Analysis of Grip Posture for Ergonomic Smartphone Interface Design

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Grip posture needs to be considered to ergonomic smartphone interface design for better usability in terms of controllability, user performance, and stability. The present study is intended to objectively classify grip postures of smartphone when users conduct tasks with hard keys. Forty five smartphone users conducted tasks with nine smartphone mock-ups in different sizes. Two cameras were located above and under a smartphone mock-up and recorded synchronized videos of grip postures. The grip postures of smartphone were classified by counting the number of fingers at each side of smartphone. Three dominant grip postures of smartphone were identified in the experiment: (1) 3-finger left, 1-finger right, and 1-finger back support (70.0%), (2) 4-finger left and 1-finger right (13.3%), and (3) 3-finger left, 1-finger right, and 1-finger top (12.0%). Device size, hand width, and hand length were found significantly influential to grip posture. The grip postures identified in the present study would be of use in ergonomic smartphone interface design.

INTRODUCTION

A systematic understanding of smartphone grip posture can be applied in design of ergonomic smartphone interface. User can hold a smartphone with a preferred way to control the smartphone. Meanwhile, grip loss may occur when the smartphone is not held stably enough in control of interface, and it can cause significant damage of device. Kim et al. (2014) also reported that grip posture influences usability in terms of controllability and user performance. Therefore, grip postures which provide a stable and comfortable grasping need to be studied in ergonomic smartphone interface design.

Grip posture was investigated by previous studies for design of mobile devices. Pelosi et al. (2009) and Myllymaki et al. (2010) analyzed grip postures for mobile phone while conducting calling and messaging tasks to determine the antenna location for the enhancement of signal transmitting quality, and classified into soft grip and firm grip. Im et al. (2010), Trudeau et al. (2012), and Kim et al. (2014) defined right hand grip, left hand grip, and both hands grip as major grip postures when analyzing usability of each touch screen control area of smartphone.

Even though previous researchers analyzed major grip postures of mobile devices, grip postures for smartphone hard key use have not been systematically investigated. Whereas grip postures for touch screen use were studied in many researches, those for hard key use were not investigated although hard key is harder to change its location once manufactured compared to graphic user interface on a touch screen.

The present study proposed a grip posture analysis method and identified dominant grip postures for smartphones with various sizes in conducting a variety of hard key tasks.

MATERIALS AND METHODS

Participants

45 smartphone experienced participants were recruited considering hand width and hand length distribution in Korea. Anthropometric data of hand width and hand length was retrieved from Size Korea, and a total of nine groups (Short & Narrow, Short & Medium, Short & Wide, Middle & Narrow, Middle & Medium, Middle & Wide, Long & Narrow, Long & Medium, Long & Wide) were used to classify participants. Finally, twenty-eight male and seventeen female smartphone users were participated, and they were 19 ~ 41 years old.

Experiment Environment

Nine smartphone mock-ups which have from 3.0" to 7.0" screens were used to find out various grip postures depending on the size of devices. The mock-ups were designed with intervals considering the size of smartphones in the market as described in Figure 1, they had a hard key at the both left and right side, and 3D printed by a rapid prototype machine (Dimension SST, Stratasys Ltd., USA).

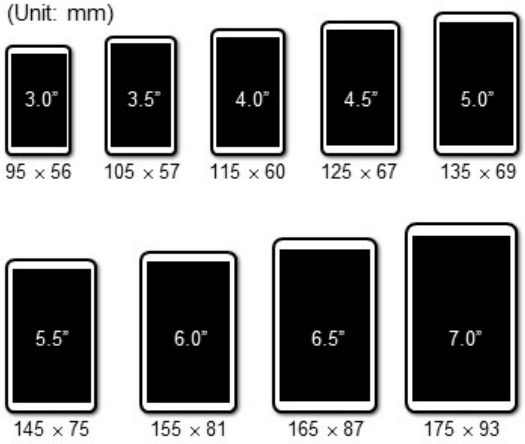

Figure 1. Nine different sizes of smartphone mock-ups

Grip posture measurement was conducted in the setting of two cameras at both above and under the smartphone mock-up to capture the grip postures while conducting tasks. The two cameras installed at above and under the mock-up recorded a synchronized video of natural grip posture while a user conducts tasks comfortably as described in Figure 2.

Tasks were defined for simulating a natural use of smartphones. The tasks consist of 'answer call', 'listen to music', 'send a message', and 'browse internet' as listed in Table 1, and specific actions such as 'turn screen on/off' and 'navigate screens' were assigned for each task.

Figure 2. Smartphone grip posture measurement environment

Table 1. The defined major tasks for smartphone use

Task	Specific Actions
Answer call	1. Grasp the phone 2. Turn volume up/down (press volume key)
Listen to music	1. Turn volume up/down (press volume key) 2. Scroll up/down 3. Show menus 4. Select a menu 5. Turn volume up/down (press volume key)
Send a message	1. Turn screen on/off (press power key) 2. Navigate screens 3. Select a message app 4. Text a word 5. Return to the home screen
Browse internet	1. Turn screen on/off (press power key) 2. Turn Wi-Fi on/off 3. Select a web browser app 4. Browse internet 5. Turn screen on/off (press power key)

Experiment procedure

Smartphone grip posture measurement was conducted by three steps including mock-up familiarization, task introduction, and grip posture measurement. In the mock-up familiarization step, participants were asked to hold and simulate controlling a smartphone with attached hard keys and printed touch screen. In the task introduction step, four smartphone tasks were introduced one by one and experiment setting was explained. Finally, participants were asked to simulate each task with right hand in a random order by balanced Latin-square design and grip postures were recorded by two synchronized cameras.

Classification of grip postures

Grip postures were classified by counting the number of fingers at each part (left, right, top, bottom, front, back) of device. For example, Figure 3 shows that 3 fingers are at the left side, 1 finger is at the right side, and 1 finger is at the back of the device, so the grip posture can be coded as L3-R1-K1. A total of 54 images for each participant were analyzed in the same way.

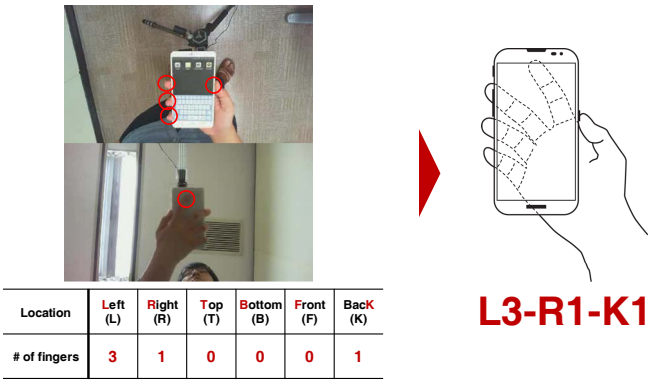

Figure 3. An example of grip posture classification

RESULTS

Grip postures for hard key use

Total nine different grip postures were found for smartphone hard key use. L3-R1-K1 (70.0%), L4-R1 (13.3%), and L3-R1-T1 (12.0%) grip postures were more than 5% of the total and identified as dominant grip postures (see Figure 4). L3-R1-K1 is a grip posture which user put 3 fingers at the left side, 1 finger at the right side, and 1 finger at the back side of the device, L4-R1 is a grip posture which user put 4 fingers at the left side and 1 finger at the right side of the device, and L3-R1-T1 is a grip posture which user put 3 fingers at the left side, 1 finger at the right side, and 1 finger at the top of the device. L4-R1 and L3-R1-T1 use all 5 fingers to grasp the device whereas L3-R1-K1 uses 4 fingers to grasp and 1 finger to support the device.

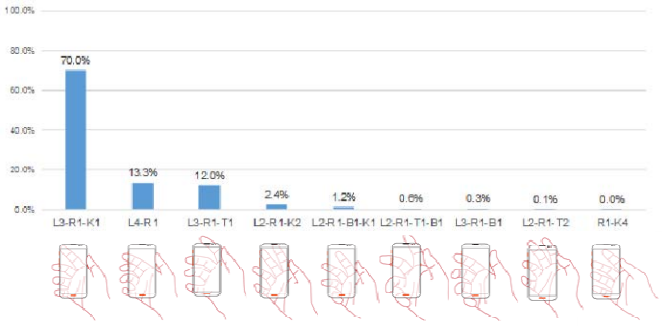

Figure 4. Grip postures for smartphone hard key use

Effect of device size and hand size

Preferred grip postures for smartphone hard key use were significantly different ($X^2[24] = 674.8$, $p < 0.001$) by device size (see Figure 5). Use frequency of L3-R1-K1 grip posture increased from 32.2% to 84.4% as device size went larger whereas L4-R1 and L3-R1-T1 decreased. Especially, L3-R1-T1 grip posture showed less than 1% for the smartphones with larger than 5.5" screen.

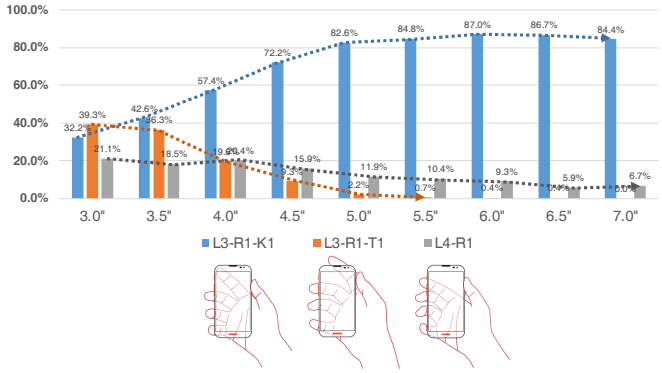

Figure 5. Major grip postures by smartphones size

Preferred grip postures for smartphone hard key use were significantly different (X^2 = 75.3 [6], $p < 0.001$) by hand width (see Figure 6). Use frequency of L3-R1-K1 grip posture decreased from 77.4% to 64.3% as hand width went larger whereas L4-R1 increased and L3-R1-T1 didn't show a certain trend.

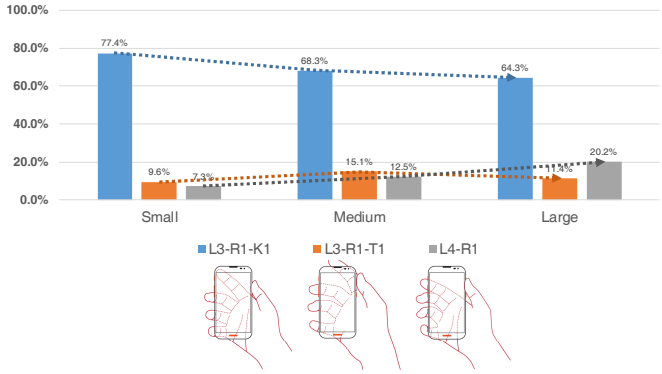

Figure 6. Major grip postures by hand width

Preferred grip postures for smartphone hard key use were significantly different (X^2 = 103.4 [6], $p < 0.001$) by hand length (see Figure 7). Use frequency of L3-R1-K1 grip posture decreased from 77.2% to 64.0% as hand width went larger whereas L4-R1 increased and L3-R1-T1 didn't show a certain trend.

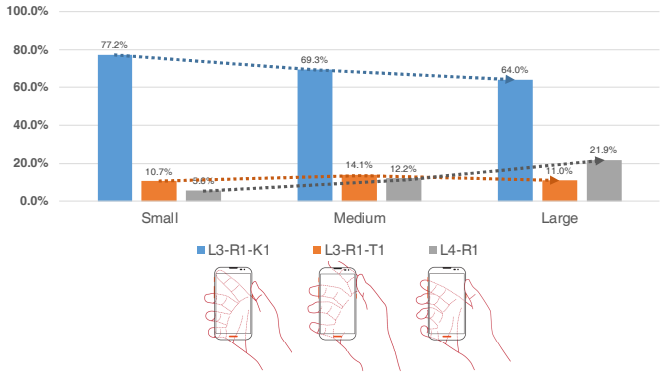

Figure 7. Major grip postures by hand length

DISCUSSION

The present study systematically analyzed grip postures for smartphones with different sizes while conducting variety of tasks using hard keys. L3-R1-K1 grip posture was found to be the most preferred for hard key use. Considering the result that L3-R1-K1 was more preferred than L4-R1 and L3-R1-T1 which use all 5 fingers to grasp the device whereas L3-R1-K1 uses 4 fingers to grasp and 1 finger to support the device, participants might prefer to hold the device just enough to press the hard keys, not as hard as they can grasp.

Preferred grip postures for hard key use were different by device size, so grip postures which have to be considered for interface design varies depending upon the size of the device. As device size gets larger, the portion of L4-R1 and L3-R1-T1 grip postures tend to be decreased. It seems when it gets hard to hold the top (L3-R1-T1) or the left side with 4 fingers (L4-R1), index finger comes down to the back side of the device and the grip posture becomes L3-R1-K1 for better stability of grasping.

Hand width and hand length were both significantly influential for grip posture. Participants with large hand could take L4-R1 grip posture more than participants with small hand. When the hand is long enough, users can take any grip postures as they wish. However, when the hand is short, users need to give up some fingers to use for grasping a device. For example, long hand user can take L4-R1 grip posture, but short hand user needs to give up index finger for grasping but use it for supporting at the back of the device, which becomes L3-R1-K1 grip posture. Hand width and hand length showed similar results, and this may because users do not grasp smartphones horizontally or vertically, but they grasp diagonally taking advantage of wide grasping area of hand.

The present study can be improved and verified with real smartphones since 3D printed mock-ups were used to analyze grip postures for various sized smartphones. Moreover, user's natural body postures such as sitting or reclining posture can be considered for analyzing more realistic situation. In addition, grip posture for left hand and both hand can be also investigated for considering more various smartphone usage. The grip postures identified in this study are expected to be used for designing comfortable and stable smartphone interface.

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