Two-button Mobile Interface: Touchscreen Based Text-Entry for Visually-Impaired Users

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***Abstract*—As the usage of mobile devices grows explosively, texting on a touchscreen becomes everyday routines for communication. For visually-impaired people, however, text-entry on the touchscreen is largely cumbersome and time-consuming due to the difficulty of locating keyboard buttons without any physical signifiers. We present new text-entry methods based on the Braille system to address this issue. The proposed Left Touch and Double Touch schemes are based on the two-button interface for Braille input, so that visually-impaired users can type textual characters without moving their fingers to find target buttons. We conducted experiments to evaluate the usability of the proposed methods and compared them with the One Finger Method and VoiceOver. The results show that the speed of the Double Touch is 3.94 second per letter (SPL) while that of the Left Touch is 2.60 SPL. The Left Touch was twice as slow as the VoiceOver but 39% faster than the One Finger Method. Although the typing speeds of the proposed schemes were slower than the VoiceOver, we found that the subjects felt the proposed schemes more comfortable to use than the VoiceOver. The convenience of using only two buttons in the mobile interface also enabled visually-impaired users to be less dependent on auditory feedback while typing texts.**

Keywords-visullay-impaired; touchscreen; text-entry; input; Braiile.

I. INTRODUCTION

Despite the technological advances, there are still groups of people that cannot benefit from the recent innovation because such advances usually aim to address the demand of the general public. One example is the touchscreen technology that fails to serve visually-impaired people. They acquire information mainly through auditory and tactile senses, whereas touchscreens require high dependency on vision. Touchscreens lack physical components to support auditory and tactile senses of visually-impaired people. Because visually-impaired cannot find a target to touch on the screen [3][8][16], regardless of the inventors' intention, visually-impaired people are naturally excluded from using touchscreens. As mobile devices and interfaces for smartphones become an essential element of modern life and communication, visually-impaired people have been facing unprecedented frustration.

Among a number of issues associated with touchscreens, we focused on text-entry methods on touchscreens for visually-impaired people. Although there are numerous assistive typing devices for visually-impaired people, such as the Braille Hansone [6], these devices are typically not light and portable, thus less desirable for smartphones. There are also existing text-entry tools for visually-impaired users. For example, iPhone, the most popular smartphone among visually-impaired users, has its own eye-free interface called VoiceOver [1]. It supports text-entry based on the standard QWERTY keyboard, using a split-tapping method [7] to find and touch each character. Although VoiceOver is a dominant text-entry interface among visually-impaired users, it still has a problem. The number of target buttons is too large, while the size of each target is too small for visually-impaired users to locate and touch easily. In addition, because VoiceOver requires high dependency on auditory sense, it is difficult to use in noisy places. Most of other existing text-entry methods have similar audio-related problems. Therefore, there is a pressing need to develop an appropriate text-entry method for touchscreens that is specifically targeted to visually-impaired people

In this research, we first review the previous approaches of alternative text-entry methods for visually-impaired users, and evaluate the advantages and disadvantages of each approach. Based on the review and evaluation, we developed new Braille based text-entry methods, called Left Touch and Double Touch. These two text-entry methods use only two buttons in the mobile interface, so visually-impaired users can input letters without changing finger positions. That is, visually-impaired users do not need to scan and search the touchscreen to find a target. At the same time, the level of dependency on auditory sense is relatively low in the proposed method.

We begin this paper with the analysis of background (Section 2), followed by the detailed presentation of our text-entry methods, Left Touch and Double Touch (Section 3). Then we report the methodology and results of our experiment (Section 4, 5). As a conclusion, we discuss the analysis of the experiment result and its implications for future research directions (Section 6).

II. BACKGROUND

In this section, we discuss basic Braille system and researches related to text-entry for visually-impaired users to provide background knowledge of our research.

A. Text-entry Methods Based on Braille

Since developed in 1825, the Braille system has been used for reading and writing characters by visually-impaired people. One Braille character consists of six dots with three rows and two columns as shown in Figure 1, so 64 different letters can be represented in principle.

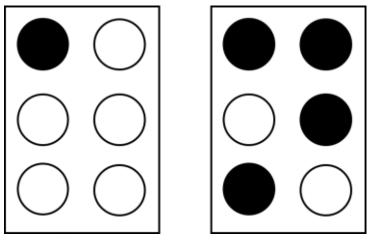

Figure 1. Examples of Braille characters (the black circle means a raised dot, and the white means a flat): Lower-case 'a' (left); Lower-case 'n' (right).

Each dot could be raised or remain flat so that people can figure out characters with tactile sense. Since most of visually-impaired people learn Braille, the advantage of text-entry based on the Braille system is the relatively low barrier for learning compared to non-Braille based entry methods.

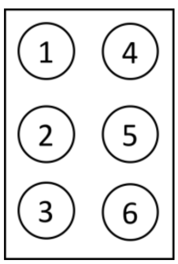

Figure 2. The numerical order of each dot.

There is a numerical order for the dots in a Braille character. As shown in Fig. 2, the three dots in the left column have an order of 1 to 3, whereas three dots in the other column have an order of 4 to 6. Since this order is widely known to visually-impaired people, recognizing Braille in different orders would be challenging for them [11]. Therefore, it is important to keep the same order when designing new text-entry methods.

Naturally, many previous Braille based text-entry methods place six buttons on a touchscreen to map the Braille cell directly. An example is *BrailleType* presented by Olivia et al [12]. In *BrailleType*, the user inputs one dot at a time by touching a corresponding button on the touchscreen. The speed was 1.45 wpm, which was relatively slower than the speed observed in other similar studies [10][14]. Paisios et al. presented four text-entry methods based on the Braille system [11]. The most preferred one was the *One Finger Method*, which is similar to *BrailleType*. In *BrailleTouch* presented by Southern et al., users input six dots in the Braille cell simultaneously using six fingers [14]. To use *BrailleTouch*, users hold a device with two hands and the screen faces away from them. This method, however, may cause difficulties since the general holding posture is opposite from the typing posture. Usually, users hold smartphones to face them for general use. In *BrailleTouch*, the average speed of experts group was 23.2wpm, while that of non-experts group was 9.4 wpm.

Mascetti et al. presented *TypeInBraille*, where users input one row at a time [10]. The speed was 6.3 wpm. Although there are no quantitative data available to be compared with other Braille-based input methods, it is possible that visually-impaired users may experience some confusion by the different order of the dots from the conventional Braille character and the need for additional training and practices [11].

Based on the review of the previous methods, we view that there are three advantages in the Braille-based text-entry method. First, visually-impaired users are already familiar with the Braille layout and the function of buttons. Second, users do not have to newly learn how to input in the Braille-based system different from VoiceOver since the input methods use Braille characters. Third, the number of target button decreases. For example, the maximum number of target in text-entry methods based on Braille is six. That is a relatively small number of target button compared to other text-entry methods, such as QWERTY. To leverage these advantages, we propose a simple text-entry layout with a smaller number of targets, for easy input way and small cognitive load. In this research, we use the *One Finger Method* as a baseline for our experiment, because it is the simplest way of input based on the standard six buttons format of Braille characters.

B. Other Text-entry Methods

Kane et al. presented *Slide Rule*, an eye-free interface for touchscreens with audio-based multi-touch techniques [7]. Later, *Slide Rule* was incorporated into the *Apple*'s *VoiceOver*, which supports QWERTY-based eye-free text-entry. In *VoiceOver*, since there are too many tiny targets, visually impaired users have to explore the keyboard with the finger to find targets [10]. Due to the small size and the lack of tactile feedback [13], even skilled users can rarely find a key without initial scanning. Due to the difficulty of recognizing the visual layout, QWERTY may not be a viable solution of text-entry design for visually-impaired users. Bonner et al. presented *No-Look Notes*, which uses the multi-touch interface and audio feedback [2]. In *No-Look Notes*, 26 letters of the English alphabet are arranged around the screen in an 8-segment pie menu reminiscent. In one segment, there are three to four letters. When a user touches a target segment, the letters in the targeted segment appear in the alphabetical order from top to bottom on the screen. The speed was 1.32 wpm. Niazi et al. applied similar mobile 3*4 keyboard concept to touch screen text-entry, and compared the results with QWERTY keyboard [18].

Oliveira et al. also presented *NavTouch*, which is a gesture-based interface [5]. The average speed was around 1.7 wpm. Heni et al. also proposed gesture based text-entry and the speed was about 12 WPM [19]. On the whole, it appears that text-entry methods not based on Braille have fundamental problems that visually-impaired users need additional training and prolonged experience to skillfully use such methods.

III. The Proposed Text-Entry Methods

Based on the review of the existing text-entry methods, in the initial stage of our research, we set the following three design principles to propose a new mobile text-entry interface for visually-impaired users:

- Principle 1: Design a text-entry method based on the Braille system for the simplicity of the interface layout, and the fewer burdens for additional training and practices.
- Principle 2: Design a text-entry method with a minimal number of targets, thereby users do not have to move their position of fingers extensively.
- Principle 3: Design a text-entry method less dependent on auditory sense, so that visually-impaired people can use it in noisy places without solely depending on auditory feedback.

A. *Two-Button Interface*

Based on the first and second design principles, we designed text-entry methods that have only two vertical buttons for Braille character input as shown in Fig. 3. In the rest of the paper, we use the term LEFT button for the button on the left side and RIGHT button for the other one.

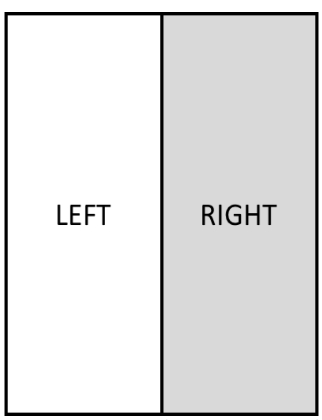

Figure 3. The layout of two-button interface.

Using this two-button interface, we propose two types of text-entry methods, called Left Touch and Double Touch. For each method, users can input a letter using the LEFT and RIGHT button. Fig. 4 shows three different holding postures for using the two-button interface. Users can hold a smartphone with one hand and typing with another hand (Fig. 4, left), hold and typing with the same hand (Fig. 4, middle) or using both thumbs for input (Fig. 4, right).

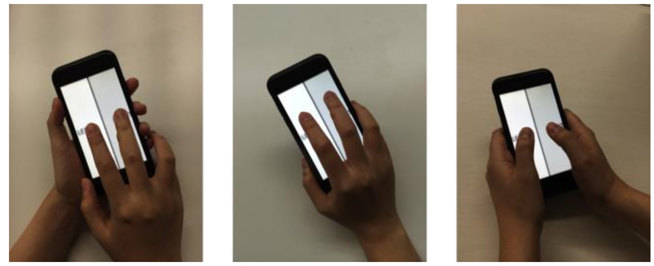

Figure 4. Holding postures for using the two-button interface: Holding with one hand, and typing with the other (left); holding and typing with the same hand (middle); typing with both thumbs (right).

One of the most important features of the two-button interface is that it minimizes the movement of fingers on the touchscreen. Users only need to lift fingers up and down at the same position. By applying the two-button interface, it is expected that Braille input on touchscreens can be convenient and easy for visually-impaired users. In the following section, we provide more detailed descriptions about each text-entry method in the two-button mobile interface.

B. *Left Touch*

Visually-impaired people recognize the numerical order of dots when understanding Braille characters. To leverage on this learned behavior, in the Left Touch method, users input dots in a regular order. The operating mechanism is simple. If a user wants to mark a dot, touch the LEFT button; otherwise, touch the RIGHT button. Users always touch buttons six times to complete one letter since one Braille character is composed of six dots. After typing one letter, the system presents audio feedback that informs users of the typed letter for confirmation.

For example, the sequence of touching the alphabet ‘n’ is ‘LEFT→RIGHT→LEFT→LEFT→LEFT→RIGHT’ as shown in Fig. 5 (top).

Users can delete letters by swiping upward on the LEFT button, and input a ‘space’ by swiping downward on the RIGHT button. When users want to restart inputting a letter, they can cancel an inputted pattern and restart input by swiping down on the LEFT button.

Visually-impaired people that are familiar with Braille can easily adopt the Left Touch method because the touching sequence is same as the natural order for the original Braille system. The layout is highly simple to reduce the need for memorizing locations and functions of buttons. Finally, the dependency on auditory sense is relatively low because users can easily recognize the completion of a letter input through the fixed number (6) of touches for each letter.

C. *Double Touch*

In the Double Touch method, a user touches a button twice to mark a dot and touches a button once to mark an empty dot. Different from the Left Touch method, users input dots in the order of row, not in numerical order of

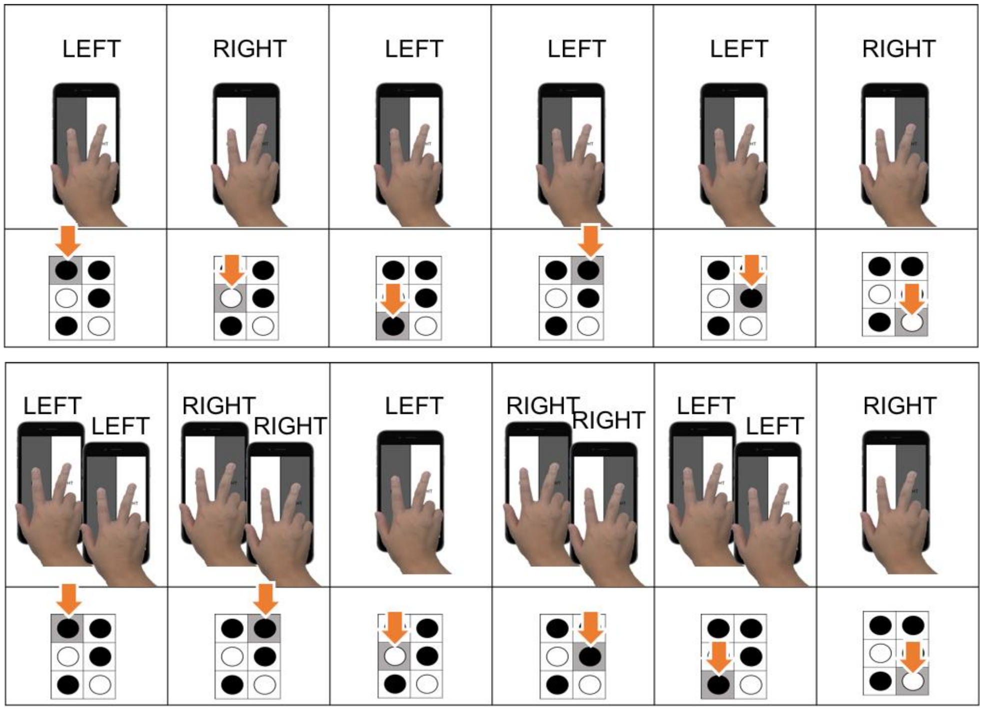

Figure 5. Way of inputting 'n' using different methods (each cell stands for each step for input, shaded buttons and dots mean a current step): Left Touch (top); Double Touch (bottom).

Braille. For example, users input dots for the first row, then for the second row, and finally for the third row. In the same row, left dots are inputted first. Therefore, the order should be 'left dot (1st row) - right dot (1st row) - left dot (2nd row) - right dot (2nd row) - left dot (3rd row) - right dot (3rd row)'.

In this scheme, we use the LEFT button for entering Braille characters in the left column and the RIGHT button for entering Braille characters in the right column. If users want to input left dots in a row as marked, they need to touch the LEFT button twice. Otherwise, if users want to input right dots in a row as empty, they need to touch the RIGHT button once. Following this rule, the sequence of entering the alphabet 'n' is '(LEFT-LEFT)→ (RIGHT-RIGHT)→LEFT→(RIGHT-RIGHT)→(LEFT-LEFT)→RIGHT' as shown in Fig. 5 (bottom).

The same audio feedback as in the Left Touch method is presented to inform users of the completion of letter input. Deleting, spacing and restarting mechanisms are also same as the ones for Left Touch. Since the order of entering each dot (1-4-2-5-3-6 in Fig. 2) is different from the conventional one (1-2-3-4-5-6), users may feel some confusion in the beginning. However, in Double Touch, dots and corresponding buttons mapped spatially to reduce cognitive load to remember the layout. Also, the way the buttons are pressed is rhythmical because a user touches the LEFT and RIGHT button alternately. The downside of this method, however, is that the number of touching may vary depending on the letters. In the worst case, the buttons have to be pressed 12 times (all dots are marked).

IV. EXPERIMENTS

We conducted an experiment with four visually-impaired participants. In the experiment, we compared the efficacy of our proposed methods, Left Touch and Double Touch with the existing methods including the One Finger Method, and VoiceOver.

A. *Participants*

We recruited four visually-impaired users for the experiment. All participants are university students from the same university located in a mid-sized city in Korea. As shown in Table 1, the average age was 24 (standard deviation=1.63, range: 22-26). Three participants were visually-impaired from birth. All of them were iPhone users, and used VoiceOver for more than two years. Also, all of them used Braille Hansone at least once. We asked the participants about their experiences with using the English Braille, since the tasks in the experiment were to type English letters. The average period of the English Braille experience was 10.75 years (standard deviation=4.03, range: 5-14).

TABLE I. PARTICIPANTS' CHARACTERIAZATION

	Age	Gender	C/A (age)	P/E(year)	P/V(year)
1	26	male	acquired(18)	5	3
2	22	female	congenital	11	2
3	24	female	congenital	13	3
4	24	female	congenital	14	3

*C/A(age)[Congenital or Acquired(age)];P/E[Period of Using English Braille];P/V[Period of Using VoieOver].

B. Apparatus

We used Galaxy S3 from Samsung for the One Finger Method, Double Touch, and Left Touch, and used iPhone4 for VoiceOver.

C. Tasks

1) Dictation

We used dictation as the main task. First, participants listened to specific sentences, and then entered the sentences with the given input method. We delivered sentence uniformly by using the Google translator [4] for Text-to-Speech method as suggested in [14]. Because all participants were not native English speakers, they were allowed to ask questions before starting text input when having troubles in identifying spellings.

2) Phrase Set

We used the 'standard set of 500 English phrases commonly used in text entry studies' developed by MacKenzie and Soukoreff [9]. Participants inputted alphabets in lower-case only. There were no numbers and punctuation marks. We recorded inputted logs and times to calculate second per letter (SPL) and to evaluate the accuracy of each entry method.

3) Procedure

Participants had four sessions of twenty-minute typing tasks. Before starting main tasks, they had a training session to learn and practice each text-entry method. Since all participants were familiar with VoiceOver, they did not have the training time for VoiceOver.

Each method was tested for one day, not to overburden participants and to reduce confusion and learning effects across the different methods compared. We did not conduct experiments for Left Touch and Double Touch continuously to avoid the ordering effect because two methods commonly use the two-button interface style. Half of the participants were given the Left Touch test first, whereas the others tried the Double Touch method first.

For data collection, we recorded both audio and video data. After finishing all experiments, the participants were asked to complete a survey concerning usability issues such as ease of use, willingness to use, and satisfaction. All survey questions were given in a five-point Likert scale (1=strongly disagree, 5=strongly agree), and open questions about the personal opinion on the method. The experiments were followed by semi-structured interviews for further details about participants' qualitative opinions.

4) Experimental Design and Data Analysis

For quantitative data, the dependent variables are speed and accuracy, with a 4 x 4 within-subjects analysis of variance: the four text-entry methods (Left Touch, Double Touch, One Finger Method, & VoiceOver) X four sessions (from the 1st to the 4th). To test the significance of the main effect, a Student Newman-Keuls (SNK) test was conducted as a post-hoc analysis. For the analysis, we assumed that for text-entry methods, the input speed would increase as sessions progress. Furthermore, we assumed that there would be significant differences among the four different input methods in terms of input speed.

V. Results

In this section, we report results of the experiments; speed, accuracy and survey results.

A. Speed

Fig. 6 shows means of the speed measured in the four sessions for each text-entry method. The unit for speed is SPL, which indicates the time taken to input one letter. Hence, the higher SPL value means that it takes longer time to input.

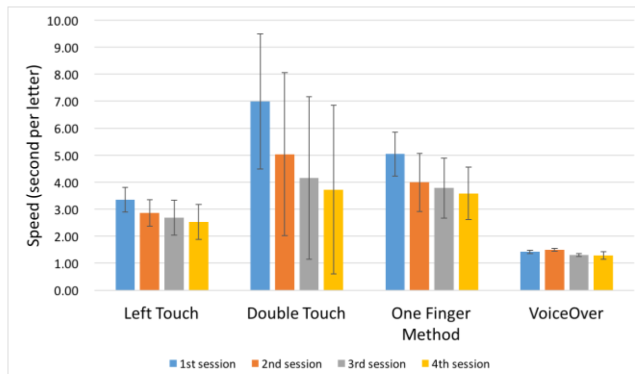

Figure 6. Speed results for the four text-entry methods across sessions (error bars± standard error).

Fig. 6 shows that VoiceOver (Mean SPL=1.38, SD=0.11) is the fastest among the four different text-entry methods compared ($F_{3,9}$=14.69, p<0.001). It was then followed by Left Touch (Mean SPL=2.86, SD=0.55), One Finger Method (Mean SPL=4.10, SD=0.91), and Double Touch (Mean SPL=4.98, SD=2.06). There was no significant difference between Double Touch and One Finger Method. The speeds among Left Touch, Double Touch and VoiceOver were significantly different from each other.

In terms of sessions, there was a significant effect ($F_{3,9}$=23.98, p<0.001). The first session was much slower than the others, with means of 4.20 SPL, 3.35 SPL (2nd), 2.99 SPL (3rd), and 2.78 SPL (4th), respectively. The SNK analysis indicates that the 1st session was significantly different from the 3rd, the 4th sessions. There was no significant difference in terms of speed for sessions of the 2nd, the 3rd and the 4th sessions.

There was a significant text-entry × session interaction ($F_{9,27}$=3.84, p<0.01).

To find the learnability effect of each text-entry, an ANOVA test was performed with the speed of sessions for each text-entry method as the dependent variables.

1) Left Touch

For Left Touch, the ANOVA test results show that there is a significant effect of session ($F_{3,9}$=28.82, p<0.0001). Although there was no significant difference between the 2nd and 3rd sessions, the 1st, 2nd, and 4th sessions were significantly different from each other. Since the speed became faster in the later sessions, the analysis result confirms that there is the learnability effect in Left Touch.

2) Double Touch

There were significant effects of session for Double Touch ($F_{3,9}$=7.08, p<0.01). Similar to the Left Touch, the speed became faster as sessions are repeated. However, the learnability effect was less than the effect observed in Left Touch. There was no significant difference in the 2nd, 3rd, and 4th sessions. Only the 1st session was significantly different from other sessions.

3) One Finger Method

Similar to the Double Touch method, significant effects in session were found for One Finger Method ($F_{3,9}$=9.22, p<0.01). While the speed became faster as sessions were repeated, there was no significant difference in the 2nd, 3rd, and 4th sessions. Only the 1st session was significantly different from other sessions. From that, it was found that the learnability effect of the One Finger Method was less than that of the Left Touch method.

4) VoiceOver

As expected, VoiceOver had little effect on learnability because the participants were already familiar with this method. Although the test results show that there was a significant effect of session ($F_{3,9}$=5.85), it was mainly due to the fastest speed of the 2nd session, which is significantly different from others. There was no significant difference in the 1st, 3rd, and 4th sessions. Note that Voiceover did not have any significant improvement in speed, whereas other text-entry methods showed about 20% improvements in speed from the first session and onward.

B. Accuracy

Regarding accuracy, there was no significant difference among the four text-entry methods, as measured in the number of errors in text input, because all participants corrected errors whenever they found them. Therefore, we analyzed the number of deleting action during the experiments instead. We set the number of deleting per letter, NPL, as a unit of analysis.

There were no significant main effects in both text-entry method ($F_{3,9}$=2.26, p>0.05) and session ($F_{3,9}$=2.99, p>0.05).

The mean number of deleting for Left Touch, Double Touch, One Finger Method, and VoiceOver were 0.0201 NPL, 0.0398 NPL, 0.0882 NPL, and 0.0507 NPL respectively. In other words, when the user types 100 letters, he/she only deleted letters 2 to 8 times only.

C. Survey Results

After completing all the experiments, we asked for participants' opinion through the survey and semi-structured interview. As shown in Table 2, in terms of ease of use, Left Touch and One Finger Method received the highest scores. VoiceOver received the highest score in willingness to use. In the satisfaction factor, the participants rated both Left Touch and Double Touch methods highly satisfactory.

TABLE II. SURVEY RESULTS ON A LIKERT SCALE (1= strongly disagree, 5= strongly agree).

	Left Touch	**Double Touch**	**One Finger Method**	**Voice Over**
Ease of use	4.25	3.00	4.25	3.75
Willingness to use	4.00	4.00	3.50	5.00
Satisfaction	4.00	4.00	3.25	3.75

VI. DISCUSSION

In this section, we discuss results of experiments

A. Speed

Among the four text-entry methods compared, it was observed that VoiceOver was the fastest one. For the accurate analysis, we used the speed from only the 3rd and 4th session, since three text-entry methods except VoiceOver showed the learnability effect. VoiceOver was still the fastest among the four different text-entry methods with 1.29 SPL. It was then followed by Left Touch (2.60 SPL), One Finger Method (3.68 SPL), and Double Touch (3.94 SPL). Left Touch was twice slower than the VoiceOver but 39% faster than the One Finger Method.

To compare this with results from previous research that used word per minute (WPM), we converted the speed unit from SPL to WPM [2][12]. The converted speed for our participants was 9.30 WPM that was faster than the speed of the methods proposed in [2], 0.66 WPM and [12], which was 2.11 WPM [12]. We speculate that the reason for large differences between our participants and the others is likely due to the following reasons; 1) all participants were experts of VoiceOver who had used the system for more than two years. 2) All participants were university students who were relatively heavy users of smart phones. This is also one of the reasons that magnify the speed difference between VoiceOver and others.

In contrast to the extensive experience of using VoiceOver, participants used other three text-entry methods for 100 minutes only. This difference was also a significant factor that affected the speed of other text-entry methods.

In case of other three text-entry methods, the speed increased with the number of sessions (Fig. 6). It indicates that there were the effects on learnability for three text-entry methods. Hence, it is possible to improve speed if users have more time to use. Two participants described that they felt experienced in using Left Touch, and that the speed would increase as time went by. Both of them mentioned that they liked to use the Braille system.

> **Quote 1 (P2).** I think this (Left Touch) will be convenient, because I am familiar with the Braille system. It will be faster if I get used to it, since it only needs six times of touching.
> **Quote 2 (P3).** The Braille system was made for the visually-impaired, so it is very convenient for us. I think it (using Left Touch) may become faster.
> **Quote 3 (P3).** At first, I tried to think what to touch. For example, to touch ‘t’, I have to touch that button. However, as I used Left Touch over time, my finger naturally moved. It felt like my finger moved automatically without even thinking.
> **Quote 4 (P4).** In case of Left Touch, I felt my finger moved faster than my thinking, because I could remember the pattern of Braille.

The participants have conceived the shape and pattern of Braille through years, so the process of recalling Braille character is highly natural and easy to them. Using the Braille-based system, we can support natural text-entry for visually-impaired users. Hence, we assumed that it is worthwhile to make comparison among the Braille-based method to identify which factors are important in terms of improving the Braille typing speed. We report them in the following section.

1) Double Touch vs. Left Touch

Left Touch was faster than Double Touch. Both Double Touch and Left Touch are based on the two-button interface. However, the number of buttons for touching an alphabet is different. In Double Touch, a user touches at least 6 times, and 12 times in worst case, whereas in Left Touch, a user touches 6 times in every case. In addition, the mapping rule in Left Touch is more natural as the order of pushing buttons is same as the conventional order of entering Braille characters explained earlier. Hence, we believe that Left Touch is the better method to apply the two-button interface than Double Touch.

2) Left Touch vs. One Finger Method

There are two main differences between Left Touch and One Finger Method; 1) One Finger Method is based on the six-button interface, so users have to change the position of fingers. 2) Different from Left Touch, the number of touching is not fixed in the One Finger Method. In Left Touch, although the average number of touching is more than other text-entry methods such as VoiceOver and One Finger Method, a user does not have to change position of fingers. From this comparison, we believe that limiting the range of finger movements and having the fixed number of touching are more important than reducing the average number of touching. This finding is also supported by the users’ quotes during the interview:

> **Quote 5 (P1).** If I can figure out the exact position of each button, the One Finger Method will be better. However, it is very difficult for visually-impaired people.
> **Quote 6 (P3).** I do not like the One Finger Method because the finger movement is too much.

B. Accuracy

We measured the error rates of text-entry methods using the NPL numbers. The measured data ranged from 2% to 8%, which is much smaller than the results in the previous research in which the error rate of expert group was 14.5%, and that of the average group was 33.1% [14]. Our participants might have been more careful not to make typing errors compared to those in the previous research.

C. Satisfaction

Satisfaction is a subjective factor. After completing all the experiments, we conducted the survey and semi-structured interviews to collect participants' opinion.

Both of the proposed two-button interfaces, Left Touch and Double Touch were well-received by the participants because their dependency on auditory sense was lessened. Fig. 7 (left) and (right) show the pictures of the participants using VoiceOver and Left Touch taken in a noisy place during the survey.

Figure 7. Different postures for VoiceOver (left) and Left Touch (right).

When visually-impaired people use VoiceOver, they cannot input without hearing auditory feedback. Therefore, the participant in the Fig. 7 placed the mobile phone close to her ear (Fig. 7 (left)). In case of Left Touch, they can recognize the patterns of each letter, thereby using auditory sense as an assistive means not as the essential one. Note that the participant in Fig. 7 (right) placed the mobile phone on the table far from her ears. The participants mentioned about this advantage of being less dependent on auditory feedback during the interview, as follows:

> **Quote 7 (P1).** When I use VoiceOver, I cannot hear any other sound. I have to concentrate on VoiceOver’s audio feedback.
> **Quote 8 (P2).** I cannot use VoiceOver in such a noisy place. When I used a folder phone, I could input without hearing any sound. However, now I cannot do that (with VoiceOver).

From this, we believe that Left Touch is more effective in a noisy place than VoiceOver, because its dependency on auditory sense is relatively less.

D. Ease of Use

Left Touch and One Finger Method were well received in terms of the ease of use. Both of them are based on the Braille system and use relatively simple input patterns.

In contrast, Double Touch received lower scores. The reason might be that Double Touch has a variable number of touching for a letter and that the order of button is different from the original Braille system as explained earlier. From this observation, we believe that distinguishing marked and unmarked dots in a Braille character by spatial differences is likely to be more user-friendly than distinguishing them using the difference in the number of touching. Note that VoiceOver also received a lower score than Left Touch. Some participants complained that the input method of VoiceOver had been too complex although they were used to VoiceOver.

E. Willingness to Use

All Participants gave five points for VoiceOver in terms of the willingness to use. The fast speed and familiarity were the main reasons behind this result, as indicated in the following quotes:

Quote 9 (P1). Until now, there is no replacement for VoiceOver.
Quote 10 (P2). I gave 5 points for VoiceOver in the 'Willingness to Use' factor because it is the most convenient for now, anyway.

Participants gave a higher score for the Left Touch than the One Finger Method because of its usability and simplicity.

F. Additional Feedback on the Two-Button Interface

In this research, we proposed two text-entry methods that are based on the two-button interface. Between Left Touch and Double Touch, we found that Left Touch is better than Double Touch in terms of speed and ease of use.

Participants suggested some interesting ideas for the potential application where two-button interface can be used. For instance, they wanted to use it in large screen interfaces.

From this feedback, we think that large screen interfaces in public places could be another exciting application for Left Touch because users do not have to fully concentrate on audio feedback, and do not have to scan the screen for input. This kind of approach matches with the ability-based design introduced by Wobbrock et al. [15] that suggested a design interface to utilize the full range of human potential not to focus on disabilities.

Quote 11 (P3). Left Touch can be used for other applications. For example, ATM has the touchscreen interface but I cannot use it appropriately. Of course, there is audio feedback, but it takes long time to use. If there were Left Touch in ATM, it would be convenient.
Quote 12 (P4). It (two-button interface) would be good if we use it in large touchscreens such as reservation machines in a train station. If we use VoiceOver in large screen, it would be difficult to scan, but we can apply the Two-button interface easily in large screens.

VII. Future Work

There were a few limitations in this research. The followings are plans to do further work.

A. Automatic Correction System

iPhone has an automatic correction system. For convenience, Left Touch and Double Touch should have such an automatic correction system like iPhone, which could greatly reduce the number of actions for deleting and restarting, thereby increasing speed of text-entry methods.

B. Abbreviation

Many visually-impaired people are familiar to use abbreviations for frequently used English words like 'with' and 'out'. However, Left Touch and Double Touch currently do not support such abbreviations. The participants were confused when they inputted some words that have well-known abbreviations. If the system supports abbreviations, it could significantly reduce the number of touching and eventually improve the speed for text-entry.

C. Finding Suitable Applications

Some participants suggested that the two-button interface would be applicable for large screen applications. As future research work, we plan to evaluate the strength of two-button interface by conducting experiments based on large screens, such as tablet PC or large touchscreen machines in public spaces. Furthermore, by conducting experiments in noisy places, we plan to evaluate the strength of low dependency on auditory feedback in our proposed methods.

D. Needs for Longitudinal Study

This study lacks the number of participants and period of using proposed methods. To get valid and statistically significant results, future work with more participants is needed. In addition, participants' experience of VoiceOver and proposed method is disparate. Therefore, for fair comparison, we plan to conduct longitudinal study for proposed methods.

VIII. Conclusion

In this study, we proposed two types of touchscreen text-entry methods for visually-impaired users, called Left Touch and Double Touch. The key components of the proposed mechanisms are to use the two-button interface and the Braille system. The proposed two-button interface limits the range of finger movements on a touchscreen; hence, visually-impaired users can input English letters more comfortably. Although the experiment results showed that the proposed methods were slower than the VoiceOver, we believe that familiarity played a major role for the results as indicated by the learnability effect and survey feedback. The survey results also indicated that the Left Touch method, in particular, had various strengths such as ease of use and satisfaction. All participants agreed that Left Touch was easier and simpler to use than VoiceOver. Compared to the VoiceOver that requires visually-impaired users to rely on audio feedback, the proposed schemes do not have such limitations. Based on the overall feedback from the participants, we expect that our proposed scheme can be easily used for large screen applications or in noisy settings including movie theaters, bus terminals or restaurants.

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 ISBN: 978-1-61208-538-8