SplitBoard: A Simple Split Soft Keyboard for Wristwatch-sized Touch Screens

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ABSTRACT

Text entry on a smartwatch is a challenging problem due to the device's limited screen area. In this paper, we introduce the SplitBoard, which is a soft keyboard designed for a smartwatch. As the user flicks left or right on the keyboard, it switches between the left and right halves of a QWERTY keyboard. We report the results of two user experiments where the SplitBoard was compared to an ordinary QWERTY keyboard, the ZoomBoard, SlideBoard, and Qwerty-like keypad. We measured the initial performance with new users for each method. The SplitBoard outperformed all other techniques in the experiments. The SplitBoard is expected to be a viable option for smartwatch text entry because of its light processing requirements, good performance, and immediate learnability.

Author Keywords

SplitBoard; text entry; soft keyboard; smartwatch

ACM Classification Keywords

H.5.2 User Interfaces (D.2.2, H.1.2, I.3.6): Input devices and strategies (e.g., mouse, touchscreen)

INTRODUCTION

Many manufacturers have begun to produce smartwatch products. Unlike the early watch-sized computers [11], new smartwatches have the computing power and battery life comparable to early smartphones. One of the challenges in migrating applications from the smartphone to the smartwatch is the relatively smaller screen size of the smartwatch; there does not seem to be sufficient room for some GUI components, such as the soft keyboard.

It is doubtful that the QWERTY soft keyboard should be adopted on smartwatches. In order to find a soft keyboard design that is suitable for a smartwatch, we examined a diverse set of alternatives. A seemingly naïve soft keyboard design, that we call SplitBoard, implemented in this study, turned out to be a promising alternative. The SplitBoard is a scrolling QWERTY keyboard. As the user flicks left or right on the screen, the SplitBoard switches between the left and the right halves of a QWERTY keyboard. The SplitBoard layout utilizes the QWERTY layout to ensure immediate learnability. To assess the initial performance of the SplitBoard, we conducted two comparison experiments with users who had no prior exposure to the interface. The SplitBoard outperformed the four other techniques included in the experiments.

RELATED WORK

Text entry for a smartwatch can be implemented through speech recognition, handwriting recognition, a separate device such as a Bluetooth keyboard, or a few buttons in the watch frame with an encoding scheme such as MDITIM [5] or EdgeWrite [14]. However, soft keyboards are the dominant text entry technique on smartphones and tablets. We were interested to see how well soft keyboards would perform on a smartwatch.

The central theme in miniature soft keyboards is the balance between the number of keys and the ambiguity of a key press [6]. The multi-tap technique used in 12-key telephone keypads is an example of explicit, user-initiated disambiguation of ambiguous keys. The English language multi-tap requires an average of over two key presses for each character [6]. Assigning frequent characters to shorter key press sequences can reduce the number of key presses. An example of such an optimization is the QWERTY-like keypad (QLKP) used in our comparison experiments as a representative of multi-tap text entry methods. An evaluation by Hwang and Lee [2] showed that the QLKP was superior to the standard telephone character layout.

Dictionary-based disambiguation can relieve the user from explicit disambiguation by key presses. On the 12-key telephone keypad, dictionary-based disambiguation brings keystrokes per character (KSPC) down to about one [6]. A word gesture keyboard [15] combines a conventional soft keyboard with the ability to draw the key sequence on the keyboard without lifting the finger for faster entry of words. A language model is needed to disambiguate the input. Word-gesture keyboards are widely available on smartphones; however, it is not known how well they perform on the small displays of smartwatches. We did not include techniques with language databases in our experiments. Dictionary-based data can be used in diverse

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ways for each keyboard design, which could be an additional comparison parameter in future work.

Tapping and sliding the finger on the display can be combined on touch screens. Sliding gestures can be either straight lines akin to selecting in one-level marking menus [3] or recognized as shapes akin to handwriting [4]. A publicly available example of a tap-gesture keyboard is the MessagEase system [9]. While tap-slide combinations can save motor effort and are potentially fast for experienced users, planning the tap-slide movements is difficult for new users, which makes these movements time consuming [3, 12]. Combining a tap or key press with some other measure, such as the tilt of the device [13] or pressure applied [8], has been proposed.

Using a two-step selection technique, where the first pointer location is used as the center of the region to zoom in for a subsequent final target selection, is a well-known technique in eye-pointing [1]. This technique is used to overcome the noise in the tracker signal. Similarly, finger pointing is very noisy in extremely small devices. *ZoomBoard* [10] is a text entry technique based on this idea. In an evaluation using a tiny (16 x 6 mm) section of the iPad3 display, ZoomBoard outperformed a QWERTY soft keyboard. The superiority of ZoomBoard on the smartwatch display is not clear because the smartwatch display is usually larger than 16 x 6 mm.

SPLITBOARD

The QWERTY layout is wide; therefore, the keys become very narrow on a smartwatch. In SplitBoard, we divided the QWERTY layout into two sections: left and right. In addition to these two main sections, SplitBoard has a third component, as shown in Figure 1, for mode keys used for selecting upper case, numeric, and symbol entry modes, including an enter key. A horizontal flick gesture is used to change the section of the keyboard to be displayed.

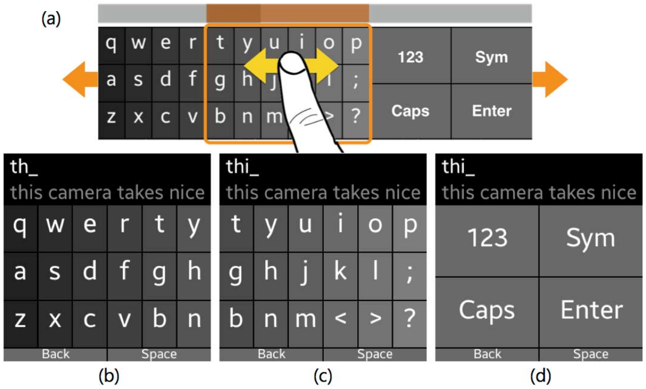


Figure 1. (a) Conceptual drawing of the SplitBoard and (b, c, and d) the three parts of the SplitBoard. When a user flicks from right to left on the part (b), the screen switches to (c).

Text can be entered by tapping on the keys. The space and backspace keys are located at the bottom of the screen. These keys are narrow but can be easily selected by touching the bezel below the screen. In our implementation of the SplitBoard, we displayed six keys per row with a two-column overlap. The number of gestures per character (GPC) changed as a function of the number of keys on a row. We conducted a simulation that estimates GPC using the 500 phrases set by Mackenzie and Soukoreff [7]. The result was approximately linear from 1.4 at 5 keys per row to 1 at 10 keys per row. We chose a two-column overlap as a compromise between key size and the number of flicks needed per character. The GPC in this case was 1.28.

EVALUATION

The conventional QWERTY keyboard (the QWERTY) is an obvious baseline for comparison. The ZoomBoard was found to be faster than the QWERTY on a very small keyboard [10]. The larger key size offered by the 12-key multi-tap technique was considered potentially important; therefore, we included the QLKP, which was found to perform better than the standard ABC keypad [2]. Finally, we wanted to include a representative of the tap-slide keyboard group. The MessagEase would have been our choice, except recent results indicate that the foreign layout causes a significant learning hurdle for new users [12]. Instead, we chose a tap-slide adaptation of the QWERTY layout that we call SlideBoard. In the SlideBoard, each key has two characters as shown in Figure 4c. We disambiguate key presses by sliding either left or right after landing on a key. A quick preliminary evaluation (3 participants, transcribing 5 phrases) showed that the SlideBoard (10.8 WPM) was faster than the MessagEase (<7.5 WPM [12]).

Before conducting the user study, we ran a simulation to compute GPC for the keyboards included in the evaluation. The results were 1.85 for both the ZoomBoard and the SlideBoard, 1.53 for the QLKP, and 1 for the QWERTY. For the ZoomBoard, the space character was counted as a single swipe gesture. For the SlideBoard, a tap and a following slide were counted as separate gestures. For the QLKP, we assumed that a user uses the space key for multi-tap segmentation when entering two characters in a same key consecutively. This result implied a better performance of the SplitBoard than other keyboards except the QWERTY.

Participants

We recruited 24 participants from our university. The participants were not native English speakers, but worked and studied in an English-speaking environment. The participants were divided into two groups of 12 participants. Participants in Group A (3 female, 9 male, mean age = 22.4) used the SplitBoard, ZoomBoard, and QWERTY. Participants in Group B (3 female, 9 male, mean age = 22.7) used the SplitBoard, QLKB, and SlideBoard.

Apparatus

The experiment was conducted on a Samsung Galaxy Gear with a 29.3 x 29.3 mm touch screen. The presented phrase and entered phrase were displayed above the keyboard area, as shown in Figure 1. The phrases were picked randomly from the 500 phrases set by Mackenzie and Soukoreff [7].

Participants wore the device on their non-dominant hand and used the index finger of the other hand to operate it.

The size of alphabetic keys was 2.9 x 5.3 mm for the QWERTY, 2.9 x 2.9 mm and 5.8 x 5.8 mm for the zoomed-out and zoomed-in ZoomBoard respectively, and 4.8 x 6.5 mm for the SplitBoard. The size of space and backspace keys on the SplitBoard was 14.5 x 1.8 mm. For keyboards used by Group B, we adjusted the positions and sizes of three function keys such that they were consistent across the three keyboards as shown in Figure 4. The size of the three function keys was 9.4 x 1.8 mm, and the sizes of the alphabetic keys in the QLKP and the SlideBoard were 9.5 x 6.4 mm and 5.6 x 6.5 mm, respectively.

Procedure

Participants entered text using the three keyboards assigned to their group. The duration of the experiment was approximately one hour per participant. Each participant completed five task blocks for each keyboard. For each block, participants were asked to transcribe five sentences. Before starting the first block for each keyboard, participants completed one sentence for practice. Participants could rest for up to 3 minutes between blocks if they felt tired. After finishing with all keyboards, participants were asked to answer a questionnaire.

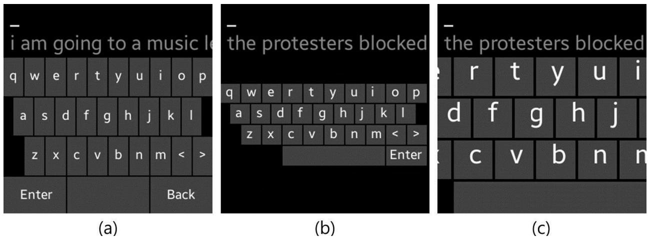
Design

In each group, *Keyboards* and *Blocks* were independent variables, and a 3(*Keyboards*) x 5(*Blocks*) within-subject factorial design was used. We fully counterbalanced the order of using the keyboards. The text entry speeds in words-per-minute (WPM), total error rates (TER), and uncorrected error rates (UER) of the keyboards were measured.

Results

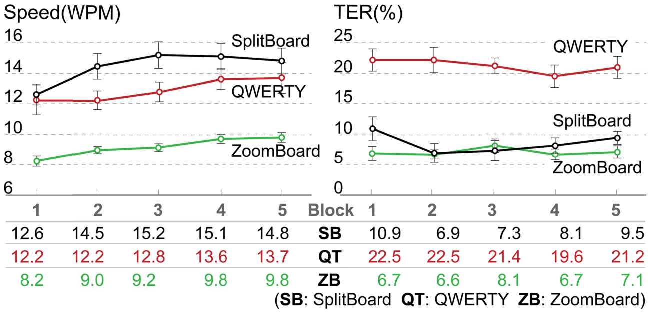
We statistically compared the WPMs and TERs of the keyboards in Group A and B using a repeated measures ANOVA (3 methods x 5 blocks) and a pairwise comparison with Šidák correction. The results of Group A are summarized in Figure 3 and Table 1. In Group A, there was a significant main effect of *Keyboards* on WPM ($F(2, 22) = 47.19$, $p < 0.001$). The SplitBoard was faster than the QWERTY ($p < 0.05$) and the ZoomBoard ($p < 0.001$). There was a significant main effect of *Keyboards* on TER ($F(2,22) = 62.416$, $p < 0.001$). The QWERTY caused more errors than the SplitBoard ($p < 0.001$). There was no statistically significant difference between the SplitBoard and the ZoomBoard ($p = 0.206$). The average UER of the SplitBoard was 0.58%. The QWERTY showed the same UER as the SplitBoard at 0.58%. The average UER for the ZoomBoard was 0.3%.

In the questionnaire results, 11 of 12 participants in Group A ranked the QWERTY as the least-preferred keyboard. All participants in Group A preferred the SplitBoard most, stating that the keys of the QWERTY were too small and led to numerous errors. They additionally stated that the frequent zooming of the ZoomBoard caused eyestrain. They mentioned that the SplitBoard was easy to use but it was inconvenient when a sentence required frequent switching between the keyboard parts.



(a) (b) (c)

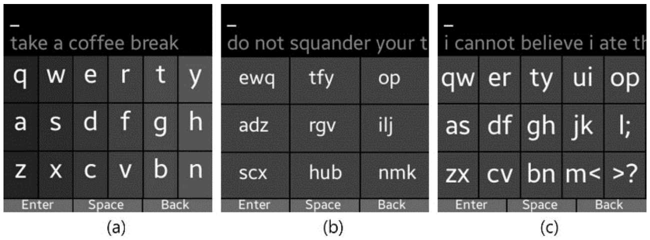
Figure 2. (a) QWERTY keyboard, (b) ZoomBoard before zooming, and (c) ZoomBoard after zooming.



1	2	3	4	5	Block	1	2	3	4	5
12.6	14.5	15.2	15.1	14.8	**SB**	10.9	6.9	7.3	8.1	9.5
12.2	12.2	12.8	13.6	13.7	**QT**	22.5	22.5	21.4	19.6	21.2
8.2	9.0	9.2	9.8	9.8	**ZB**	6.7	6.6	8.1	6.7	7.1

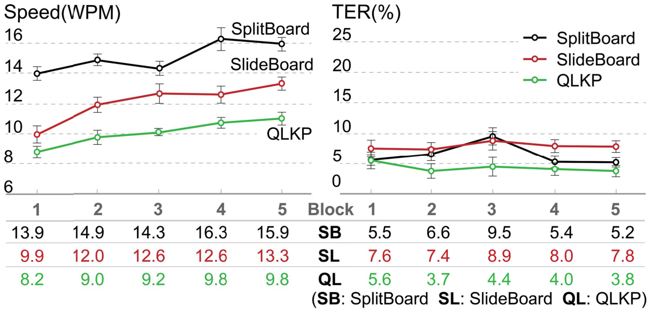
(**SB**: SplitBoard **QT**: QWERTY **ZB**: ZoomBoard)

Figure 3. Average text entry rates in WPM and total error rates over five blocks in the Group A. Error bars show SEM.



(a) (b) (c)

Figure 4. (a) SplitBoard, (b) QLKP, and (c) SlideBoard.



1	2	3	4	5	Block	1	2	3	4	5
13.9	14.9	14.3	16.3	15.9	**SB**	5.5	6.6	9.5	5.4	5.2
9.9	12.0	12.6	12.6	13.3	**SL**	7.6	7.4	8.9	8.0	7.8
8.2	9.0	9.2	9.8	9.8	**QL**	5.6	3.7	4.4	4.0	3.8

(**SB**: SplitBoard **SL**: SlideBoard **QL**: QLKP)

Figure 5. Average text entry rates in WPM and total error rates over five blocks in Group B. Error bars show SEM.

The results of Group B are summarized in Figure 5. There was a significant effect of *Keyboards* on WPM ($F(2, 22) = 97.382$, $p < 0.001$). The SplitBoard was faster than the QLKB ($p < 0.001$) and SlideBoard ($p < 0.001$). There was a main effect of *Keyboards* on the typing accuracy ($F(2, 22) = 10.568$, $p < 0.001$). The QLKB was more accurate than the SplitBoard ($p = 0.036$). There was no significant difference between the TERs of SplitBoard and SlideBoard. The average UERs of the SplitBoard, QLKB, and SlideBoard were 0.4%, 0.4%, and 0.7%, respectively.

Out of the 12 participants in Group B, 9 preferred the SplitBoard to the other two keyboards. In addition, 10 of 12 participants least preferred the QLKB because of both its unfamiliar layout and the 2-second timeout to discriminate keys, which often caused errors. Three participants ranked the SplitBoard as the second most preferred keyboard due to the frequent switching required for certain words.

DISCUSSION

Oney et al. [10] showed that the ZoomBoard outperforms the QWERTY for a keyboard size of 16 mm. Our results show that this is no longer true for a keyboard size of 29 mm; both the SplitBoard and QWERTY outperformed the ZoomBoard. It seems worthwhile to investigate the relative efficiency of these keyboards for different keyboard sizes.

There are additional topics to be considered as part of future work. First, we are interested in the effect of long-term learning on the efficiency of these keyboards. We measured only beginner performance in the current study and the relative efficiency of the keyboards may change when people further develop their skills. Another question relates to the efficiency of these keyboards in mobile settings. The performance of the QWERTY in the current study may be due to the stationary writing situation, and standing or walking users might not be able to hit keys equally well.

Yet another question is how the use of a language model would improve these keyboards. In this study, we avoided any dictionary-based features and focused only on the key entry efficiency of the keyboards. This is a clear shortcoming of this study, considering that every modern touchscreen keyboard uses a language model. For more practically meaningful results, it is necessary to compare these keyboards after they are augmented with a dictionary-based feature. Among the keyboards compared in the current study, we expect that the QWERTY may benefit most from a dictionary-based feature (e.g., dictionary-based auto-correction) because it suffers from the highest error rates. The QWERTY with an auto-correction feature may become a viable option considering its high WPM despite the high error rate in this study.

A language model may be also used to optimize the key layout of the SplitBoard. The bigram statistics of a language may be used to design a key layout to minimize switching between the two sides of the SplitBoard. QWERTY users may be unfamiliar with the resulting key layout, but there may exist an optimal trade-off to reduce switching while maintaining learnability.

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