Thumb Reach of Portuguese Young Adult When Interacting with a Touchscreen of One-Handed Device

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ABSTRACT
The main purpose of this study was to identify the thumb reach envelope of Portuguese young adults for a one-handed device. The correlation between the thumb reach versus the hand length and thumb length was also analyzed. One hundred and forty-two Portuguese young adults participated in the study. The thumb reach envelope of Portuguese young adults was identified. The results of this study also found that people with a larger hand length and thumb length tend to have a larger thumb reach. However, few other factors, such as the way participants hold the mobile phone, participant's experience with touchscreen device and possibility of misunderstood the instructions during the survey were suspected to influence the thumb reach envelope. The results of this study also showed the thumb reach area of participants is displaying elliptical shape that runs from top right to bottom left areas of the device screen.

KEYWORDS: mobile phone, anthropometry, thumb interaction, heat map

1. INTRODUCTION

Currently, it is easy to find people using hand-held devices, such as mobile phone, tablet, camera, and music player. Few studies found that people grasp their mobile devices in many postures, such as single hand, two hands, and in a cradle mode (Karlson et al., 2006a; Hoober, 2013; Gold, 2012). It is also possible to see people using their mobile devices in a flat or tilt position on the table, especially if they are using tablets (Young et al., 2013). However, researchers have also identified that people can easily change from one posture to another posture very often (Hoober, 2013; Umami et al., 2014).

Gold et al. (2012) and Hoober (2013) confirmed that people commonly use their thumb to interact with the touchscreen of mobile devices. Another study found that the use of the thumb in one-handed interaction was also considered to be a more effective way than the use of stylus or index finger (Katre, 2008).

It is widely known that many data collections on dimensions of human body and its specific parts, included foot, hand, and other body parts, were done in a structural state. An effort of Otten et al. (2013) on the thumb reach measurement seems to be the first study of the thumb measures in functional state. The results of Otten et al. (2013) study are useful for handheld device designers and engineers. Additionally, the methodology they developed can be helpful for other researchers as a guideline in collecting the thumb reach envelope data for a specific application (Budnik, 2013).

The current study aimed to collect functional anthropometry of thumb for Portuguese young adults. This study is very important since there is a lack of pertinent data for the Portuguese population. The current study was also done to identify the correlation between the hand length and thumb length, as the structural anthropometry, and thumb reach envelope, as the functional anthropometry of the thumb.

2. MATERIALS AND METHOD

The current study involved 142 participants (69 females and 73 males). They were mainly students, teachers and researchers. All participants had normal body posture and dominantly use their right hand to perform their daily activities. They were in the age range from 18 and 35 years old with a mean of 22.4 (SD = 3.7) years old.

A mobile phone from Samsung, model of Galaxy S7562, was used for the test. Dimensional specification of the mobile phone is presented in Table 1.

Table 1 - Dimensional specification of mobile phone used in the observation.

Body dimensions	Length	: 121.5 mm
	Width	: 63.1 mm
	Thickness	: 10.5 mm
Screen size	Diagonal	: 101.6 mm (4 inch)
	Height	: 87 mm
	Width	: 52.5 mm
Distance between the screen edges and device edges	Top	: 17.75
	Bottom	: 16.75
	Right	: 5.3 mm
	Left	: 5.3 mm

A drawing application for mobile phones, Drau v1.3.5, which was available on the Google Play Store™, was installed in the mobile phone. The application was used to record the thumb reach of participants by mean of the area covered by a color when the participants were swiping their thumbs on the canvas. The canvas was divided into 200 cells (20 cells high and 10 cells wide; each cell has 4.35 mm high and 5.25 mm wide) (Figure 1). The brush was set in the fixed thickness of 3 points (approximately 1.06 mm).

Figure 1 – Cells in canvas of Drau application on an Android mobile phone.

The hand length and thumb length dimensions were measured from digital hand images that were captured by using a Canon LiDE 210 digital scanner. An image-based measurement software from ImageJ (available at http://rsbweb.nih.gov/ij/) was used to conduct some pertinent measurements based on the hand/finger images and saved images from the Drau application.

In the experimental phase, the participant was asked to hold the mobile phone in one hand as he/she normally grabs it in their daily use securely and comfortably. Then the participant was asked to color the canvas area by using his/her thumb. The participant should keep the mobile phone position in swiping some areas in the canvas/screen. The colored area is the normal reach of the thumb that can be achieved by the participant comfortably. This area is possible to be classified as the comfortable area.

The current study was designed to consider the hand length and thumb length as independent variables and the maximum thumb reach and shape of reachable area as response variables. The maximum thumb reach was measured from bottom-right of the mobile phone. Thumb reach envelope is obtained from the area that could be reached by the participants' thumb on the mobile phone screen. The line generated by the participants' thumb swipe showed the track of contact center between the thumb and screen. Each cell that was covered by the line of the closed curve drawn by the participant (based on experimenter's judgment) was included in the individual participant's thumb reach. The maximum thumb reach was defined as the farthest distance that could be comfortably reached by the thumb of participant.

Person's correlation analysis was used to know the strength of correlation between the maximum thumb reach and the hand length and thumb length. Heat map analysis was used to identify the area that could be reached by the participants. The heat map was also used to visually inspect the shape of reachable area. Percentage of participants who could comfortably reach an individual area (cell) was also displayed on the heat maps.

3. RESULTS AND DISCUSSION

The study found the participants' body height, hand length and thumb length mean are 1702.5 mm (SD=94.0 mm), 177.9 mm (SD=12.1 mm) and 62.7 mm (SD=4.9 mm), respectively. The measurements also showed the length of the tip to joint of the thumb and joint to root of the thumb are 31.0 mm (SD=3.4 mm) and 31.6 (SD=3.1 mm), respectively. Test of data distribution using Kolmogorov-Smirnov shows the body height, hand length, thumb length, tip to joint of the thumb, and joint to root of the thumb data are normally distributed ($p < 0.05$). Test of Kolmogorov-Smirnov also shows that the thumb reach data is normally distributed ($p < 0.05$) with the mean of 89.0 mm (SD = 6.0 mm).

The Pearson's correlation analysis between the maximum thumb reach vs. the hand length and thumb length found a significant, but weak, correlation with the coefficient of 0.45 and 0.42 respectively ($p < 0.01$). It means people with a larger hand length and thumb length tend to have a larger thumb reach. The finding of this study is in accordance to that of Otten et al. (2013) that clearly concluded the existence of significant, but weak, correlation between the maximum thumb reach and length of the thumb. However, this result is in contrast to the conclusion obtained by Kim and Jung's (2010) study, in which they found that the hand size does not affect the thumb reach. This discrepancy might be caused by few factors, such as the way participants hold the mobile phone, participant's experience with touchscreen device and possibility of misunderstood the instructions during the survey.

The analysis of the heat map showed that the participants can comfortably touch an area between 21.0 and 42.1 mm from the bottom and between 55.9 and 69.0 mm from the right (Figure 2). Visual inspection of the heat map found that the thumb reach area of participants is displaying an elliptical shape. This result is similar to the finding of Karlson et al. (2006b) and Otten et al. (2013). According to Karlson et al. (2006b), the thumb movements along the axis running from northeast (top right) to southwest (bottom left) is perceived as easier for the right-handed users. Otten et al. (2013) revealed that from the physiological perspective, such movements follow the abduction and adduction. In other words, the elliptical shape of the reached area shows the easiest area that is covered by the thumb movement toward and away from the palm. However, the thumb reach of participants in the current study is farther than that of Otten et al.'s study (2013). Besides, there are also differences in the touchable area between this last study and the current one.

The current study found that there is no participant that could reach all areas on the screen easily (Figure 2). This finding shows a little difference from the study of Otten et al. (2013), which found few participants could reach all areas on the screen. The differences may occur due to the differences on the size of the device used in the experiment and the way participants were grasping their mobile devices.

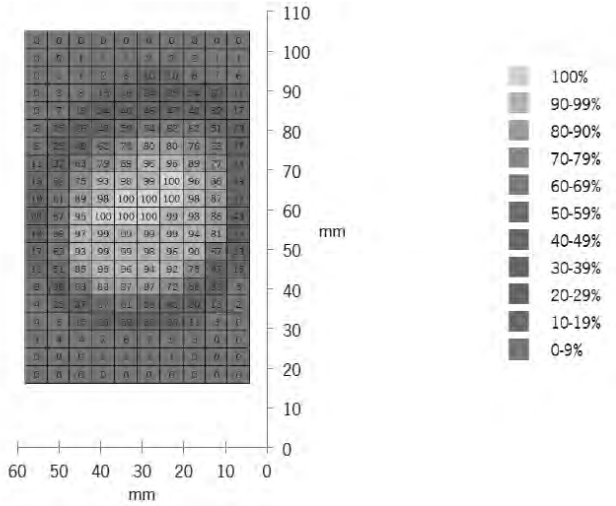

Figure 2 – Heat map displaying the % of participants that could comfortably reach an individual cell on the screen.

4. CONCLUSIONS

In this study, the main purpose was to identify the thumb reach envelope of Portuguese young adults for one-handed device. It was identified that the participants could comfortably touch an area between 21.0 and 42.1 mm from the bottom and between 55.9 and 69.0 mm from the right. Additionally, the results of this study also found that people with a larger hand length and thumb length tend to have a larger thumb reach. However, few other factors, such as the way participants hold the mobile phone, participant's experience with touchscreen device and possibility of misunderstood the instructions during the survey were suspected to influence the thumb reach envelope. The results of this study also showed that the thumb reach area is displaying an elliptical shape. The elliptical shape of the reached area shows the easiest area that can be covered by the thumb movement toward and away from the palm for the right-handed users.

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