Analysis of Perceived Discomfort and EMG for Touch Locations of a Soft Keyboard*

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Abstract. With diversity of mobile services (e.g., messenger, and social network service) on smartphone, the demand of text input using a soft keyboard is increasing. However, studies on subjective and physiological responses of users for various touch locations are lacking. The present study investigated the ergonomic responses according to touch locations of a soft keyboard on smartphone. The experiment of the present study measured perceived discomfort using Borg's CR-10 scale and electromyography on forearm (abductor pollicis longus, and extensor digitorum communis) and thumb (abductor pollicis brevis, and first dorsal interossei) muscles. Perceived discomfort was significantly varied from 0.7 (extremely weak discomfort) to 2.5 (weak discomfort) depending on touch locations. %MVC at abductor pollicis brevis was significantly varied from 10% to 23% according to touch locations. The experimental results of the present study can be utilized in the ergonomic design of a soft keyboard.

Keywords: Soft Keyboard, Discomfort, EMG, Two-thumb Input, Smartphone.

1 Introduction

Recently, with diversity of the smartphone services, the frequency of text input using soft keyboard has increased. It has reported that 88% of users are using the information search, email, and web-surfing on smartphone (KISA, 2011). Furthermore, 79.6% of smartphone users have used messenger or social network services. From these reasons, the demand of the text entry with soft keyboard has been increased.

The layout of soft keyboards can be classified into 2 types: 1) 3×4 layout, 2) QWERTY layout. The 3×4 layout consists of 12 buttons and is similar to the traditional layout used in a cellular phone. On the other hands, the QWERTY layout consists of 26 buttons and is similar to the standard PC keyboard.

Various studies related to the soft keyboard have been carried out; however, they still have limits in three aspects: two-thumb entry, electromyography (EMG) analysis,

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and grip position. First, studies on two-thumb entry are rare compared to one-thumb entry (Karlson, 2006). Second, EMG studies are few (Park, 2010; Ryu, 2011; Kim et al., 2011) because text entry on smartphone is conducted by small muscles in the thumb. Finally, most of the perceived discomfort studies for various touch locations (Park and Han, 2007) did not take account of the smartphone grip strategy for text entry.

This study analyzed perceived discomfort and EMG for touch locations of a soft keyboard. The locations of touch divided into five lows and five columns. EMG was measured on two muscles of the thumb and two muscles of the forearm by referring to Jonsson et al., 2011. The experimental results obtained in this study can be utilized to design of soft keyboard for smartphones.

2 Methods and Material

2.1 Participants

Ten male participants with smartphone usage experience were involved in this experiment. Their average age was 24.7 and their dominant hand was all right-side. The participants did not have any pain or discomfort on the thumbs and upper extremity at the experimental day.

2.2 EMG Measurement Protocol

Surface EMG system (Telemyo, Noraxon, USA) was used in this experiment. The diameter of surface electrode (Bio Protech, South Korea) was 1 cm and the centroid distance between a pair of electrodes was 2.5 cm. The MyoResearch XP Master Edition (Noraxon, USA) was used in measurement and analysis of EMG. This study used four pairs of electrodes to measure EMG signals with 1,000 Hz sampling rate on four muscles.

Four measurement muscles were selected by referring to a related study (Jonsson et al., 2011). Two muscles (abductor pollicis brevis (APB) and extrinsic muscle abductor pollicis longus (APL)) of the four were related to the movement of the thumb. APB and APL identically relate to thumb abduction motion; however, they are intrinsic muscle and extrinsic muscle, respectively. The rest of two muscles (first dorsal interossei, (FDI), extensor digitorum communis (EDC)) were related to the movement of the fingers (index, middle, ring, and little fingers). FDI and EDC relate to flexion and extension motions, respectively. They are intrinsic and extrinsic muscles.

2.3 Experimental Design

One factor (touch location) within-subject design was applied in the experiment. Touch location consisted of 5 rows and 5 columns as illustrated in Fig 1. The touch thumb was designated to each of the column based on users' touch behavior. For the left 2 columns, the buttons were touched by the left thumb; for the right 2 columns, the buttons were touched by the right thumb; lastly, for the middle column, the buttons were touched by both the left and right thumbs.

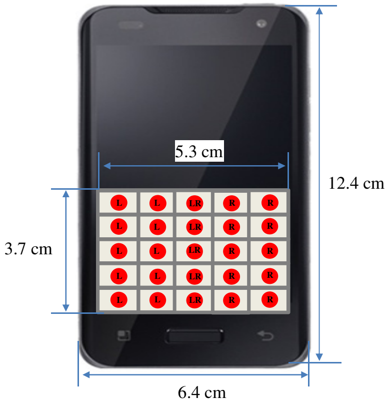


Fig. 1. Touch locations (L: left thumb, R: right thumb, LR: left and right thumb)

Dependent variables were two (rating of perceived discomfort and percent of maximum voluntary contraction (%MVC)). Perceived discomfort was measured by Borg's CR-10 scale (Kwon et al., 2009; Borg, 1998). %MVC was calculated by dividing measured voltage with MVC of each participant. MVC of the present study was measured by applying the Caldwell protocol (Chaffin et al., 1999).

The experiment of this study was conducted by 6 stages (introduction, electrode attachment, MVC measurement, practice, main experiment, and debriefing). First, we explained research purpose and experimental methods to each participant and obtained informed consent. Second, the electrodes were attached on the muscles of participants. Third, MVC of each participant was measured by applying the Caldwell protocol. Fourth, enough practice was allowed participants to accustom the experiment method and procedure. Fifth, the main experiment was conducted which presses the button of soft keyboard in random order. Finally, a brief debriefing was carried out.

2.4 Analysis Protocol

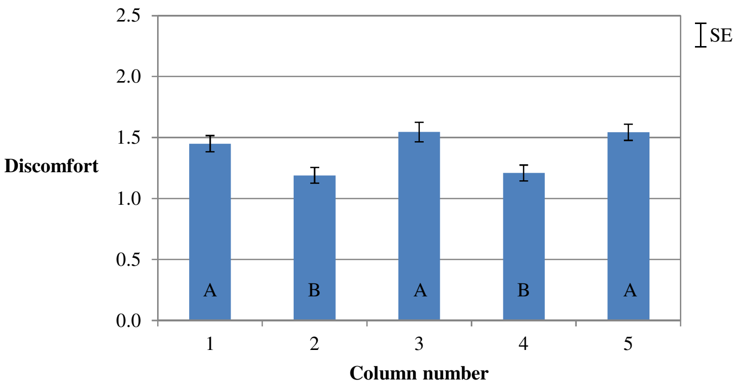
EMG data was analyzed in 4 stages (rectification, smoothing, RMS calculation, %MVC calculation). First, EMG data was rectified. Second, rectified data was smoothed (RMS window = 100 ms) in order to eliminate noise. Third, root mean square (RMS) for the smoothed data was calculated. Finally, %MVC was calculated by dividing RMS with MVC.

The statistical analysis of the present study was conducted using MINITAB 16.0 (Minitab Inc., USA) with significance level (α) 0.05. One-factor within subject ANOVA was carried out for each of touch location (25 levels), touch row (5 levels), and touch column (5 levels). As post-hoc analysis, Bonferroni test was applied.

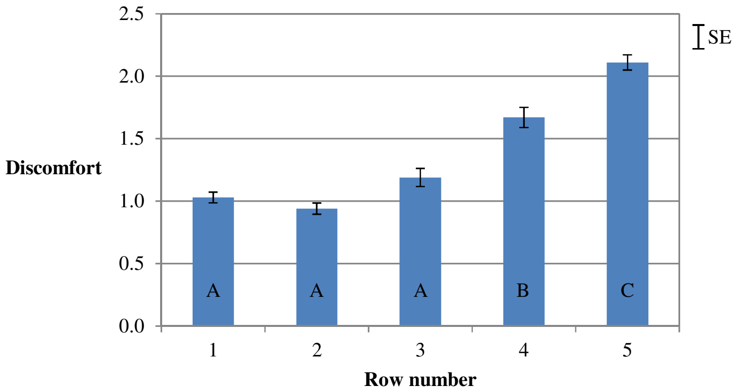
3 Results

The perceived discomforts for each touch location were significantly different ($F(24, 215) = 7.38$, $p < 0.001$). Maximum value (2.5: weak) of the perceived discomforts was 3.5 times greater than the minimum value (0.7: very weak). On the other hand, the perceived discomforts between the left and right thumbs were not significant ($F(1, 238) = 0.04$, $p = 0.84$).

The perceived discomforts of 2nd and 4th columns were significantly lower than those of other columns ($F(4, 235) = 2.99$, $p = 0.02$; Fig 2.a). The perceived discomforts were divided into two: 1) small discomfort group: 2nd column ($\bar{x} \pm SE$; 1.19 ± 0.13) and 4th column (1.21 ± 0.13), 2) large discomfort group: 1st column (1.45 ± 0.13), 5th column (1.54 ± 1.13), and 3rd column (1.55 ± 1.60). This tendency seems to be caused because the initial locations of the left thumb and right thumb were located around 2nd and 4th columns, respectively.



(a) Touch column



(b) Touch row

Fig. 2. Perceived discomfort for touch columns and rows

The perceived discomforts of upper rows (1^{st} - 3^{rd}) were significantly lower than those of lower rows (4^{th} and 5^{th}) ($F(4, 235) = 36.37$, $p < 0.001$; Fig 2.b). The perceived discomforts for rows were divided into two: 1) small discomfort group: 2^{nd} row (0.94 ± 0.09), 1^{st} row (1.03 ± 0.09), 3^{rd} row (1.03 ± 0.09), 2) large discomfort group: 4^{th} row (1.67 ± 0.16) and 5^{th} row (2.11 ± 0.12). This tendency seems to be explained by the initial location of the thumbs, which located around 2^{nd} row.

%MVC for APB was only significant across touch rows ($F(24, 216) = 3.55$, $p< 0.001$) and columns ($F(24, 216) = 3.55$, $p< 0.001$). %MVC for the left thumb's APB increased 1^{st} (10 ± 0.9), 2^{nd}(13 ± 1.2), and 3^{rd} (23 ± 1.8) columns in ascending order. Similarly, %MVC for the right thumb's APB increased 5^{th} (16 ± 1.8), 4^{th} (18 ± 1.5), and 3^{rd} (23 ± 1.8) columns in ascending order. In addition, %MVC for APB significantly increased from 1^{st} row (13 ± 1.4) to 5^{th} row (20 ± 1.8). This trend was occurred because APB muscle is contracted while the thumb is abducted.

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