The Effect of Touch-key Size and Shape on the Usability of Flight Deck MCDU

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***Abstract*—This paper focuses on the effect of touch-key size and shape on the usability of the multifunction control display unit (MCDU) of the flight deck. A total of thirty subjects participated in the trials on the touchscreen-MCDU to perform the task of preflight preparation. The sizes of the touch-key were 7mm, 10mm, 13mm, 16mm, 19mm and 22mm; the touch-keys were divided into two shapes: rectangle and square ones. The completion time of the task, the error rate and participants' subjective ratings were collected as the indicators of the usability, and Analysis of Variance (ANOVA) was done to test the data. Results showed that both touch-key size and shape affected the usability. The usability of the touchscreen-MCDU increased as the touch-key size increased up to a certain size (19 mm in this study), at which they reached asymptotes. The square touch-keys provided a better usability than the rectangle ones when the width was the same. However, when the width reached 19mm, the usability stayed the same for both shapes.**

Keywords-touch screen; flight deck; MCDU; touch-key size; interface.

I. INTRODUCTION

Touch screen has been widely used in mobile phones, tablets, laptops, etc., all due to its intuition, convenience and adjustability. People are used to using touch screen instead of traditional keyboard as the input method in their daily life. Despite its spreading use in the daily life, touch screen can also be introduced into other fields.

As the function of the flight deck grows with the need of airlines, the complexity of the operating environment and avionics systems also advances at a rapid pace. The complexity of the flight deck brings more workload for the pilots and raises the risk of pilots' operations. The idea of introducing touch screen into the flight deck might simplify the flight deck interface and help pilots perform better [1]. Rockwell Collins has unveiled its touch-control single primary flight display [2]. Garmin G3000 also implemented the touch screen technology on the flight deck [3]. The USA Joint Strike Fighter F-35 used two touch screen displays to replace the traditional displays on the flight deck [4]. At the 2011 Pairs Air Show, Thales first exhibited its next generation touch-screen cockpit concept [1]. The implement of touch screen into the flight deck might be a trend for the next generation flight deck. MCDU is one of the most important input devices on the flight deck. The traditional keyboard of MCDU has always been made up of buttons and switches ever since its first implement into the flight deck. However, touch screen has earned its way into the design of MCDU. Thales [1] and Barco [5] both brought the inspiration of touch screen into their new concept of the MCDU. Though the concept of bringing touch-screen MCDU into the flight deck has come up, few studies focused on the human factors issue. This paper will focus on the human factors study of the touch-screen MCDU on the flight deck.

With the widely use of touch screen, quite a number of researchers studied touch screen interfaces. The studies about touch screen included: target sizes [6][7], gestures [8][9], extra muscle fatigue [10][11], touch screen for older or disabled users [12], etc. Touch screen target size is one of the most important element of the interface. Among the studies, touch screen target size has always been popular, but the appropriate sizes for different touch screen devices varied. Colle & Hiszem [13] found that the 20 mm was an appropriate key size for touch screen numeric keypad. Kim [14] suggested in his study that the appropriated touch-key size of the In-Vehicle Information System should be 17.5mm. Parhi [6] recommend that the target size should be at least 9.2 mm for single-target tasks and 9.6 mm for multi-target tasks for one-handed thumb use of mobile handheld devices equipped with a touch-sensitive screen. Schedlbauer [15] did further study based on the experiment of Colle & Hiszem [13], and ended with the conclusion of 12mm to be the appropriate size. Though, studies about touch screen have been researched for almost two decades, nevertheless, there were few studies about the target size of the MCDU on the flight deck.

This paper will describe an experiment about the target size of the MCDU on the flight deck, investigate the difference of the usability for different sizes and propose an appropriate target size for the touch screen MCDU on the flight deck. In Section 2, the method of how to perform the experiment will be discussed. Section 3 shows the usability results of the experiment from three perspectives: time, error rate and subjective ratings. The issue to be considered in the experiment and the conclusion of the experiment is described in Section 4 and 5, respectively.

 ISBN: 978-1-61208-382-7

II. METHOD

A. Subjects

A total of thirty subjects participated in the human factors experiment. They were selected from the Flying College of Beihang University, male, who had learnt flying skills for at least one and a half years and understood how to use the real MCDU on the flight deck. All of them were willingly to participate in this experiment. Their ages ranged from 18 to 24 years old (mean = 21.3, SD =2.76). They had normal vision and no motor impairments.

B. Apparatus

According to the procedure of Crane [16] proposed in her study, a PC experiment was carried out before the final experiment on the flight deck. The experiment of this paper was conducted on a laptop and the further experiment would be planted in a flight deck simulation.

The experiment was conducted with a Lenovo Flex 2 laptop, which was equipped with the Windows 8 operation system and a touch screen. The size of the touch screen was 145×310mm, and the resolution was 1366×768 pixels.

The simulated MCDU software was projected onto the Lenovo laptop. The simulated MCDU software was similar to the real A320 MCDU and can perform the "initial A" function of the preflight preparations (see Figure 1). The soft keys to be pressed on the MCDU contained two different types: 1) the alphabet and digit keys of square sizes and 2) the "R*" and "L*" keys of rectangle sizes. The width of the keys was the same.

Figure 1. The simulated touch screen MCDU software

C. Experiment Design

The independent variables of this experiment are the touch-key size and shape of the MCDU. Two kinds of touch-keys with the same width were used in the interface: square ones and rectangle ones. The ratio of width/height of the rectangle keys designed here was 1.5. The width started at 7mm, and was incremented by 3mm. A preliminary research was conducted to determine the largest touch-key size. As said in the introduction, the appropriate target size suggested by other researchers ranged from 10mm to 20mm [6][7][13][14][15]. Taking the previous studies and their conclusions into account, the largest size of the simulated MCDU was determined to be 22mm. The final set of the touch-key size included: 7mm, 10mm, 13mm, 16mm, 19mm and 22mm. Figure 2 is part of the interface. It showed the six set of square touch-key sizes for the touch screen MCDU. Figure 3 showed the comparison of the square and rectangle touch-keys on the same interface.

D. Experiment Tasks

The task of preflight preparation was chosen to be the experiment task, which consisted of eight sub-tasks. First, subjects pressed the key of "INI" to start the task. As soon as the key of "INI" was pressed, the software started to record the time. Second, enter the ICAO code of the airport of departure and landing (ZYTL/ZBTJ), press "R1" and then "L6" to return. Third, the ICAO code of the alternate airport (ZBSH) should be entered, and press "L2" to confirm the entry. Fourth, flight number "CSN6125" should be entered and press "L3" to confirm that. Fifth, cost index "35" would be entered, and "L5" would confirm the entry. Then, enter cruise altitude "FL310" and press "L6" to confirm it. After this, subjects pressed "R3" to confirm the status. In the end, the key of "F-PLN" was pressed to finish the trial, meanwhile, the time record stopped. In addition, the key turned blue whenever the key was pressed.

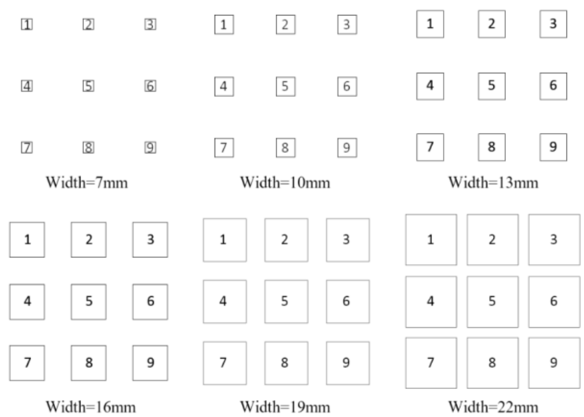

Figure 2. Six set of square touch-key sizes on the touch screen MCDU

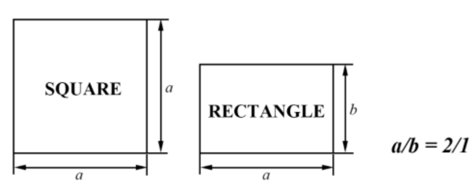

Figure 3. Comparision of the square and rectangle touch-key sizes on same interface

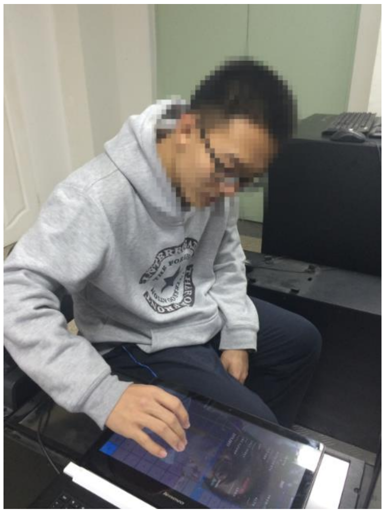

Figure 4. The positon of subjects performing the experiment

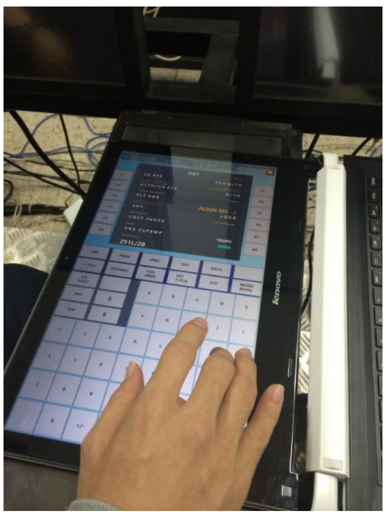

Figure 5. Subject performing the task on the touch screen MCDU

When performing the tasks, the laptop was put on the right side of the subjects to imitate the positon of the real MCDU on the flight deck (see Figure 4). Figure 5 showed the situation of one subject performing the task on the touch screen MCDU.

E. *Experiment Procedures*

The experiment consisted of four steps. First, the demographic information, such as age, eyesight and flying skills experience, was collected. Second, experimenters explained the purpose and procedures of this experiment to each subject. Written instructions of the experimental objectives and procedures were also given to help them understand. Third, after the subjects fully understood the experiment, they practiced on the touch-screen MCDU to become familiar with the interface and memorize the operation tasks. Fourth, in the main experiment, the subjects were asked to operate the given tasks. The subjects were told to finish the task as quickly and accurately as possible. There was no rule on which finger they used, however only one hand can be used. Subjects completed the operation task, which was already described in Section D. Experiment tasks. For each of the 6 different sizes, the same operation would be performed. To avoid the influence of fatigue and familiarity with the operation tasks, the order of the sizes randomly showed up. After each of the six tasks, the subjects were asked to fill a usability questionnaire to evaluate the usability of the interface. A Likert scale questionnaire was used, ranging from 1-9, where 1 meant the interface was too hard to operate and 9 meant the interface was perfect. In the end, the subjects were asked to give comments on sizes of the touch-key.

III. RESULTS

The results of this experiment included two kinds of data, the objective one and the subjective one. The objective data collected in this study included TIME and ERROR. TIME means the time it took to finish the task, i.e., the time from the point of pressing the "INI" key to the point of pressing the "F-PLN" key. ERROR means the number of errors occurred during the task. The subjective data was the ease of use and satisfactory of the subjects for each size.

The interface we designed had keys of two different shapes: rectangle and square. The error rate for both two shapes was also calculated.

A. *Time*

For completion time, one trial with extremely abnormal data was eliminated from the data set. The trail data was eliminated because it showed a completely different trend with the other data. The time for operating the task on the interface with the largest size was almost two times longer than the smallest size. The interview after experiment showed that the subject who performed this data was disturbed when he completed the task. Then, the largest size and the mean of the remaining trials were calculated for each size. The mean completion time of all the subjects was calculated first, and the ANOVA test was performed. The result of the ANOVA showed that Time was significantly affected($F(5,84)=5.925$, $p<0.002$). No surprisingly, as the size grew, participants were able to finish the task within a shorter time period. However, except for the smallest size, the completion time slowly decreased in comparison with the increase of the key size (see Figure 3). There is no significant difference between the size of 19mm and 22mm ($F(1, 18) = 0.075$, $p>0.5$).

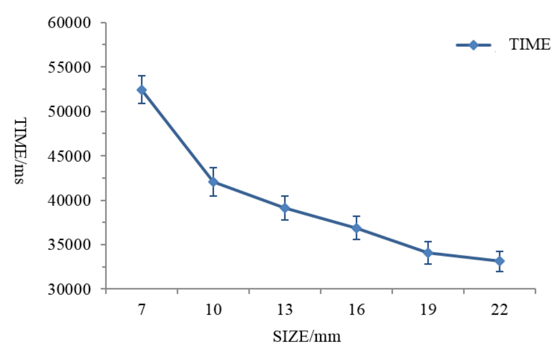

Figure 6. Mean compeltion time of different touch-key sizes

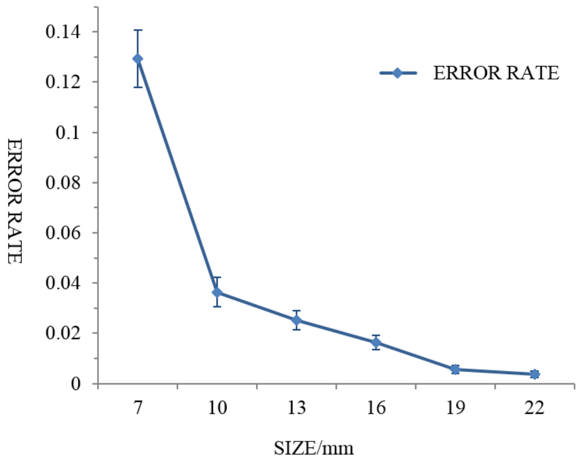

Figure 7. Mean error rate of different touch-key sizes

B. *Error Rate*

Error rate was the ratio of the number of errors occurred during the task to the total number of operations of the task. The mean error rate of all the subjects was calculated first, and the ANOVA test was performed. The error rate of the task is shown in Figure 8. Error rate was significantly affected by size ($F(5,84)= 17.94$, $p<0.001$). Errors declined as size increased. The smallest size (7mm) made an extremely high error rate which was three times compared to the 10mm size. The error rate of next three sizes showed a slow decline as the size increased. And there was no significant difference between the size of 19mm and 22mm ($F(5, 84)= 1.119$, $p>0.1$).

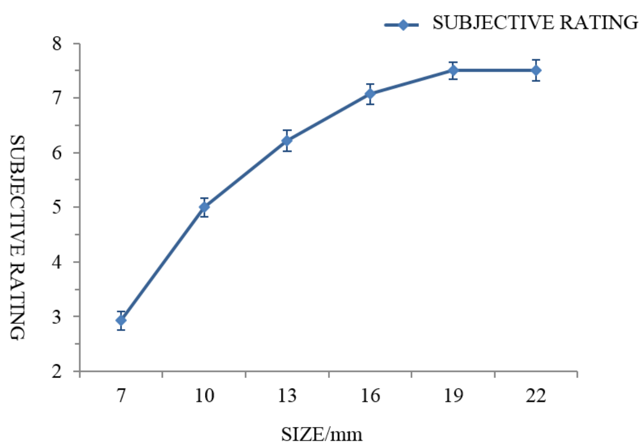

Figure 8. Mean subjective ratings of different touch-key sizes

C. *Subjective Ratings*

The mean subjective ratings of all the subjects was calculated first, and the ANOVA test was performed. The subjective ratings of the task are shown in Figure 9. The subjective ratings was also significantly affected by size ($F(5,84)=29.18$, $p<0.001$). The subjective ratings increased as the size increased. The bigger the key was, the better subjective ratings were given by the subjects. There was no significant difference between the size of 19mm and 22mm.

D. *Error Rate Comparision between the Retangle and Square*

The error rate of the rectangle and the square keys was also calculated. The error rate of the two shapes is shown in Figure 9.

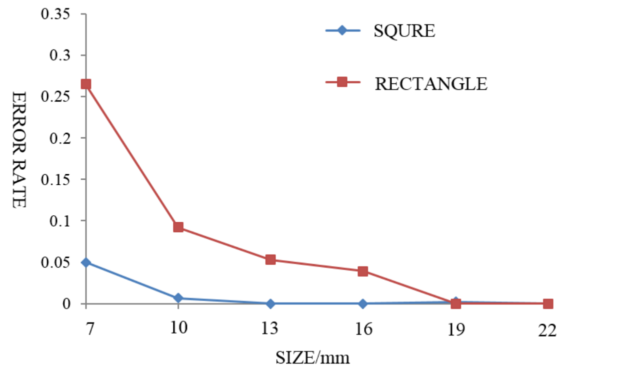

Figure 9. Error rate comparison between two different touch-key shapes(retangle and square touch-keys)

The ratio of height/width for the rectangle keys used in the experiment was less than 1. Under these circumstances, the error rate of the rectangle keys was higher than the square ones when the width was smaller than 16mm. However, with the larger size, 19mm and 22mm, subjects seldomly made mistakes. So the trend of the two lines coincided.

IV. Discussion

Overall, the usability of MCDU of the flight deck increased as the touch-key size increased. When the touch-key size was larger than 19mm, the completion time, error rate and subjective ratings did not differ much.

From the data we obtained from the experiment, some subjects gave higher values to the size of 19mm than the size of 22mm. For the ones who rated this way, an interview was done to determine the reason. Some subjects assumed the reason for this was that the spacing between the touch-keys decreased as the width of the touch-keys increased, which caused a cluster in the interface. As a result of the cluster, subject had a feeling that they would accidently tap on the adjacent touch-keys. Others claimed that the 22mm touch-keys were too large to perform for them under the circumstance. Studies about these questions would be done in the future.

Meanwhile, the error rate of the two different touch-key shapes was also examined. The result showed that error rate differed between different touch-key shapes. The error rate of the square keys was lower than the rectangle ones. However, the error rate reached an asymptote at the width of 19mm. The reason for this might be the difference in the tapping area. The square keys had larger area when the width was the same, correspondingly, the error rate was lower.

 ISBN: 978-1-61208-382-7

In this study, we focused on the factors of the key size and shape related to usability; in addition, other design factors, such as the key spacing and the location of the keys, should be investigated.

V. CONCLUSION

In this study, the effect of touch-key sizes and shapes on the usability of MCDU of the flight deck was examined. The usability of the MCUD on the flight deck increased with increased touch-key sizes. However, the usability reached an asymptote beyond certain touch-key sizes. When the ratio of the height/width was less than 1, the usability of the square touch-keys was better than the rectangle ones with the same width. However, the usability reached an asymptote when the width reached 19mm. Moreover, the touch-key sizes proposed by this study cannot be directly applied to the design of MCDU touch-key sizes because the experiment was only a PC simulated experiment. Therefore, a number of further studies should be performed to determine the size of the real MCDU of the flight deck.

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ACKNOWLEDGEMENTS

The work presented in this paper has been carried out as part of the Chinese project the National Key Technology R&D Program of the Ministry of Science and Technology (2014BAK01B03), led by China National Institute of Standardization.