Designing for a Thumb: An Ideal Mobile Touchscreen Interface for Chinese Users

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Abstract. This paper focuses on designing for cross-cultural users; specifically, it describes a study conducted to determine the "Comfort Zone" and optimal touch target size for one-handed thumb use. Similar studies have provided general measurements for touch targets, but they are not applicable to all the slots on a touchscreen, nor are they consistent with the actual physiological measurements (i.e., the size of hands and fingers) of Chinese users. The study used repeated measures in a within-subject design of 16 (slots) × 5 (target sizes) × 10 (repetitions). The results indicated the Comfort Zone for the right thumb of Chinese users is significantly different at 0.01 level, and falls on a fan-shaped area located on the inclined left side of the screen. Different locations were required for different optimal touch target sizes.

Keywords: Design/evaluation for cross-cultural users, One-handed, mobile devices, touchscreens, touch target size.

1 Introduction

As the market share for smartphones grows, multi-point touch technology is increasing in popularity. In the design of touchscreen-based devices, the small interface is unique and is the interface for finger touch interaction, which differs from traditional interaction design. Direct thumb interaction on a small touchscreen raises several issues. On mobile devices, the human fingers – and particularly the thumb – replace traditional methods of small-screen interaction, such as the keyboard and stylus. It also raises several issues:

1. Not all the slots of a small-screen are suitable for finger touch interaction, particularly for thumb interaction. The morphology of the hand and particularly the thumb makes it difficult to reach the corners of the screen.
2. The problem of accuracy is recurrent because of the narrowness of the screen with thick information patterns, and this problem is exacerbated if the user is moving.
3. Standard touchscreen interface design guidelines give general guidance but do not account for users from non-western cultures. Differences in physiological measurements (such as the size of hands and fingers) between Chinese and westerners challenge the standard design guidelines.

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The objective of this study is to describe the shape and location of the "Comfort Zone" and the "Inaccessible Zone" for the right thumb of Chinese users. On the basis of this study, different slots of the screen were proposed for the minimum size of touch targets. We expect guidelines derived from these experimental results will help inform future cross-cultural research on smartphone interfaces designed to support the one-handed use of small touchscreen-based mobile devices.

2 Related Works

The beginning of touchscreen research occurred somewhat recently. Designing for the touchscreen is still at an early stage, whether in China or in the West; it dates back only to 1999, when touchscreen technology was first applied to mobile phones (MOTOROLA A6188). The design philosophy of the finger touch interaction area underwent a revolutionary change in 2007 with the advent of the iPhone and multi-point touch technology. Research on thumb interaction with touchscreen-based devices is a relatively new field, but the issues of reaching far targets, accuracy and cross-cultural users have not yet been resolved.

2.1 Target Accessibility

The borders of the screen are more difficult to reach [1], particularly with the thumb because the morphology of the hand constrains thumb movement. This will degrade interaction in the screen areas that are farthest from the natural extension of the thumb. In addition, thumb movements may also be hampered near the borders of the screen because of the thickness of the device's edges around the screen [2]. Thus, there should be a Comfort Zone and an Inaccessible Zone in the touchscreen for the thumb. In "Tapworthy-Designing Great iPhone Apps", Josh Clark discusses the design guidelines of iPhone apps; in particular, he discusses how right thumb interaction impacts app interface design, "Rule of Thumb: The comfort zone for the right thumb falls on the opposite side of screen, at the left edge and bottom of the screen. (The top right and bottom right corners are the toughest thumb zone for right-handed users.)[3]"

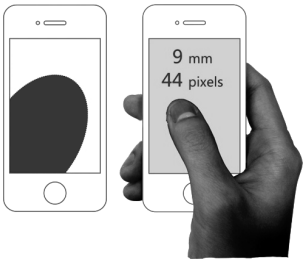

Fig. 1. Rule of Thumb and Magic Number 44

2.2 Accuracy

Direct thumb tapping is intuitive, it requires attentiveness and the following mistakes are easily made: a) Mis-Tapping（tap failed), and b) Missed Tapping (the tap was omitted because the target flashed). For users, the former more commonly happens with the vast majority of small-screen interface designs. Thus, our experiment was designed for the first case.

Smaller touch targets are more difficult for users to tap than larger ones. However, it is unclear exactly how large touch targets must be to offer the best ease of use for the majority of users. There is information from the industry about the minimum target size for touch interfaces. Apple's iPhone Human Interface Guidelines recommend a minimum target size of 44 pixels wide and 44 pixels tall [4]. Microsoft's Windows Phone UI Design and Interaction Guide suggests a touch-target size of 34 px with a minimum touch target size of 26 px [5]. Nokia's developer guidelines suggest that the target size should be no smaller than 1 cm x 1 cm or 28 x 28 pixels [6]. In ergonomics, smartphone predecessors had defined the minimum size for targets with the correct rate of operation. These definitions stated that 7 mm is the minimum size for targets to be easily accessible with the index finger and 9 mm for the thumb. Another study [7] has shown that 9.2 mm is the minimum size for targets to be easily accessible with the thumb. An MIT Touch Lab study of human fingertips with the objective of investigating the mechanics of tactile sense found that the average width of the index finger is 1.6 to 2 cm (16 – 20 mm) for most adults [8]. This converts to 45 – 57 pixels, which is wider than what most mobile phone guidelines suggest.

2.3 Summary

Josh Clark has not clearly explained the argument for or quoted sources delineating the comfort zone. We can neither distinguish an experimental result from a designer's empiricism nor know if it is consistent with actual physiological measurements (such as the size of hands and fingers) of Chinese users. We also note that guidelines are neither consistent with one another nor are they applicable to all slots on a touch-screen, although they do provide a general measurement for touch targets. In addition, walking is the most common activity of users when using their phones in daily life; this tendency will likely continue in the future. Do the guidelines specify measurements for moving?

3 Method

The study used a 16 (slots) ×5 (target sizes) × 10 (repetitions) repeated measures in its within-subject design, such that a total of 19,200 (16×5×10×24) units of experimental data were collected.

3.1 Independent Variable

Slots (16). The 16 target slots were defined by dividing the display into a 4×4 grid of cells (Fig. 2). Each slot was named by a combination of letter and number (e.g., A1).

Four rows were named A/B/C/D from top to bottom, and four columns were named 1/2/3/4 from left to right. Additionally, the 16 slots were not displayed on the front page. Participants were unable to detect the slots and were told that there were 16 slots. For each trial, the target was located in a random position in one of the 16 slots. Any part of the target could not be beyond the limit of the slot where it was displayed. As shown in Fig. 3, the location of the target center was random but was set by condition.

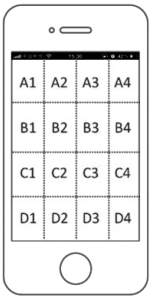

Fig. 2. Sixteen Slots of the Touchscreen

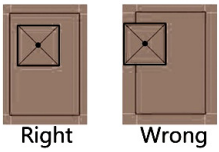

Fig. 3. The Regulation of Target Location

Target Sizes (5). Target sizes were set at 7, 8, 9, 10 and 11 mm on each side by the method of constant stimuli. We performed pilot studies to determine the appropriate target sizes for the study. Pilot studies indicated that performance ratios leveled off for target sizes greater than 11 mm; therefore, this represented the largest recommended practical size for singular targets. In accordance with the five groups of target sizes, the study was divided into five sessions, which were researched consecutively by the Latin square design. In each session, the same size target was randomly displayed one after another on all 16 slots. Each target size was repeated 10 times in every slot (16) for a total of 160 (10×16) trials in a session. Red-squares were designed as the target in this study.

3.2 Dependent Variables

Accuracy Ratio. Accuracy Ratio = (Successful Tapping trials / Total Displayed trials) × 100%. All the accuracy dates of each slot were recorded automatically by

an experimental program in the phone. In each trial, a red-square was displayed randomly and disappeared after a successful tapping.

Comfort Zone. The mean Accuracy Ratio of the Comfort Zone is significantly higher than that of the other part of screen ($P < 0.01$).

Minimum Size of Touch Target. The minimum size of the touch target for each slot may be defined as when its mean Accuracy Ratio reaches 95%. This value may not be measured directly, but can be obtained indirectly by linear interpolation. Linear interpolation is used to draw a curve with "Target Size" as the abscissa and the "Mean Accuracy Ratio" as the vertical axis; from 95% of the longitudinal axis, a straight line is drawn parallel to the horizontal axis to intersect the curve at point a. From point a to the abscissa, vertical and horizontal axes are drawn perpendicular at the intersection to arrive at the threshold.

3.3 Participants

The within-subject design method was adapted. A total of 24 Chinese participants (12 male and 12 female) were recruited via online announcement, such as through email and campus BBS – the only restriction was that participants must be right-handed. The age of the participants varied between 20 and 37 years, with a mean of 24.5 years. Participants received $5 for their time. On the basis of GB10000-88 [9], "Human Dimensions of Chinese Adult", hand width and thumb length were recorded for each participant to choose typical Chinese users.

3.4 Equipment

The experiment was performed on an iPhone4 that measured 115.2×58.6×9.3 mm, with an 88.9 mm screen, as measured diagonally. The display resolution was 640×960 pixels with approximately 13 pixels per millimeter. The study interface and control program were developed specifically for this study, at:
http://www.taobao.com/go/chn/mobile/uedresearch.php

3.5 Task

The participant's task for each target trial was to tap the target. All tasks were performed walking and one-handed, using only the right-hand thumb for interacting with the touchscreen. The participants were instructed to perform the tasks intuitively without thought. They were also told that capability and reaction time would not be measured in this study and that there was enough time to finish the task. The walking speed of the participants was limited to 1-1.5 m/s, which is normal speed for Chinese adults. Their walking distance was limited to an indoor environment measuring 4 m×4 m.

3.6 Procedures

The researcher greeted the participants and provided them with a brief overview of the study. Before the experimental task, there was a practice session; targets were presented once at each size in each slot, for a total of 80 trials. After the practice session, users completed the experimental task. Researchers were responsible for logging in the website (http://www.taobao.com/go/chn/mobile/uedresearch.php) for every participant.

On the front page, there were several parameters that were required to be filled in by the researchers, including target size, participants' name and the type of finger (index finger and thumb could both be measured on this website, but only the thumb results will be shown and discussed in this paper). Then, the researcher pressed the OK button. When the experimental phone was transferred to the participant, the task began. At the end of every session, participants were sent a pop-up dialog: "Congratulations. All finished." Sixteen accuracy dates from Slot A1 to Slot D4 were displayed on the following page after pressing the OK button. Researchers were responsible for saving screen shots as JPG files in the iPhone Photo Library. After this, the session was over. The participant was allowed to rest for 3 minutes before the next session until all 5 sessions were completed.

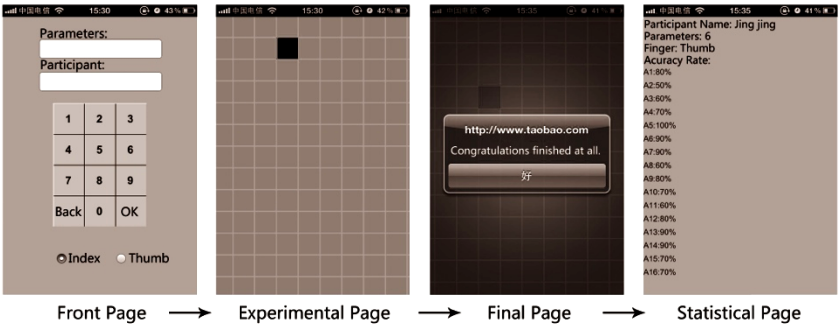

Fig. 4. Procedures of Study: Four phase of Each Session

4 Results

4.1 Accuracy Ratio

All the screen shots were collected and the dates were analyzed by SPSS. The Accuracy Ratio was analyzed using a 5×16 repeated measures analysis of variance with factors of target size (7, 8, 9, 10 and 11 mm) and location (16 slots derived from a 4×4 division of the screen). Erroneous trials were eliminated from the data set and the mean accuracy ratio of the remaining trials was computed. Repeated measures analysis of variance showed that the order of presentation of the techniques had no significant effect on accuracy ratio.

Table 1. Accuracy Ratio of Sixteen Slots in Each Session

Slots	Size=7 mm		Size=8 mm		Size=9 mm		Size=10 mm		Size=11 mm	
	Mean	(Standard Deviation)	Mean	(Standard Deviation)	Mean	(Standard Deviation)	Mean	(Standard Deviation)	Mean	(Standard Deviation)
A1	0.865	(0.114)	0.900	(0.119)	0.910	(0.117)	0.935	(0.135)	0.975	(0.044)
A2	0.870	(0.138)	0.920	(0.076)	0.930	(0.103)	0.965	(0.075)	0.995	(0.022)
A3	0.860	(0.127)	0.895	(0.110)	0.900	(0.108)	0.960	(0.082)	0.975	(0.055)
A4	0.770	(0.205)	0.855	(0.139)	0.915	(0.099)	0.935	(0.109)	0.960	(0.052)
B1	0.870	(0.142)	0.895	(0.139)	0.920	(0.149)	0.960	(0.069)	0.960	(0.050)
B2	0.935	(0.088)	0.920	(0.089)	0.935	(0.118)	0.975	(0.044)	0.975	(0.055)
B3	0.870	(0.145)	0.870	(0.108)	0.925	(0.079)	0.945	(0.076)	0.975	(0.044)
B4	0.750	(0.201)	0.890	(0.091)	0.925	(0.097)	0.950	(0.069)	0.965	(0.075)
C1	0.840	(0.167)	0.870	(0.126)	0.960	(0.068)	0.975	(0.044)	0.980	(0.052)
C2	0.845	(0.154)	0.910	(0.097)	0.960	(0.060)	0.975	(0.055)	0.965	(0.059)
C3	0.820	(0.161)	0.855	(0.170)	0.905	(0.143)	0.930	(0.086)	0.985	(0.049)
C4	0.750	(0.176)	0.830	(0.138)	0.915	(0.093)	0.930	(0.098)	0.985	(0.037)
D1	0.810	(0.152)	0.855	(0.154)	0.900	(0.165)	0.915	(0.131)	0.960	(0.060)
D2	0.885	(0.114)	0.915	(0.093)	0.930	(0.073)	0.955	(0.069)	0.975	(0.064)
D3	0.865	(0.104)	0.880	(0.120)	0.900	(0.097)	0.945	(0.093)	0.965	(0.059)
D4	0.745	(0.199)	0.760	(0.239)	0.840	(0.143)	0.935	(0.089)	0.960	(0.114)

As shown in Table 1, accuracy improved significantly as the target size increased. No slots reached a 95% accuracy level with target sizes below 9 mm. All 16 slots reached a 95% accuracy level with target sizes of 11.

4.2 Comfort Zone and Accessible Zone

Rule of Thumb. To verify whether the Rule of Thumb applies to Chinese users, we selected 9 slots (B1+B2+B3+C1+C2+C3+D1+D2+D3) as the approximate area that suggested by Josh Clark. These 9 slots formed the test area named Suggested Comfort Zone, whereas the other area of the screen was named Suggested Accessible Zone. To verify significant differences between the two areas of the screen, the differences in the measurement data were compared with a paired t-test. If this division also applies to Chinese users, significant differences in accuracy ratio would be found between the two areas (Suggested Comfort Zone v. Suggested Accessible Zone) in all 5 sizes in the experiments. This would mean that the accuracy ratio of the Suggested Comfort Zone would be significantly higher than that of the Accessible Zone, for any target size.

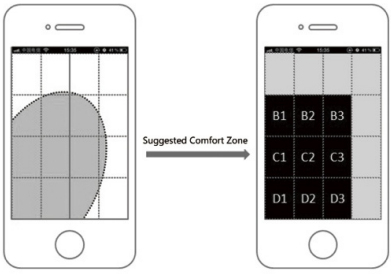

Fig. 5. Suggested Accessible Zone

However, the paired t-test analysis showed that there was no significant difference in the accuracy ratio when aiming for the 8, 9, 10, and 11 mm targets (Suggested Comfort Zone v. Suggested Accessible Zone: 8 mm targets, $t\,(19) = 0.99$, $p = 0.34$; 9 mm, $t\,(19) = 1.83$, $p = 0.08$; 10 mm targets, $t\,(19) = 0.86$, $p = 0.40$; 11 mm targets, $t\,(19) = -0.91$, $p = 0.37$). When the target was 7 mm, the two areas showed significant difference in the accuracy ratio (Suggested Comfort Zone v. Suggested Accessible Zone: 7 mm targets, $t\,(19) = 3.17$, $p = 0.01$). As shown in Figure 6, the accuracy ratio improves significantly as targets grow from 8 mm to 11 mm in both areas, whereas the significant difference between the two areas was disappeared. This division maybe suitable for Westerners, but this presents problems for Chinese users.

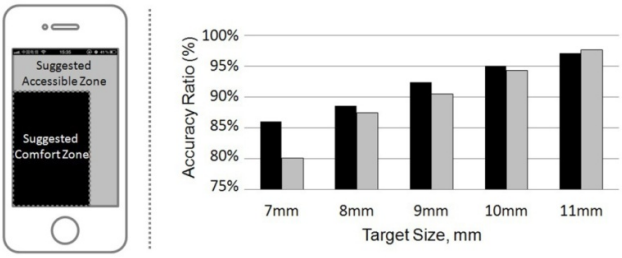

Fig. 6. Paired t-test results of the Suggested Comfort Zone and Suggested Accessible Zone

Comfort Zone for Chinese User. The Comfort Zone might be related to the natural extension of the thumb. As shown in Fig. 7, we located a fan-shaped area located on the inclined left side of the screen by observing the movements of the right thumb. Thus, we have another hypothesis for the Comfort Zone. We selected 7 particular slots (A2+A3+B1+B2+C1+C2+C3+D2) as the approximate fan-shaped area. These 7 slots formed the test area named the "Groping Comfort Zone", while the other area of the screen was named the "Groping Accessible Zone". Similarly, if the new division applies to Chinese users, significant differences in accuracy ratios would be found between the two areas (Groping Comfort Zone v. Groping Accessible Zone) in all 5 sizes of the experiments.

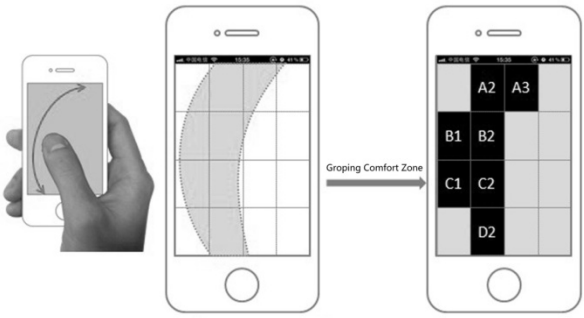

Fig. 7. Groping Comfort Zone

The paired t-test analysis showed that the accuracy ratio for the two areas (Groping Comfort Zone v. Groping Accessible Zone) differed significantly from one another when aiming for the 7, 8, 9 and10 mm targets, and the accuracy ratios of the Groping Comfort Zone were significantly higher than the Groping Accessible Zone (Groping Comfort Zone v. Groping Accessible Zone: 7 mm targets, $t\,(19) = 3.73$, $p = 0.001$; 8 mm targets, $t\,(19) = 3.57$, $p = 0.002$; 9 mm targets, $t\,(19) = 2.89$, $p = 0.009$; 10 mm targets, $t\,(19) = 3.10$, $p = 0.006$). When the target size increased to 11 mm, it was easier to aim and tap the target, and the significant difference disappeared between the two areas (Groping Comfort Zone v. Groping Accessible Zone: 11 mm targets, $t\,(19) = 0.46$, $p = 0.650$). Compared with the Rule of Thumb, the fan-shaped area was more reasonable for the Chinese user, especially when the touch target size was below 11 mm. Additionally, we also found that the accuracy ratios for Slot A4, C4, D1 and D4 were the lowest of all. Thus, high-frequency operation should be located in a reasonable area of the screen, and these 4 slots (A4, C4, D1 and D4) should be avoided as much as possible.

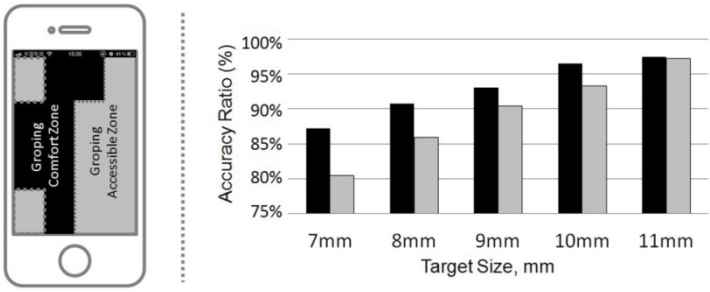

Fig. 7. Paired t-test results of the Groping Comfort Zone and Groping Accessible Zone

4.3 Minimum Size of Touch Target

The minimum sizes of touch target were obtained by linear interpolation. The results showed that the different locations required different minimum touch target sizes. More than half of the screen required a touch target size larger than 10 mm. The minimum

touch target sizes were obtained as follows: A1=10.4 mm, A2=9.6 mm, A3=9.8 mm, A4=10.7 mm, B1=9.8 mm, B2=9.4 mm, B3=10.2 mm, B4=10.0 mm, C1=8.9 mm, C2=8.8 mm, C3=10.4 mm, C4=10.5 mm, D1=10.8 mm, D2=9.8 mm, D3=10.3 mm, and D4=10.6 mm.

5 Conclusion

In an effort to determine the Comfort Zone and minimum target sizes for Chinese users with one-handed thumb use of mobile devices, we examined the interaction between target size and target locations in detail. Based on our findings, we recommend a fan-shaped area located on the inclined left side of the screen as the Comfort Zone for the right thumb; in addition, the minimum size of the touch target was different in different locations of the screen. More than half of the screen required a touch target size larger than 10 mm.

References

1. Karlson, A.K., Bederson, B.B.: ThumbSpace: Generalized One-Handed Input for Touchscreen-Based Mobile Devices. In: Baranauskas, C., Abascal, J., Barbosa, S.D.J. (eds.) INTERACT 2007. LNCS, vol. 4662, pp. 324–338. Springer, Heidelberg (2007)
2. Roudaut, A., Huot, S., Lecolinet, E.: TapTap and MagStick: Improving One-Handed Target Acquisition on Small Touch-screens. In: AVI 2008, pp. 146–153 (2008)
3. Clark, J.: Tapworthy-Designing Great iPhone Apps, pp. 58–60 (2010)
4. https://developer.apple.com/library/ios/navigation/
5. http://msdn.microsoft.com/en-us/library/hh202915v=VS.92.aspx
6. http://library.developer.nokia.com/index.jsp?topic=/S60_5th_Edition_Cpp_Developers_Library/GUID-5486EFD3-4660-4C19-A007-286DE48F6EEF.html
7. Parhi, P., Karlson, A., Bederson, B.: Target Size Study for One-Handed Thumb Use on Small Touchscreen Devices. In: Proc. MobileHCI 2006, pp. 203–210 (2006)
8. Dandekar, K., Raju, B.I., Srinivasan, M.A.: 3-D Finite-Element Models of Human and Monkey Fingertips to Investigate the Mechanics of Tactile Sense. Journal of Biomechanical Engineering, 685 (2003)
9. http://wenku.baidu.com/view/4e23160a79563c1ec5da719c.html