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Analyzing thumb interaction on mobile touchpad devices

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ABSTRACT

A touchpad is a convenient device component on account of its mobility and portability, and is used more widely nowadays to control various devices. This study investigated the usability of a touchpad when subjects performed the task of pressing a target on a mobile device. The 3.5-inch mobile device was used in an experiment in which the subject pressed a single target. A total of 24 right-handed subjects participated in the experiment. The breadth and length of the thumb of each subject were measured. Task performance times and the number of errors were analyzed. The results showed that task performance times increased as the target size decreased and that the target location was in the lower-right corner. In terms of the length of the thumb, the group of the longest thumb had the lowest performance. The results of this study can be used to design touchpad-related interfaces using thumb-based control for other mobile devices.

Relevance to industry: The results of this study are expected to be useful in the development of a mobile interface that considers the specific features of the user's thumb.

1. Introduction

Since home computers first became popular decades ago, the graphical user interface (GUI) has been widely used. This interface has led to the development of new input devices, regardless of the operating system. In addition to the mouse, an example of a widely used indirect input device is the touchscreen, while direct input devices include the joystick, trackball, track point, and touchpad (Karat et al., 1986; Park et al., 2000; Rathod et al., 2012). With the development of new input devices, human-computer interface (HCI) researchers have conducted studies to evaluate the usability of these various input apparatus. This research has been accelerated by evaluating the user experience and overall usability for mobile devices (Park et al., 2013a,b; Park et al., 2015). In the initial stages of research, a variety of input devices, such as the trackball and track point, as well as the touchpad, have been placed on mobile devices to compare the usability among input devices (Kim et al., 2017; Im et al., 2015; Park and Han, 2010; Park et al., 2008; Westerman et al., 2001).

The touchpad is widely built into remote controls for television and virtual reality (VR) devices. Recently, Samsung TV and Apple TV remote controls have a touchpad that can scroll and select menu. It is also considered the main input device for the controller of the VR device. Samsung's new Gear VR controller and HTC Vive controller have touchpads that require thumb movement. This study can be used as a basic research to utilize the touchpad with the movement of the thumb in various devices.

Many studies have been conducted to evaluate touchpad usability with regard to the target size in the screen (Akamatsu and MacKenzie, 2002; Hertzum and Hornbæk, 2013), the control display (CD) ratio (Puspasari and Lee, 2012), the size of the touchpad (Puspasari and Lee, 2012; Avera et al., 2015), and the touchpad location placed on laptops (Kelaher et al., 2001; Burnett et al., 2013).

First of all, the target size is an important factor because it affects the accuracy and touch performance. Akamatsu and MacKenzie (2002) divided the target sizes during a pointing task and identified the operation time and target error rate. They found that the smaller the target size is, the longer the operation time and higher the target error rate; however, they did not analyze the proper target size of the touchpad.

Second, the CD ratio is an indicator of the distance a cursor is moved against the control by a user, which should be considered in the design of an indirect input device. However, the CD ratio is a contended value; studies have shown differing results (Puspasari and Lee, 2012). Puspasari and Lee (2012) showed a low accuracy rate and quick task speed when the CD ratio is 1:2. They additionally showed a long performance time and highest operation accuracy when the CD ratio is 1:0.5.

Third, for research on touchpad size, a large size of a touchpad

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(100 × 60 mm) provides fast operation and low operation accuracy. On the other hand, a small touchpad size (65 × 36 mm) provides slow operation speed and high operation accuracy (Puspasari and Lee, 2012).

Fourth, according to the study of Avera et al. (2015), the user tends to utilize only the center area of the touchpad regardless of the size of the touchpad. Kelaher et al., (2001) and Han and Kim (2016) analyzed a touchpad location on a notebook from an ergonomic point of view (e.g., wrist flexion and shoulder flexion, muscle fatigue). Both studies suggested that a touchpad is placed on the right side of a notebook for the right-handed users. Despite the fact that many studies relating to touchpad usability have been conducted, relatively few studies have been performed on the appropriate target size for pointing tasks in the screen. The appropriate target size when using the touchpad is an important research issue when designing menus in the user interface, such as television remote controls and VR devices.

The aim of this study is to, therefore, analyze the impact of touchpad usability in terms of the size of the target on the screen. For the usability analysis, we analyzed the performance time (i.e., the first transition time and task completion time) and the number of errors. As a measure, the performance time was further investigated to determine whether it would be proportional to the task difficulty, which was defined by Fitts (MacKenzie, 1992; Soukoreff and MacKenzie, 2004). It additionally serves to (1) present an appropriate target size on screen for mobile devices, (2) investigate whether the target location on the screen affects the touchpad usability, and (3) identify whether human dimension characteristics (i.e., the thumb breadth and length) affect the touchpad usability.

2. Methods

2.1. Subjects

A total of 24 right-handed subjects (12 males, 12 females) participated in the experiment. Their average age was 22.6 (± 2.5). They all had normal vision and movement and previously used a mobile device with a touchscreen.

The average thumb breadth and length of the subjects were respectively 18.7 mm (± 1.9 mm) and 56.3 mm (± 3.5 mm). The thumb breadth was measured according to the interphalangeal joint breadth standard (Fig. 1, A). The thumb length was measured by the length between the thumb tip and saddle point (between the thumb and index finger) standard (Fig. 1, B). The measurement standard was based on the "Size Korea" publication on the average human body measurements of Koreans. The thumb breadth and length data according to gender was summarized in Table 1. The average thumb breadths of male and female subjects were respectively 19.81 mm and 18.7 mm while the average thumb lengths of male and female subjects were respectively 60.3 mm and 55.3 mm.

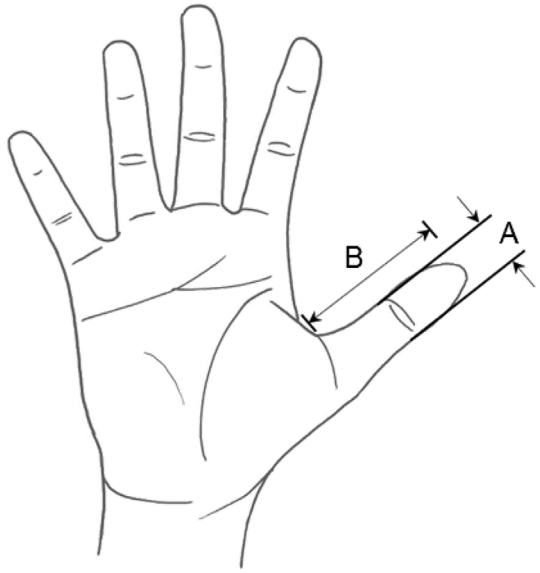

Fig. 1. Thumb breadth (A) and length (B) measurement criteria.

Table 1
Finger measurement data according to gender.

Group	Thumb breadth				Thumb length			
	Avg.	5th	50th	95th	Avg.	5th	50th	95th
Male	19.81	17.3	19.2	23.2	60.3	50.6	56.6	61.5
Female	18.7	17.2	18.7	20.4	55.3	50.5	55.2	60

It is known that the average thumb breadth of a Korean is 20.1 mm and the thumb length is 58 mm, whereas the average thumb breadth of an American is 22.5 mm and the thumb length is 66.5 mm (Greiner, 1991; Size Korea, 2010). Note that the exact methods to measure the thumb length and breadth of US army participants were not mentioned in the literature. It is possible that the difference between measurement methods can result in the difference between results of the two countries.

2.2. Experimental design

We combined a small Synaptics touchpad module with mobile devices operating the Microsoft Mobile Pocket PC operating system to implement the mobile device powering by a touchpad. Each mobile device had an 8.9 cm (breadth 5.3 cm, vertical 7.1 cm) screen and a resolution of 240 × 320 pixels. Although the resolution of the device in this experiment was somewhat less than 240 × 320 pixels, it did not present an issue. The touchpad module was the same as those used in laptops that detect the location and movement of one or more fingers touching the surface through the measurement of capacitance in small contact pads.

The target button in the screen test was implemented on a small area of 35 × 35 mm (Fig. 2). The following was considered: 1) The appropriate target size, which was identified in the current study, is also applicable to any screen size, 2) Some applications, such as the virtual keyboard on a smartphone or the remote controller in televisions and VR devices, can be potential subjects, and 3) The Synaptics touchpad size was also 35 × 35 mm; thus, the CD ratio could be set to 1:1 in the experiment.

The sizes of the destination button were finally set to 5 mm, 7 mm, and 11.7 mm, which were the values that could be expressed when the buttons were arranged in 7 × 7, 5 × 5, and 3 × 3 grid menu types in the screen area. Owing to the insufficient number of studies conducted on the optimal button size when using the touchpad on a mobile device, we referenced a study on the optimal button size on the touchscreen. In the case of time-based tasks, Park and Han (2010) recommended 7 mm and 10 mm, while Parhi et al. (2006) recommended 11.5 mm.

The Synaptics touchpad has a size of 35 mm × 35 mm, which is the average size of the touchpad in the notebook. Puspasari and Lee (2012) mentioned that it is difficult to determine the optimal size of the touchpad. Specifically, we utilized the touchpad of the same size as the display area to minimize the influence of the CD ratio. In future work, we can experiment using the touchpad of different sizes. As previously mentioned, the operation of the machine to utilize the GUI can be influenced by the usability CD ratio (Karlson and Bederson, 2007). In this study, we did not focus on finding the best CD ratio of the touchpad; rather, the subjects could set their preferred CD ratio in the preliminary experiment. We thus conducted the experiment because the CD ratio could be directly set in many devices.