A Study on Touch Screen Numeric Keypads: Effects of Key Size and Key Layout

Steve N.H. Tsang, Alan, H.S. Chan, and K. Chen

Abstract—**The demand for touch screen displays, from personal mobile devices to public self-service kiosk, has drastically increased since last decade. Touch screen kiosks normally involve numeric data entry for functioning, underlying the necessity for optimizing the design of numeric keypads for improved performance. The present study was thus conducted to investigate the effects of key size and key layout for numeric keypads with a numeric data entry task. The results showed that keying performance was affected by both key size and key layout, and the effects of them in terms of entry speed, accurate rate and completion rate were discussed.**

Index Terms—**Touch screen displays, key size, key layout, numeric data entry**

I. Introduction

Beyond doubt, the use of touch screen displays is emerging in recent years, ranging from personal gargets to public devices. The competitiveness of touch screens can be attributed to their small size, ease of use and programmable nature. Comparing to traditional display control systems, touch screen displays integrate control and display into one component for saving of space. Besides, without an external control keyboard, users can make responses intuitively on touch screens, eliminating the need of prior training. Last but not least, the programmable nature of touch screen displays means that there is high flexibility in the design of touch screen interface through appropriate modification of application programs. However, there is always limited screen size for touch displays, such that display parameters like key size, spacing and layout should be considered thoroughly for the interface design. In this regard, the purpose of this study was to examine optimal setting in display factors for touch screens in a bid to improve the overall usability of touch screen devices.

Among different display parameters for touch screens, key size is one of the vital factors affecting user performance [1]–[3]. Most studies have consistently reported that larger key sizes were superior to smaller key sizes in keying performance. Bender [4] found that with soft keyboard operating on a touch screen, keying performance with the key size of 30 x 30 was better than that with 10 x 10 mm when participants were asked to enter a 4-digit numeric string in a standing posture. Colle and Hiszem [1] tested a wider range of key sizes (10, 15, 20 and 25 mm square key), and reported that the 20 mm key was the best size in keying performance and was the most preferable size by participants among the choices. Recently, Schedlbauser [5] found that 15 mm square key yielded higher keying speed and lower error rate than 12 mm square key for finger touch input. In contrast, the study of Scott and Conzola [6] was one of the few reporting that key size did not have any significant effects on keying speed and error rate with the testing square key sizes of 16, 18, and 20 mm.

In fact, most of the previous studies on touch screen keypad design were based on keying performance with a telephone-style numeric key pad (regarded as the fixed layout in this study). The participants were required to enter the numeric digits from 0 to 9 as per the sequence of a displayed string. However, there was no study investigating the keying performance in the situation that the keys on the keypad were randomized from trial to trial, making the key arrangement on a keypad unpredictable and unmemorable. The random layout keypad or scramble keypad is commonly used for entry of secure information to prevent onlookers from detecting the code being entered. It was posited that entry speed of the fixed layout would be faster than that of the random layout. However, regarding accuracy rate, the random layout would impose participants to visually search instead of recalling from memory for the location of the correct key, such that greater cognitive load would be resulted compared with the fixed key layout.

The effects of key size and key layout on touch screen numeric keypad performance were examined in the present study. Two key sizes (large: 20 x 20 mm, and small: 14 x 14 mm) and two layouts (fixed and random) were tested in the experiment. Participants were instructed to enter a 10-digit numeric string as per the sequence of a displayed string in a standing posture, simulating the daily practice of interacting with the touch screen kiosks used for accessing information or for self-service in public spaces.

II. Method

A. Participants

Thirty-seven students (22 males and 15 female) aged between 18 and 25 years (median = 22) from City University of Hong Kong voluntarily participated in this experiment. Thirty-six of them were right handed and only one was left handed. Participants were classified as being left or right-handed by self reporting on handedness. All of them had normal or corrected-to-normal vision (Optical Co., Inc., Model 2000P Orthorator). They all gave informed consent before the start of the experiment and did not report any physical or health problems involving their hands and fingers.

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B. Apparatus and software

A personal computer (Pentium® 4 CPU, 2.80 GHz) and a 17-inch touch screen monitor (Sunway Technology, Model SW-17008) were utilized for carrying out the experiment. The computer program for stimulus display and response data collection was prepared with Visual Basic 2010. There was a numeric keypad with ten number keys, from 0 to 9, for response input. The keypad was in a 4 (row) x 3 (column) matrix-like layout and the first and last keys in the bottom row were missing. Two keypad sizes - large and small - were tested in the experiment. Each key of the large and small keypad was 20 x 20 and 14 x 14 mm in size (3.27˚ x 3.27˚ and 2.67˚ x 2.67˚ at a viewing distance of 350 mm), respectively. The edge-to-edge distance between adjacent keys was 3 mm (0.49 ˚). A digit of 5 (height) x 3 (width) mm (0.82˚ x 0.49˚) was printed on the center of each key. On top of the keypad was a rectangle box sized 100 (height) x 380 (width) mm (16.26˚ x 57.00˚), showing the digits that had been entered. Immediately above the box was a 10-digit-long numeric string (with similar width and height to the rectangle box), which was randomly generated from the program as a string to be followed with. On the left hand side was a place showing the testing condition and response data for particular trial. The touch screen monitor was positioned on a work table and its centre was at a height of 1310 mm from the floor, at which all participants could respond comfortably in a standing posture. The monitor was aligned with the coronal plane without any inclination. The luminance of the screen was 26.25 cdm^{-2} and the ambient lighting was around 450 lux.

C. Experimental design

Participants were instructed to input a 10-digit string in the sequence of a displayed string generated for each trial with a numeric keypad shown on the touch screen display. Two factors, each of two levels, were studied in the experiment here. They were key size (large - L and small - S) and key layout (fixed - F and random - R). With respect to key size, a 20 x 20 mm (75 x 75 pixels) square key was used for the large size condition, and a 14 x 14 mm (50 x 50 pixels) key was for the small size condition. As to key arrangement, the fixed layout was characterized by its telephone-keypad-like arrangement with digit 1 starting from the top left corner and increasing by 1 digit for the next key in zigzag order and finally with digit 0 in the last row of middle column. However, for the random key arrangement, all key digits were arranged in a non fixed sequence which was randomized from trial to trial, making it unpredictable and unmemorable. The two key design factors were studied with a factorial design, resulting in 4 (2 key size x 2 key layout) different test conditions. Each participant had to complete all the test conditions and each condition contained 10 test trials. The test order for the conditions was counter balanced to avoid carryover effect. The entry speed, accuracy rate and completion rate were measured for further analysis. For any false response, an error box popped up, and a new trial request was then displayed.

Entry speed was measured in digits per minute ($Dmin^{-1}$), which was the ratio between the length of a numeric string (10 digits) and the execution time elapsed from the first tap (the first digit) to the last tap (the tenth digit) of the numeric string (min). Accuracy rate was defined as the ratio between the number of error-free trials and the total number of test trials for each test condition (i.e. 10). Since a trial would be stopped when an unmatched tap was detected, completion rate was used to measure the ratio between the number of digits the participant successfully entered and the total number of digits for all trials in each test condition (i.e. 10 digits for a string x 10 test trials = 100).

D. Procedure

Verbal instructions for the task were given to every participant before the start of the experiment. They stood at a distance of 350 mm directly in front of the touch screen and were instructed to use their dominant hand and finger(s) to perform the task (Fig. 1). Few practice trials were provided to get them familiar with the operation of the touch screen displays before the real test. In each trial, a 10-digit numeric string was randomly generated and displayed on the screen. Participants then tapped on the numeric keys one by one in accord with the entire sequence (from left to right) of the displayed numeric string. After 10 digits were correctly entered, the word 'Correct' would be shown and then a new numeric string would be generated, indicating the start of a new trial. The procedure was repeated in all trials in each condition and four different conditions were tested in the experiment. Participants were asked to react as fast and accurately as they could. Depending on individual's ability and pace, the experiment took approximately 10 minutes to complete.

Fig. 1. The participant is performing the experiment with one hand and in a standing posture.

III. Results

Altogether, 1480 (37 participants x 4 conditions x 10 trials) data, in which 1165 and 315 were correct and incorrect responses, respectively, were collected in the experiment. The response data were summarized and analyzed as below.

A. Mean entry speed

For the 1480 response data, the 315 incorrect responses were excluded and only the 1165 correct responses were retained for analysis. The overall mean and standard deviation for entry speed were 100.67 and 35.32 $Dmin^{-1}$, respectively. The large key size had a speed advantage of 29.68 $Dmin^{-1}$ compared with the small one, accounting for an increase of 25.82% in entry speed. As to key layout, the entry speed with the fixed layout was 117.39 $Dmin^{-1}$, while it was 84.20 $Dmin^{-1}$ with the random layout, showing that participants generally entered with faster speed under the fixed layout condition.

Further examination of entry speed was conducted with the repeated measures analysis of variance (ANOVA). The main factors of key size [$F_{(1, 36)} = 165.445$, $p < 0.001$] and key layout [$F_{(1, 36)} = 190.116$, $p < 0.001$] were found significant, as was their two-way interaction [$F_{(1, 36)} = 64.543$, $p < 0.001$] . Therefore, the entry speed with large key size and fixed layout was significantly faster than that with small and random one, respectively. An interaction plot of key size and layout is shown in Fig. 2. The plot shows that the discrepancy in entry speed between the fixed and random layout was greater when the large key size was used. Also, the effect of key size on entry speed was larger in the fixed layout, while the effect was weakened in the random layout. Overall, the entry speed with the large key size was faster than that with the small key size regardless of key layout.

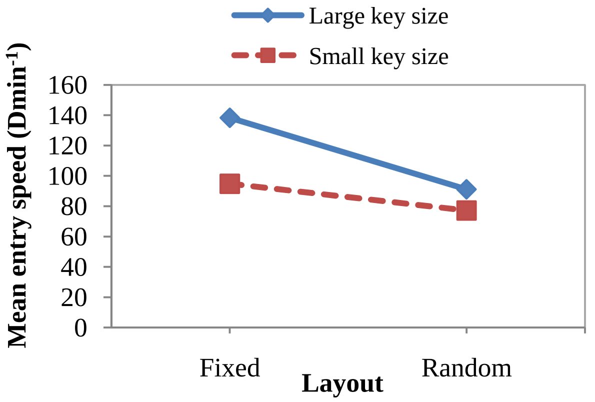

Fig. 2. An interaction plot of mean entry speed for key size and layout

B. Mean accuracy rate

Altogether there were 315 (21.28%) incorrect responses recorded. The accuracy rate for the large key (81.62%) was higher than that for the small key (75.81%). When it comes to the effect of key layout, surprisingly, the random layout (79.32%), though non-significant, had slightly higher accuracy than the fixed layout (78.11%), implying participants might pay more attention when they were responding to the unfamiliar random layout condition.

Repeated measures ANOVA was then performed for further examination of accuracy rate. Only the main factor of key size [$F_{(1,36)} = 6.687$, $p < 0.05$] was found to be significant and no interaction effect of key size and key layout [$F_{(1,36)} = 2.92$, $p > 0.05$] was observed. The results indicated that responding to the large key size yielded significant higher accuracy than to the small key size, and key layout did not affect response accuracy rate.

C. Mean completion rate

The overall completion rate across test conditions was as high as 89.40%. The highest completion rate (91.11%) was found with the large key size, while the lowest (87.68%) was with the small key size. Not much difference in completion rate was observed between the fixed (89.03%) and random (89.76%) layouts. The results of repeated measures ANOVA showed that key size was significant [$F_{(1,36)} = 7.931$, $p < 0.01$], while key layout [$F_{(1,36)} = 0.272$, $p > 0.05$] and their interaction [$F_{(1,36)} = 1.859$, $p > 0.05$] were non-significant . The findings revealed that participants had significantly more digits correctly entered with the large key size.

IV. Discussion

The effects of key size and key layout on entry speed, accuracy rate and completion rate were comprehensively studied in the experiment. Regarding the key size, the results here were in agreement with some past studies that larger key sizes were superior to smaller key sizes in entry performance [1], [2], [4], [7], [8]. Among the previous studies of numeric keypad performance on touch screen displays, the task nature and setting of the studies of Scott and Conzola [6] and Colle and Hiszem [1] were comparable to our study, in which participants were asked to enter a 10-digit numeric string with a numeric keypad. The key sizes tested by Scott and Conzola [6] were 16, 18, and 20 mm and that tested by Colle and Hiszem [1] were 10, 15, 20 and 25 mm. Scott and Conzola [6] found that there was no difference in entry performance between the key sizes, while Colle and Hiszem [1] reported that significantly better keying performance was obtained with larger key sizes, however, no significant difference was found between performance with key size of 20 and 25 mm. Colle and Hiszem [1] also measured the subjective preference towards the key sizes they tested, and found that the key size of 20 mm was more preferred by participants. In this study, key sizes of 14 and 20 mm were tested and the 20 mm key was superior in terms of keying speed, accuracy and completion rate. Combining the results of Scott and Conzola [6], Colle and Hiszem [1], and the results here, it may be concluded that key size between 16 - 20 mm is a decent range for desirable keying performance. If subjective preference is taken into account, a key size of 20 mm is more preferred, which was measured in the study of Colle and Hiszem [1]. A key size of 15 mm is a cut-off point at which degradation in keying performance is observed, while a key size beyond 20 mm will not further improve keying performance.

As numeric keys were randomly displayed in the random layout, participants needed to spend extra time on visual search for the correct location of each key. This additional workload was not needed with the fixed layout as participants were familiar with it and could easily recall key locations from their memory. Therefore, entry time was comparatively lengthened with the random layout, leading to a significantly slower entry speed than that with the fixed layout. As to the accuracy between the two layouts, surprisingly, no significant difference was found and the accuracy of tapping with the random layout was even slightly higher than that with the fixed layout. It might be explained by the fact that participants needed to pay much more attention to search for a correct key from a group of randomly ordered keys during the response to the random layout. The accuracy thus was not as worse as expected.

V. Conclusion

Based on the obtained results here, the authors would like to make the following recommendations on key size and key

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layout with the aim of optimizing the design of numeric keypad for improved keying performance. First, for improving entry speed, a fixed instead of a random layout should be used to minimize the cognitive load required for identifying the correct key locations. Besides, it is advantageous to use larger rather than smaller key size. Combining the results of previous studies and this one, for number entry task, a key size of 20 mm is most preferred and a key size smaller than 15 mm should be avoided. A key size larger than 20 mm will only have slight or even no improvement in keying performance.

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