2; (c) selecting the dots by first activating dot No. 2 and then deactivating it on the way back from dot No. 3

born blind, five became blind later in life and two could differentiate between light and dark. All participants were able to read and write Braille letters. Ten participants were right-handed, one left-handed and three ambidextrous. Five of them already had a lot of experience with touch-based mobile phones and the talking fingertip method.

Procedure

Participants were provided with a short description and five minutes of training with each method. Both methods could be used with either the right or the left hand, depending on users' preferences. To assess the training effect throughout usage, participants had to enter 16 two-word texts (with 19±1 characters, including spaces) successively with each input method. As the participants' native language is German, we could not use the well-known standard phrase set of MacKenzie and Soukoreff (2003). Each text was read to the participants. Participants were told to enter the text as quickly and accurately as possible without interruptions. Participants were instructed to use only lower case letters and no abbreviations. They were not allowed to correct incorrectly entered characters (cf. Oliveira *et al.*, 2011). In case of an error, they were instructed to simply go on with the next character. After the text entry with each method, questions to assess participants' opinions and preferences were asked. We collected the users' levels of agreement to four statements regarding the ease of comprehension, ease of use, speed and intention to use the method using a five-point Likert scale (cf. Oliveira *et al.*, 2011).

Data analysis

We measured the words per minute (wpm = number of correct characters per minute divided by five) and MSD error rate (Soukoreff and MacKenzie, 2003) for the methods and compared the beginning (i.e. first four tasks) with the end (i.e. last four tasks) of the test, to analyse the training effect. A two-way repeated measures analysis of variance (ANOVA) was calculated to compare participants' performance depending on the factors training progress and input method. *t*-Tests for pairwise comparisons were conducted. Assumptions of normality for each level of the factors and sphericity were checked and confirmed.

Results

The results show that EdgeBraille achieves similar performance as TalkBack at the end of the test, in terms of wpm (EdgeBraille mean = 3.97, SD = 1.00; TalkBack mean = 3.64, SD = 1.35; $F_{1,13} = 0.79$, $p = 0.389$) as well as error rate in per cent (EdgeBraille mean = 8.43, SD = 5.21; TalkBack mean = 10.58, SD = 9.99; $F_{1,13} = 0.46$, $p = 0.512$).

Regarding the training progress, it is not surprising that the wpm rates are significantly higher ($F_{1,13} = 33.69$, $p < 0.000$) in the last four tasks (mean = 2.94, SD = 1.03) than in the first four tasks (mean = 3.81, SD = 1.18). To investigate if the training effect occurs for EgdeBraille as well as TalkBack two *t*-tests were calculated. The analysis showed a significant increase in wpm for EdgeBraille ($t_{13} = -6.14$, $p < 0.000$), as well as for TalkBack ($t_{13} = -2.76$, $p = 0.016$). The results are also shown in Figure 2 (left figure).

The average usability ratings of EdgeBraille are slightly higher for all four scales (ease of comprehension, ease of use, speed and intention to use) than for TalkBack. However, these differences are not statistically significant (see Table II). Regarding the participants' preference, we found that EdgeBraille was preferred by eight users, while TalkBack was only preferred by four (and two were indecisive).

The short-term evaluation reveals a similar performance and a higher number of preferences for EdgeBraille compared to TalkBack. As an attempt to level out previous experience with the talking fingertip method, we conducted a further study to investigate EdgeBraille in longer-term use.

5. Longer-term use evaluation

A two-week evaluation with a subset of seven users of the short-term evaluation was conducted, to understand how the users' performance and opinions evolve over time.

Figure 2 Text input rate (wpm) in short-term lab (left) and longer-term use (right) evaluation

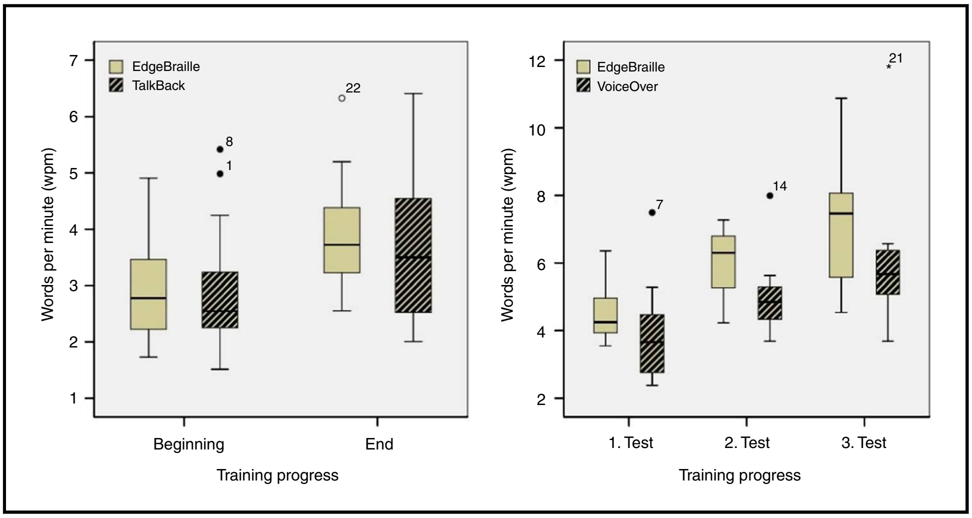


Table II Average user agreement to the four statements for each input method (1 = strongly disagree, 5 = strongly agree) with standard deviation (±) *t*-value with degree of freedom and significance (*p*-value)

	EdgeBraille	*TalkBack*	t_{13}	*p-Value*
Easy to comprehend	4.82±0.46	4.36±1.01	1.72	0.109
Easy to use	4.04±1.12	3.39±1.24	1.34	0.202
Fast	3.57±1.16	3.04±1.31	1.15	0.269
Would use	3.82±1.35	3.43±1.49	0.67	0.516

Participants

Five men and two women between the age of 18 and 57 (mean age = 38.86 years, SD = 14.29) participated. Two of them were blind from birth, four lost their vision later in life and one could still differentiate between light and dark. Five of the participants were right-handed and two ambidextrous. Two of them were users of the talking fingertip method.

Procedure

For the longer-term evaluation we used the iPhone 4 (with iOS 5.1.1), which was configured to work exactly in the same way as TalkBack in the short-term evaluation. Participants had to enter given texts (92-99 characters per method) in a specific sequence every day with EdgeBraille as well as VoiceOver. The input was logged to ensure participants conducted all training sessions. At the beginning, the eighth and the 15th day of the study, a lab session was organized to assess the participants' performance and opinion. Participants had to enter five texts (two words with 19 ±1 characters) and were asked about their opinions towards the methods.

Data analysis

The same data analysis scheme was conducted like in the short-term evaluation (ANOVA and *t*-tests).

Results

At the end of the two-week training, participants were able to enter text at an average with 7.17 (SD = 2.14) wpm with EdgeBraille and 6.29 wpm (SD = 2.60) with VoiceOver, which is no statistically significant difference ($F_{1,6} = 1.92$, $p = 0.215$). The data analysis shows a significant training effect ($F_{2,5} = 12.76$, $p = 0.011$), and a significant difference in wpm between the first and the third test for EdgeBraille ($t_6 = -3.72$, $p = 0.010$) as well as VoiceOver ($t_6 = -4.86$, $p = 0.003$). Figure 2 (right figure) illustrates these results.

The analysis of the user ratings reveals that averaged over all three lab sessions EdgeBraille always received a slightly (not statistically significant) higher rating than VoiceOver in all four scales. The detailed results are shown in Table III. Regarding the preferences, we allowed the participants to state multiple preferences. We found a clear preference for VoiceOver in the first session (five participants preferred VoiceOver, one EdgeBraille and one was indecisive). This changed in the second session, where EdgeBraille was the most preferred input method (four preferred EdgeBraille, one VoiceOver and two were indecisive). In the last session the preference for EdgeBraille and VoiceOver was balanced (three preferred EdgeBraille, three VoiceOver and one was indecisive).

6. Discussion

With regard to performance measures, our results show no difference between EdgeBraille and the talking keyboard approaches. Also, looking at reported results from related work, EdgeBraille has a comparable input speed as TypeInBraille and Perkinput, but seems to be faster than BrailleType and slower than BrailleTouch.

In our research, participants stated that Braille-based methods are especially suitable for people who do not know the QWERTY keyboard layout very well. On the other hand for people familiar with the keyboard it is easy to find specific letters. Two disadvantages of Braille-based methods compared to keyboard-based methods are the need to know all Braille characters by heart and that it is not clear, which characters exist, as they cannot be directly accessed with the talking fingertip technique. Therefore, a Braille-based text input method should also provide a possibility to search for unknown characters. Regarding the prototypical implementation of EdgeBraille, participants were also missing some control characters such as delete, enter, cursor back and cursor forward. These could be implemented by assigning unused Braille combinations, although those are not standardized and therefore could decrease learnability.

However, our participants appreciated that with EdgeBraille there are fewer elements on the screen compared to talking keyboard and that the elements are larger. Also, compared to the talking keyboard methods, Braille-based approaches do not completely depend on speech output and special characters can be entered more easily.

Another advantage of EdgeBraille pointed out by our participants is that Braille letters are entered in one stroke and users can make use of their knowledge about the shape of Braille letters ("It is almost like writing for a sighted person"). An important factor decisive for the usage and perceived usefulness of Braille-based text input seems to be the ease of transferring the learned Braille patterns into input mechanisms. An analogue and direct matching of Braille-based patterns and input mechanisms seems to be preferred. This applies to all approaches that enable to input a Braille character in a single step and do not segment the process in different steps. According to our observations in the EdgeBraille evaluation and self-reported data by the participants' column wise strategies for entering the Braille letter are more common and preferred. Thus if multi-step input is considered a column wise approaches should be applied.

Table III Average user agreement to the four statements for each input method (1 = strongly disagree, 5 = strongly agree) with standard deviation (±) *t*-value with degree of freedom and significance (*p*-value); mean over all three lab sessions

	EdgeBraille	*TalkBack*	t_6	*p-Value*
Easy to comprehend	5.00±0.00	4.67±0.51	1.73	0.134
Easy to use	4.57±0.32	3.90±0.98	1.57	0.167
Fast	3.90±0.79	3.38±0.52	1.28	0.249
Would use	4.10±1.08	3.86±0.77	0.37	0.723

Due to the lower number of target elements in Braille-based approaches (typically six elements) compared to keyboard implementations (typically more than 26 elements) the Braille-based interfaces can be designed much smaller. This concurs with the feedback obtained from participants, that they would prefer a smaller version of EdgeBraille and expected it to be faster than the full-screen version. The call for a smaller version was supported by participants stating slowness due to the large distances between the dots as the main disadvantage of EdgeBraille.

Furthermore, participants mentioned that the smaller version could be operated when holding the mobile phone in one hand and swiping with the thumb. In this way the second hand is free for other activities. This possibility of a one-handed operation exists for EdgeBraille and TypeInBraille, whereas Perkinput require the usage of multiple fingers and a stable positioning of the mobile phone. BrailleTouch requires multiple fingers of both hands. The two-handed method with the smart phone display turned away from the user is very fast but it has important limitations related to its application. When using the method both hands are occupied and alternation between different tasks types (e.g. text input and menu navigation) may be tedious.

Another aspect worth noticing is that the currently used six-point Braille version could be extended to improve text input performance. By the implementation of Grade-2 Braille, contractions and abbreviations could be entered instead of whole words.

Based on these insights, EdgeBraille offers specific possibilities of further improvement of Braille-based methods. EdgeBraille could be used in scaled down versions, which do not occupy the whole screen's real estate. Therefore it could better be integrated with applications, because text input is no goal in its own but typically used in combination with other interface elements. This applies also to TypeInBraille and BrailleType but not to Perkinput and BrailleTouch as the size of the interface is directly related to the user's hand size and could not be scaled down to very small configurations. We expect that smaller versions enable further increases in performance because the required traces for the users' fingers are shorter. At the same time we expect an increase of errors in a smaller version, as it becomes more difficult for the users to avoid non targets.

Finally, all Braille-based methods discussed in this paper – including EdgeBraille – use six-point Braille. Though it seems that for text written with a mobile phone six-point Braille is sufficient, participants of our research activities call for the eight-point version to have a greater repertoire of characters. EdgeBraille could be easily extended to an eight-point version, and we expect only minor performance degradation. Similarly Perkinput, TypeInBraille and BrailleType could be easily extended to eight-point versions. In the case of BrailleTouch an extension to eight-point would be problematic, as users will encounter difficulties in handling the device in a stable manner.

7. Improvements

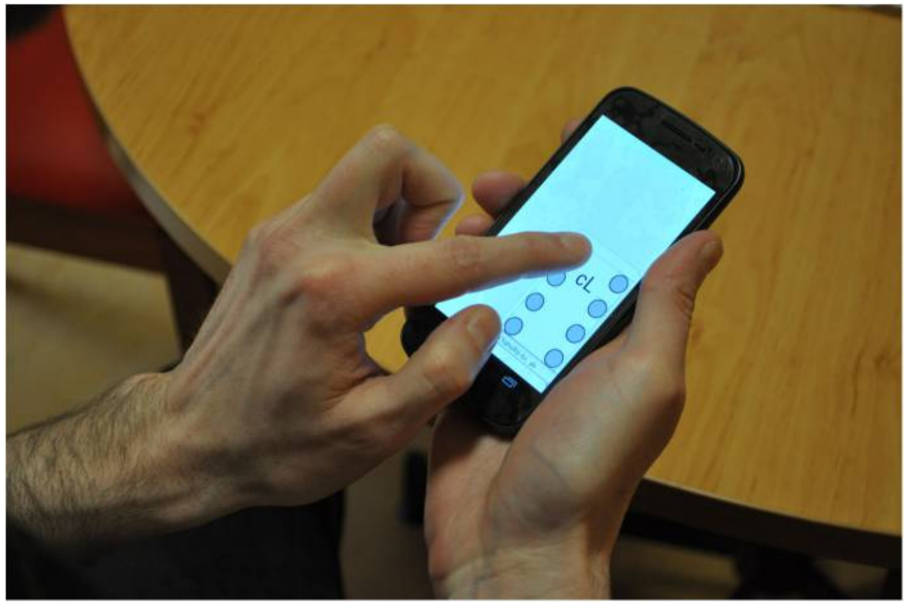
To analyse the identified improvement potential – smaller size and eight-point Braille – we developed a version of EdgeBraille allowing input of eight-point Braille, which was scalable to different sizes. The main advantage of eight-point Braille is that it allows input of 256 possible characters thus the whole ASCI set of characters can be implemented.

We created two versions of eight-point EdgeBraille, one scaled by the factor 0.5 (occupying a quarter of the screen, see Plate 1) and one scaled by factor 0.3 (occupying a ninth of the screen). These smaller versions could seamlessly be used as alternative text input method instead of the talking keyboard, by integrating it with typical smart phone use cases (e.g. writing e-mails).

To provide tactile feedback, we used regular screen protection foil where the area occupied by eight-point EdgeBraille was cut out, to create a perceptible edge for guidance of the input finger. This approach for providing tactile feedback is similar to the one presented by Zimmermann *et al.* (2014). The authors found that these haptic structures can serve as additional feedback in nonvisual situations (demonstrated for an in-vehicle application).

In the eight-point version of EdgeBraille we also extended the range of functions. We added the possibility to delete characters and to search for unknown characters, by assigning unused Braille combinations. For example, to delete a character the unassigned dot 7 (down, left corner)

Plate 1 8-point Braille version of EdgeBraille (scale 0.5), guidance with display protection foil



was used. Moreover the text written so far could be spoken to the user by the text to speech engine. A double tap anywhere on the screen triggers the text to speech engine.

Also a possibility to search for unknown characters was implemented. For activating the search mode the user has to activate dot 7 and 8; then audio feedback that the search mode has been activated is provided to the user. As a next step the user has to type in the first letter of the wanted character. After that the eight dots are assigned with special characters and the user can select the desired character by activating that certain dot. For example if the user wants to search for the character @ she has to activate dot 7 and 8, after that she types in the letter "a". Every dot is now assigned with a special character. By moving her finger across the dots she can scan through the possible characters (in this case @, ", #, ´ and .) using the talking fingertip technique, and by selecting dot 1 the character @ is written. By these means the text input method could be used in a more realistic manner than before.

The prototype was installed on a Galaxy Nexus Android 4.2 device. The input area of the 0.5 version is 30 mm×42 mm and dots are separated 5 mm vertically and 15 mm horizontally, with each dot having a diameter of 7 mm. The defined areas for the 0.3 version was accordingly smaller (input area 19 mm×23 mm, dots separated 3 mm vertically and 10 mm horizontally, dot diameter of 4 mm).

Proof-of-concept

We conducted a first proof-of-concept study with seven participants, two men and five women aged between 13 and 58 years (mean age = 23.57 years, SD = 15.80). Two participants were born blind, two late blind (born visually impaired), two blind on the right eye with low vision on the left eye (5-10 per cent) and one participant had residual vision. All participants were right-handed. Six owned a touch-based mobile phone (and therefore already had a lot of experience with the talking fingertip method) and one owned a phone with hardware buttons.

In the study every participant had to enter a set of phrases using EdgeBraille in the 0.5 version as well as the Android text talkback keyboard. The order of methods and phrases was counterbalanced. Of particular interest was the input of special characters, thus we based our set of phrases on the phrases used by Költringer and Grechenig (2004). Our phrase set consisted of the following types: Twitter, German text, e-mail address, password, English text (phrase set by MacKenzie and Soukoreff, 2003) and web address. The time needed for input of a phrase was logged by the application. At the end of a trial we presented the 0.3 version of EdgeBraille to the participants and let them try it out. Then an interview was conducted to gain further feedback on the advantages and disadvantages of the presented methods.

Initial results

The proof-of-concept reveals that users are able to enter text including special characters using the eight-point version of EdgeBraille in both sizes (0.5 and 0.3). Input speed and error rate differ widely depending on the experience with Braille-based input in general and knowledge of eight-point Braille in particular. In Table IV you see, that the mean wpm values are higher for VoiceOver than for the 0.5 version of EdgeBraille for almost all text types, probably also due to the initial experience of six of the participants with the talking keyboard method. Only for passwords, which include several special characters, participants were quicker with EdgeBraille. The differences are not statistically significant ($p > 0.05$).

Considering the experience advantage of VoiceOver in the present proof-of-concept study, it has still to be proven, if EdgeBraille could achieve similar results or even outperform VoiceOver in long-term use. However, from the initial results we see that the eight-point version of EdgeBraille is a promising approach for entering special characters, which is cumbersome to do with the talking keyboard approaches.

Moreover we could show, that it is possible to use a scaled down version of EdgeBraille with a perceptible edge provided by cut out screen protection foil. All participants stated that the guidance by screen protection foil was helpful, although two participants stated that in real life they would only use it if possible without foil, as the edges provided by the foil may be distracting when performing other tasks than text input. Regarding size the 0.5 version was perceived well, the 0.3 version was perceived as too small by five participants. Providing the user the possibility to tailor the size of the input element to their preferences might be a suitable option.

8. Conclusions and future work

In this paper we presented a new Braille-based text entry method and discussed different approaches of text entry for VIB people on touchscreen devices. Braille-based text entry mechanisms are an important possibility to complement current text input paradigms based on talking keyboard. Overall EdgeBraille was perceived well by the users, possesses favourable handling characteristics and performed comparable to talking keyboard. Especially when considering the improvements and in combination with haptic touchscreens, EdgeBraille has potential to become a convenient form of text input for Braille literate users.

In future work we plan to examine the optimal size that balances speed and error, and analyse text input performance of the eight-point EdgeBraille approach in detail. Furthermore we want to work on the integration of Braille-based text input with typical smart phone use cases.

Table IV Average wpm for each input method with standard deviation (±) *t*-value with degree of freedom and significance (*p*-value)

	EdgeBraille	*VoiceOver*	t_6	*p-Value*
Twitter	0.98±0.59	1.78±0.70	−1.94	0.100
German text	1.99±0.80	3.40±1.69	−1.92	0.104
E-mail address	1.87±0.73	2.49±1.75	−1.16	0.289
Password	1.59±0.95	1.32±0.49	0.69	0.519
English text	3.18±1.29	5.20±2.34	−2.20	0.070
Web address	2.18±0.86	2.61±0.88	−1.86	0.112

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