Analysis of Grip Posture for Ergonomic Smartphone Interface Design

Younggeun Choi¹, Hayoung Jung¹, Jangwoon Park², Heecheon You¹

¹Department of Industrial and Management Engineering, Pohang University of Science and Technology, Pohang, South Korea
²School of Engineering and Computing Sciences, Texas A&M University – Corpus Christi, Corpus Christi, Texas, USA
Contents

- Introduction
  - Background
  - Research Objectives
- Methods
  - Measurement of Grip Postures
  - Classification of Grip Postures
- Results
  - Dominant Grip Postures by Device Size
  - Dominant Grip Postures by Hand Size
- Discussion
Importance of Ergonomic Smartphone Interface

- Understanding **user-preferred grip postures in one-handed operation of hard keys** on smartphones is needed.

  - **Operational efficiency of the hard keys can be improved** if they are properly located based on **user-preferred grip postures**

  - **Improperly designed locations of the hard keys** may lead to significant **discomfort in the fingers** (Finneran and O'Sullivan, 2013; Wobbrock et al., 2008)

  - **One-handed hard key operations** which require smartphone grasping and hard key operations simultaneously **can cause more discomfort** than two-handed hard key operations
Wobbrock et al. (2008) analyzed operation efficiency of user interfaces on a PDA consisting of touchscreens at the front and back and hard keys on the side.

<table>
<thead>
<tr>
<th></th>
<th>Thumb-on-front</th>
<th>Thumb-on-back</th>
<th>Index-on-front</th>
<th>Index-on-back</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two-handed</td>
<td><img src="thumb-front.png" alt="Thumb-on-front" /></td>
<td><img src="thumb-back.png" alt="Thumb-on-back" /></td>
<td><img src="index-front.png" alt="Index-on-front" /></td>
<td><img src="index-back.png" alt="Index-on-back" /></td>
</tr>
<tr>
<td>One-handed</td>
<td><img src="thumb-front.png" alt="Thumb-on-front" /></td>
<td><img src="thumb-back.png" alt="Thumb-on-back" /></td>
<td><img src="index-front.png" alt="Index-on-front" /></td>
<td><img src="index-back.png" alt="Index-on-back" /></td>
</tr>
</tbody>
</table>

⇒ No research has been reported regarding analysis of user-preferred grip postures to determine the proper locations of hard keys on smartphones.
Research Objectives

Analysis of preferred grip posture for ergonomic smartphone interface design

1. Identification of user-preferred grip postures in one-handed hard key operation
2. Measurement and analysis of grip postures and use frequencies
3. Analysis of effects by smartphone size and hand size on grip posture
Participants

- **45 smartphone users** (male: 28; female: 17) with right hand grip for one-handed operation
- **9 groups with 3 hand length and 3 hand width categories for each gender**

### Korean Hand Size

#### Male

<table>
<thead>
<tr>
<th>Hand length</th>
<th>Hand width</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 33rd</td>
<td>≤ 83 mm</td>
</tr>
<tr>
<td>≤ 181 mm</td>
<td>83 ~ 87 mm</td>
</tr>
<tr>
<td>34th ~ 66th</td>
<td>≥ 87 mm</td>
</tr>
<tr>
<td>181 ~ 188 mm</td>
<td>169 ~ 173 mm</td>
</tr>
<tr>
<td>&gt; 66th</td>
<td>≥ 188 mm</td>
</tr>
</tbody>
</table>

#### Female

<table>
<thead>
<tr>
<th>Hand length</th>
<th>Hand width</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 33rd</td>
<td>≤ 74 mm</td>
</tr>
<tr>
<td>≤ 166 mm</td>
<td>74 ~ 78 mm</td>
</tr>
<tr>
<td>34th ~ 66th</td>
<td>≥ 78 mm</td>
</tr>
<tr>
<td>166 ~ 173 mm</td>
<td>170 ~ 175 mm</td>
</tr>
<tr>
<td>&gt; 66th</td>
<td>≥ 175 mm</td>
</tr>
</tbody>
</table>
9 smartphone mock-ups with different sizes (3.0” ~ 7.0” screen sizes) and weights (100 ~ 190 g)
Major Tasks & Specific Actions

- **Major tasks** such as answering a call, listening to music, texting, and browsing the web **were defined with specific actions**

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Specific actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Answering a call</td>
<td>1. Grasp the phone&lt;br&gt;2. Answer a call by flicking the screen&lt;br&gt;3. Turn volume up/down by <strong>volume key</strong></td>
</tr>
<tr>
<td>Listening to music</td>
<td>1. Turn volume up/down by <strong>volume key</strong>&lt;br&gt;2. Scroll up/down&lt;br&gt;3. Show menus&lt;br&gt;4. Select a menu&lt;br&gt;5. Turn volume up/down by <strong>volume key</strong></td>
</tr>
<tr>
<td>Texting</td>
<td>1. Turn screen on by <strong>power key</strong>&lt;br&gt;2. Navigate screens&lt;br&gt;3. Select a message app&lt;br&gt;4. Send a message&lt;br&gt;5. Return home</td>
</tr>
<tr>
<td>Browsing the web</td>
<td>1. Turn screen on by <strong>power key</strong>&lt;br&gt;2. Turn Wi-Fi on/off&lt;br&gt;3. Select a web browser app&lt;br&gt;4. Browse the internet&lt;br&gt;5. Turn screen off by <strong>power key</strong></td>
</tr>
</tbody>
</table>
Measurement of Grip Postures

- Videotaped by 2 web cameras (LifeCam Studio, Microsoft Co. Ltd., USA) placed above and below the hand while participant performed the tasks in standing.
# Demo: Hard Key Operation Tasks

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Specific actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Answering a call</td>
<td>1. Wrap the phone  2. Answer a call by clicking the screen  3. Turn volume up/down by volume key</td>
</tr>
<tr>
<td>Listening to music</td>
<td>1. Turn volume up/down by volume key  2. Scroll up/down  3. Play/pause  4. Select a music  5. Turn volume up/down by volume key</td>
</tr>
<tr>
<td>Testing</td>
<td>1. Turn meters on/off by power key  2. Adjust meters  3. Select a message app  4. Send a message  5. Return home</td>
</tr>
<tr>
<td>Decreasing the tick</td>
<td>1. Turn meters on/off by power key  2. Turn Wi-Fi on/off  3. Select a web browser app  4. Browser the internet  5. Turn meters on/off by power key</td>
</tr>
</tbody>
</table>
Classification of Grip Postures

- Encoded by indicating locations of the fingers on the mock-up and the number of fingers at corresponding location

<table>
<thead>
<tr>
<th>Location</th>
<th>Left (L)</th>
<th>Right (R)</th>
<th>Top (T)</th>
<th>Bottom (B)</th>
<th>Front (F)</th>
<th>Rear (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td># of fingers</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

L3-R1-K1
9 grip postures were identified for operating the power key and volume key.

L3-R1-K1 (70.0%), L4-R1 (13.3%), and L3-R1-T1 (12.0%) were found dominant with 95% of use frequency.
Dominant Grip Postures

Holding from the **left and right side** of a smartphone while supporting the **back** with the index finger

**L3-R1-K1**

70.0%

Holding from the **left and right side** of a smartphone

**L4-R1**

13.3%

Holding from the **top, left, and right side** of a smartphone

**L3-R1-T1**

12.0%
Dominant Grip Postures by Device Size

- The use frequency distribution of grip posture varied significantly by smartphone size ($\chi^2(12) = 674.8$, $p < 0.001$)
Dominant Grip Postures by Hand Size

- The use frequency distribution of grip posture varied significantly by hand width and hand length with a similar pattern ($\chi^2(4) = 75.3, p < 0.001$ for hand width and $\chi^2(4) = 75.3, p < 0.001$ for hand length).
Discussion (1/5)

- Analyzed **preferred grip postures in one-handed operations** of smartphone hard keys

- L3-R1-K1 posture was the most preferred
  - for **efficiency in operation** of hard keys and **stability in grip**

- Holding from the **left and right side** of a smartphone while supporting the **back** with the index finger

  **L3-R1-K1**  
  70.0%

- Holding from the **left and right side** of a smartphone

  **L4-R1**  
  13.3%

- Holding from the **top, left, and right side** of a smartphone

  **L3-R1-T1**  
  12.0%
Discussion (2/5)

- Dominant grip postures changed by device size
  - 3.0” ~ 4.0”: L3-R1-K1, L4-R1, and L3-R1-T1
  - 4.5” ~ 5.5”: L3-R1-K1 and L4-R1
  - 6.0” ~ 7.0”: L3-R1-K1

⇒ users tend to **move their index finger for secure grip and support.**
Dominant grip postures changed by hand size

- Hand width small → large: L4-R1, 12.9%↑ and L3-R1-K1, 13.1%↓
- Hand length small → large: L4-R1, 16.3%↑ and L3-R1-K1, 13.2%↓

Users usually **grasp a smartphone along a diagonal direction of their hand** with a straight wrist posture while keeping the smartphone display vertical.
Need to be verified for users with more diverse hand sizes than those of the present study and consider more use contexts other than standing.

- Users having smaller and larger hand sizes need to be considered.
- Sitting and walking contexts can be considered.
The identified dominant grip postures can be used for determination of proper locations of hard keys on a smartphone.

- The proper locations of hard keys can be designed by investigating the preferred hard key control area determined by the dominant grip postures of various hand sizes.
- An ergonomic evaluation of the performance of the designed hard key locations can be performed in terms of time efficiency, accuracy, and comfort.
Thank you for your attention