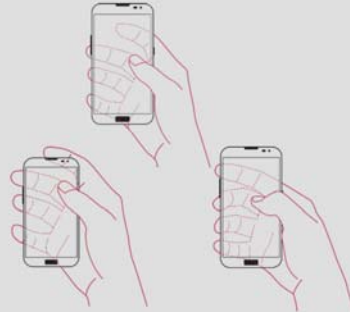




Development of an Ergonomic Design Process for Smartphone Hard Key Locations



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Global Contributor to Eco-Techno-Humanopia

Contents

- **Introduction**
 - Background
 - Research Objectives
 - **Determination Process of Smartphone Hard Key Locations**
 - **Case Study: Locations of Hard Keys for a Smartphone**
 - **Discussion**
-



Importance of Ergonomic PUI

- ❑ **Improperly designed physical user interface (PUI) in mobile devices** may lead to significant **discomfort in the fingers** (Finneran and O'Sullivan, 2013; Wobbrock et al., 2008)
 - **Usability of hard keys can be improved** if they are properly located based on **user-preferred grip postures**
 - **One-handed hard key operations** which require smartphone grasping and hard key operations simultaneously **can cause more discomfort** than two-handed hard key operations

One-handed

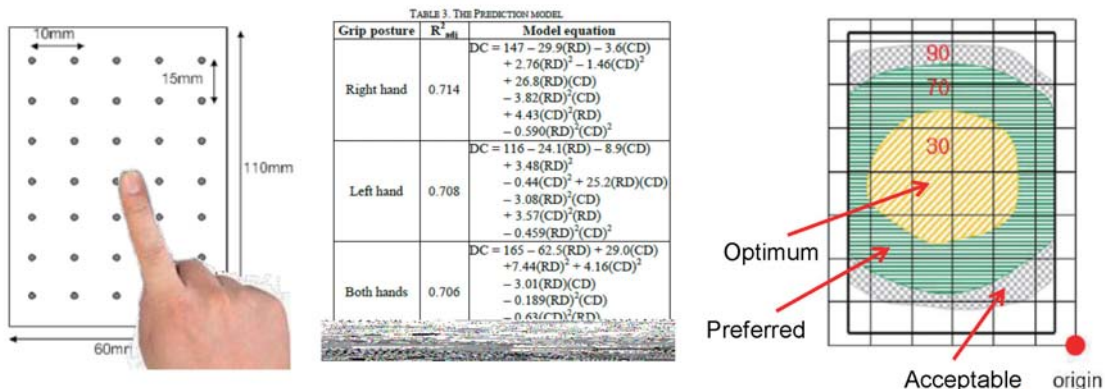


Two-handed



Ergonomic Layout of GUI (1/2)

- ❑ Im et al. (2010) **developed an icon layout guide** based on **discomfort score for each icon location** on a touchscreen of smartphone
 - Measured **discomfort scores for 35 locations** on a touchscreen with **100 point scale in their right hand, left hand, and both hands**
 - Proposed **ranges for icons with 3 discomfort levels** (acceptable, preferred, optimum)
 - Developed a **model which estimates discomfort score** depending on the location of an icon for right hand, left hand, and both hands

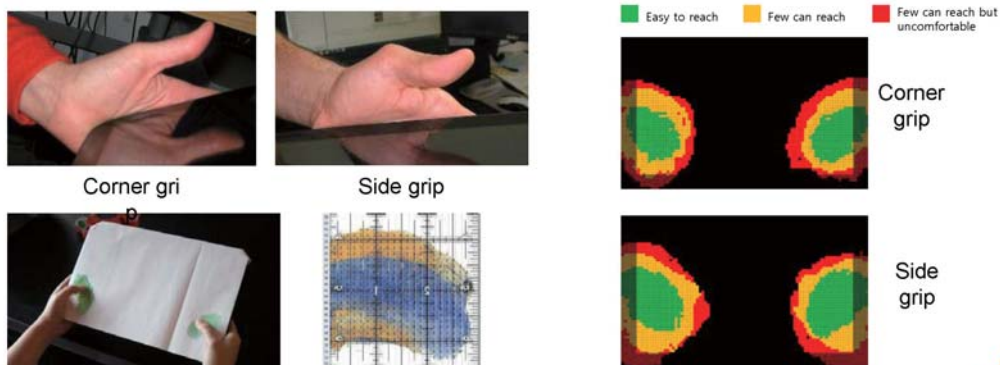


Ergonomic Layout of GUI (2/2)

□ Odell and Chandrasekaran (2012) measured **thumb reach envelopes** for design of **keyboard layout on a tablet PC**

- **Two types of grip postures (corner grip, side grip)** were considered
- Participants colored the paper on a tablet PC mock-up with their painted thumb
- Three paint colors were applied depending on **the level of comfort to reach (easy to reach, few can reach, few can reach but uncomfortable)**.

⇒ Limitations: **A guide for design of hard key locations** has not been studied.

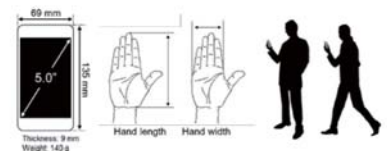


Objectives of the Study

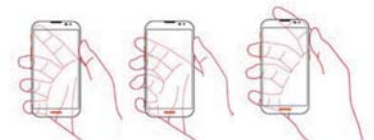
Development of a Method for Determination of Smartphone Hard Key Locations for Usability

1) **Analyze characteristics** of smartphone-user interface:

Systematic analysis on device, user, and use context



2) **Identify major grip postures**: User preferred grip postures conducting tasks in various contexts

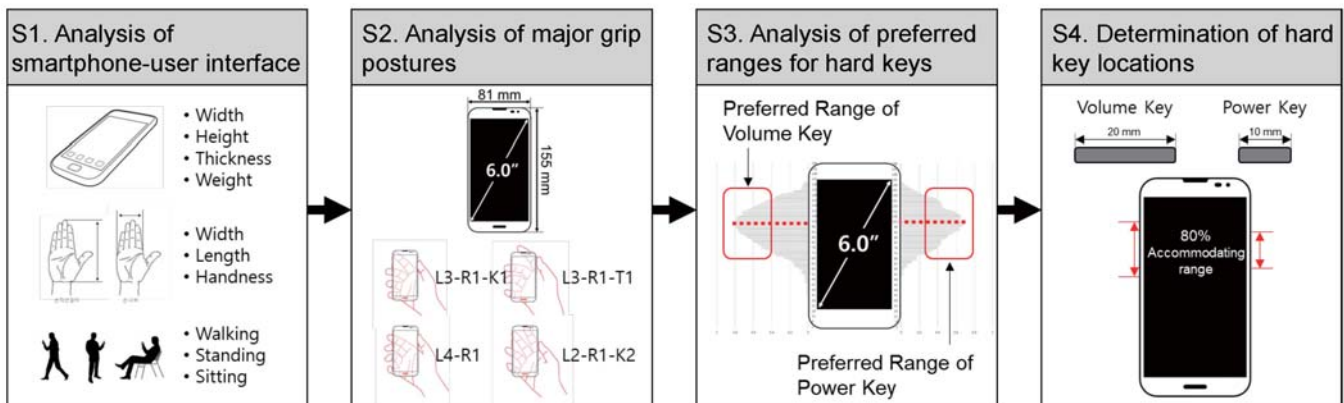


3) **Derive preferred control ranges** for hard keys: Collecting preferred control ranges for hard keys in major grip postures

Smartphone Hard Key Location Determination Process

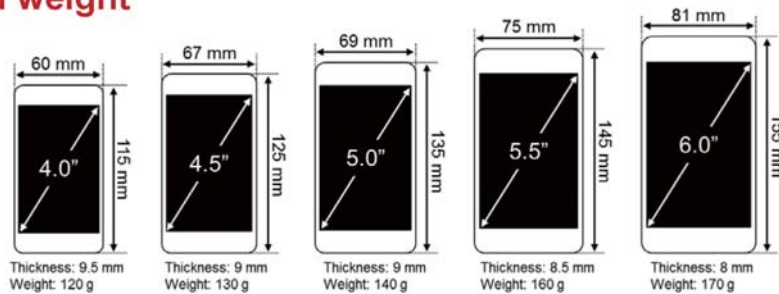
Hard Key Location Determination Process

□ A four-step process for determination of **user-preferred smartphone hard key locations based on preferred grip postures** for smartphones with various sizes was proposed.

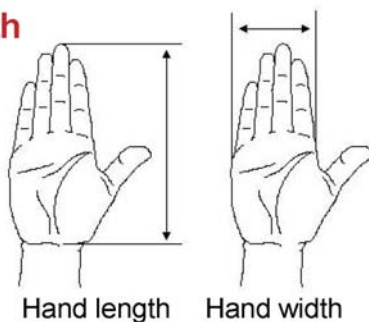


Step 1. Analysis of Smartphone-User Interface (1/2)

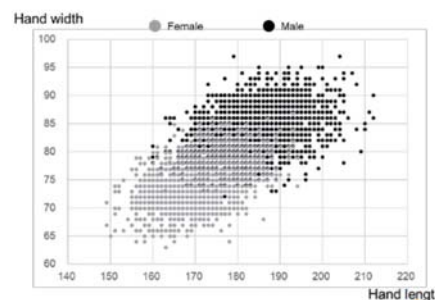
- Analyze dimensions of a target smartphone including screen size, height, width, thickness, and weight



- Analyze hand anthropometric data of smartphone users including hand length and hand width



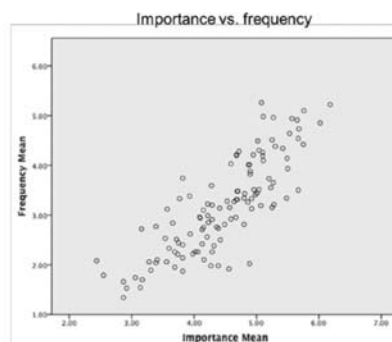
Korean hand size distribution (Size Korea 2010)



Step 1. Analysis of Smartphone-User Interface (2/2)

- Analyze types of major tasks and specific actions in smartphone usage

| Task list | n | Min. | Max. | Mean | S.D. |
|----------------------------|-----|------|------|------|------|
| Check/Read Email | 141 | 1 | 7 | 6.18 | 1.23 |
| Send Email | 144 | 1 | 7 | 6.02 | 1.21 |
| Answer Phone Call | 146 | 3 | 7 | 5.76 | 1.23 |
| Look Up a Contact | 143 | 2 | 7 | 5.75 | 1.2 |
| Call a Contact | 145 | 2 | 7 | 5.68 | 1.22 |
| Add a Contact | 143 | 2 | 7 | 5.67 | 1.17 |
| Conduct an Internet Search | 145 | 1 | 7 | 5.67 | 1.39 |
| Send a Text | 145 | 1 | 7 | 5.65 | 1.61 |
| Read a Text | 146 | 1 | 7 | 5.57 | 1.63 |
| Browse the Internet | 145 | 1 | 7 | 5.53 | 1.4 |
| Take a Photo | 146 | 1 | 7 | 5.5 | 1.42 |
| Connect to Wireless | 144 | 1 | 7 | 5.49 | 1.51 |
| Get Driving Directions | 142 | 1 | 7 | 5.48 | 1.45 |
| Check Calendar | 145 | 1 | 7 | 5.42 | 1.64 |
| Listen to Voice Mail | 145 | 1 | 7 | 5.3 | 1.29 |
| Edit a Contact | 143 | 2 | 7 | 5.28 | 1.26 |
| Add an Appointment | 144 | 1 | 7 | 5.27 | 1.57 |
| Hang Up | 145 | 1 | 7 | 5.27 | 1.45 |



- Analyze types of use context for smartphone



Step 2. Analysis of Major Grip Postures

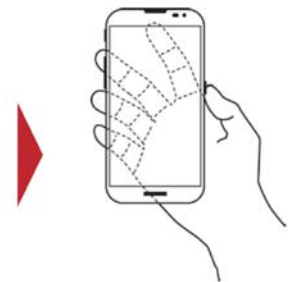
- Capture smartphone grip postures while conducting various smartphone tasks
- Classify the types of grip postures to quantitatively analyze the preferences of each grip posture



2 cameras recording participants hand from above and below the hand



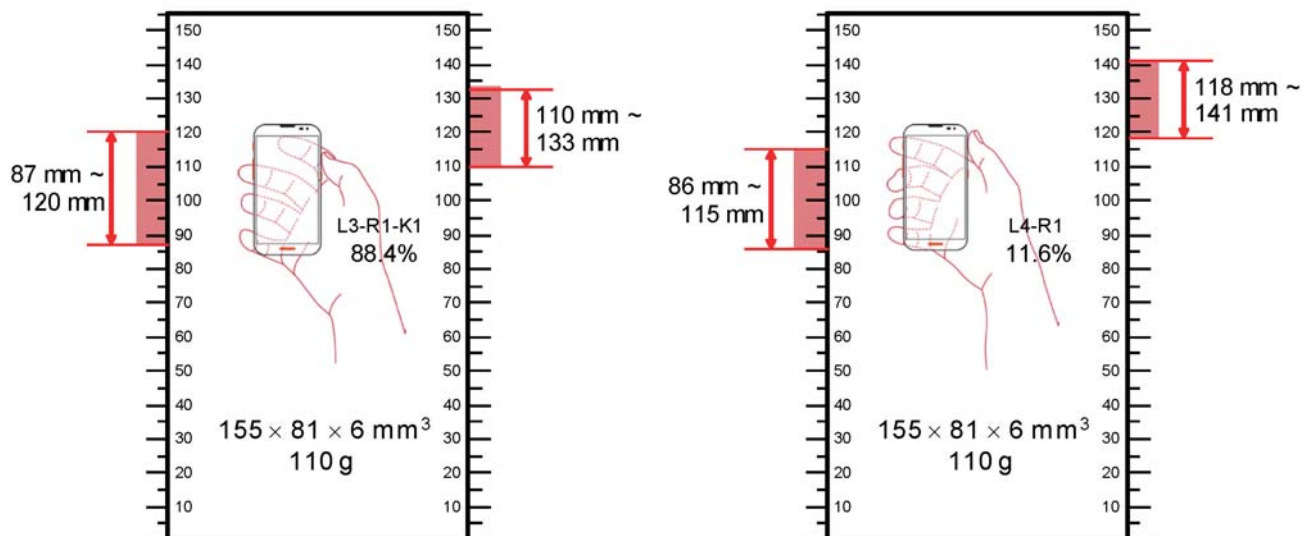
| Location | Left (L) | Right (R) | Top (T) | Bottom (B) | Front (F) | Back (K) |
|--------------|----------|-----------|---------|------------|-----------|----------|
| # of fingers | 3 | 1 | 0 | 0 | 0 | 1 |



L3-R1-K1

Step 3. Analysis of Preferred Ranges for Hard Keys (1/3)

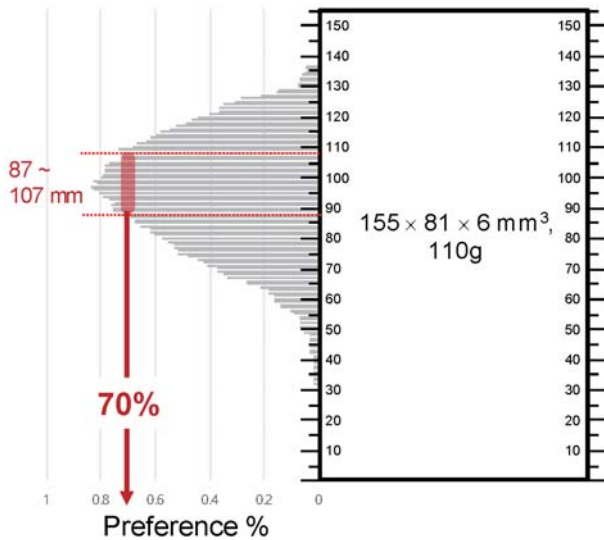
- Collect preferred ranges for each participant in each grip posture



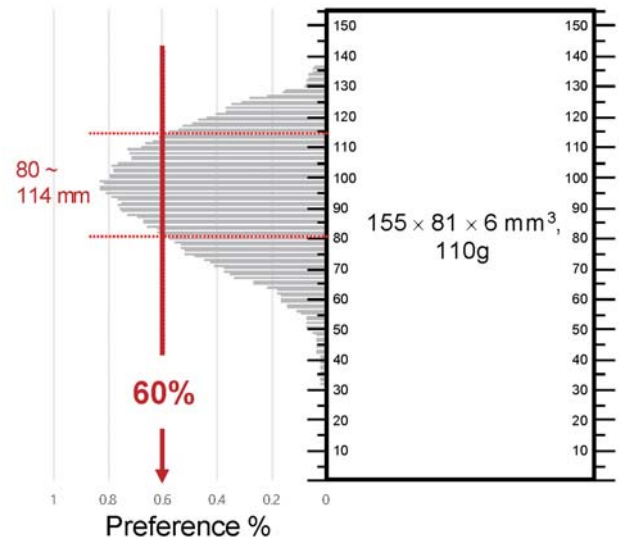
Step 4. Determination of Hard Key Locations

- Determine hard key locations which **provide highest preference considering hard key sizes**

Best location for 20 mm hard key



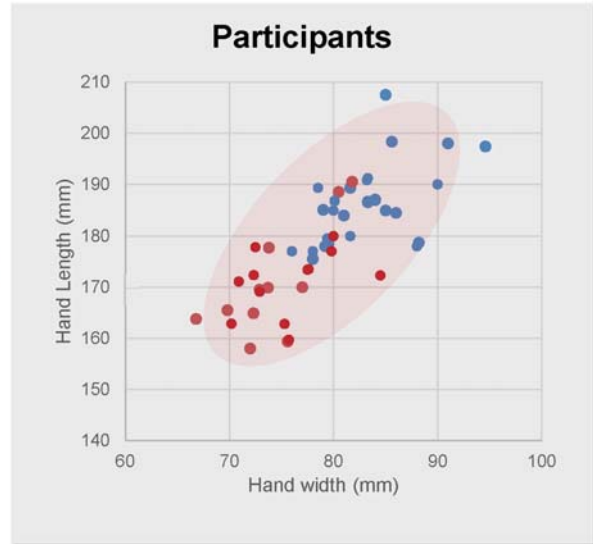
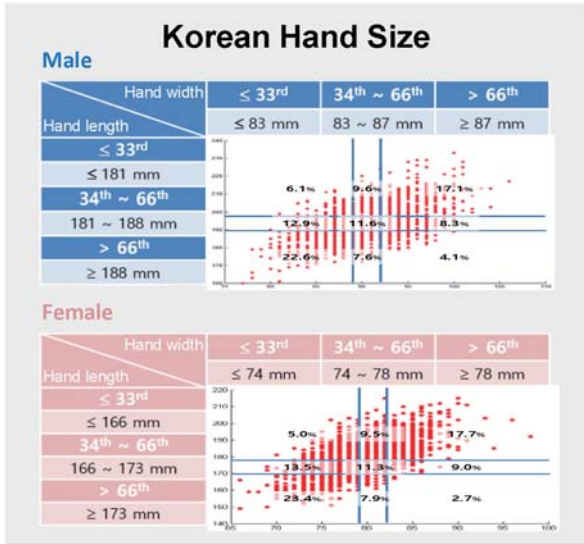
Range of > 60% preference for hard key



Case Study: Determination of Hard Key Locations for a 5.0" Smartphone

Participants

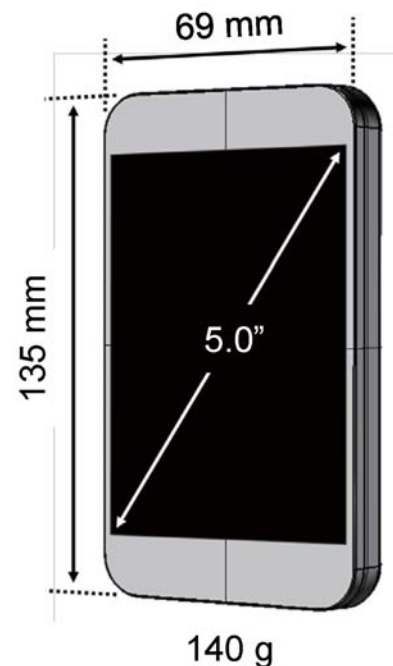
- 45 right-handed smartphone users (male: 28; female: 17; age: 18 ~ 58 years)
- 9 groups of 3 hand-length categories × 3 hand-width categories for each gender



Mock-up for Grip Posture Measurement

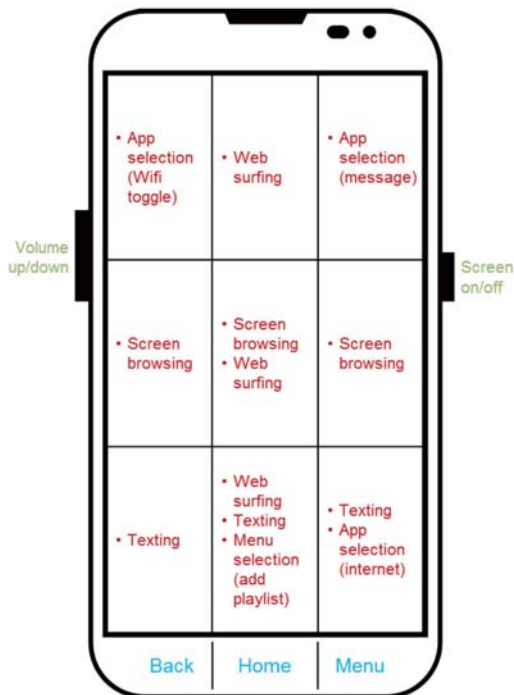
- A smartphone mock-up with a screen size of 5.0" was prototyped by a 3D printer (Dimension SST, Stratasys Ltd., USA)

| No. | Manufacturer | Model | Screen Size (inch) | Height (mm) | Width (mm) | Thickness (mm) | Weight (g) | Power Key | | Volume Key | |
|-----|--------------|---------------|--------------------|-------------|------------|----------------|------------|-----------|----------|------------|----------|
| | | | | | | | | Size (mm) | Location | Size (mm) | Location |
| 1 | Apple | iPhone 4 | 3.5 | 115.2 | 58.6 | 9.3 | 137 | 9.5 | Top | 14.5 | Left |
| 2 | Apple | iPhone 5 | 4.0 | 123.8 | 58.6 | 7.6 | 112 | 9.5 | Top | 14.5 | Left |
| 3 | Apple | iPhone 6 | 4.7 | 138.1 | 67 | 6.9 | 129 | 10 | Top | 22.5 | Left |
| 4 | LG | G3 | 5.5 | 146.3 | 74.6 | 8.9 | 149 | 8.5 | Back | 24 | Back |
| 5 | LG | G pro2 | 5.9 | 157.9 | 81.9 | 8.3 | 172 | 4.5 | Back | 23 | Back |
| 6 | Samsung | Galaxy S4 | 4.99 | 136.6 | 69.8 | 7.9 | 130 | 13 | Right | 24.5 | Left |
| 7 | Samsung | Galaxy Note 3 | 5.5 | 151.2 | 79.2 | 8.3 | 168 | 11 | Right | 23 | Left |
| 8 | Samsung | Galaxy W | 7.0 | 191.8 | 99.6 | 8.8 | 245 | 12.5 | Right | 24 | Right |
| 9 | Pantech | Vega No 6 | 5.9 | 158.6 | 83.2 | 9.9 | 209 | 12 | Right | 26.5 | Left |
| 10 | Pantech | Vega Iron 2 | 5.3 | 144.2 | 73.5 | 7.9 | 153 | 10 | Right | 22 | Left |



Major Tasks & Specific Actions

□ Major tasks such as answering a call, listening to music, texting, and browsing the web were defined with specific actions (Kietrys et al., 2015; Dunn et al., 2013; Berolo et al., 2011; Levy et al., 2010)



| Tasks | Specific actions |
|--------------------|--|
| Answering a call | <ol style="list-style-type: none"> 1. Grasp the phone 2. Answer a call by flicking the screen 3. Turn volume up/down by <i>volume key</i> |
| Listening to music | <ol style="list-style-type: none"> 1. Turn volume up/down by <i>volume key</i> 2. Scroll up/down 3. Show menus 4. Select a menu 5. Turn volume up/down by <i>volume key</i> |
| Texting | <ol style="list-style-type: none"> 1. Turn screen on by <i>power key</i> 2. Navigate screens 3. Select a message app 4. Send a message 5. Return home |
| Browsing the web | <ol style="list-style-type: none"> 1. Turn screen on by <i>power key</i> 2. Turn Wi-Fi on/off 3. Select a web browser app 4. Browse the internet 5. Turn screen off by <i>power key</i> |

Measurement of Grip Postures

□ Videotaped by two web cameras (LifeCam Studio, Microsoft Co. Ltd., USA) placed above and below the hand while participant performed the tasks in standing



Two cameras recording a participant's hand from above and below the hand



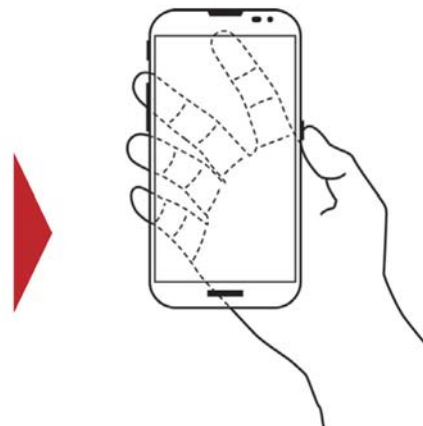
Demo: Hard Key Operation Tasks

| Tasks | Specific actions |
|--------------------|---|
| Answering a call | <ol style="list-style-type: none"> 1. Grasp the phone 2. Answer a call by flicking the screen 3. Turn volume up/down by <i>volume key</i> |
| Listening to music | <ol style="list-style-type: none"> 1. Turn volume up/down by <i>volume key</i> 2. Scroll up/down 3. Show menus 4. Select a menu 5. Turn volume up/down by <i>volume key</i> |
| Texting | <ol style="list-style-type: none"> 1. Turn screen on/off by <i>power key</i> 2. Navigate screens 3. Select a message app 4. Send a message 5. Return home |
| Browsing the web | <ol style="list-style-type: none"> 1. Turn screen on/off by <i>power key</i> 2. Turn Wi-Fi on/off 3. Select a web browser app 4. Browse the internet 5. Turn screen on/off by <i>power key</i> |



Classification of Grip Postures

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

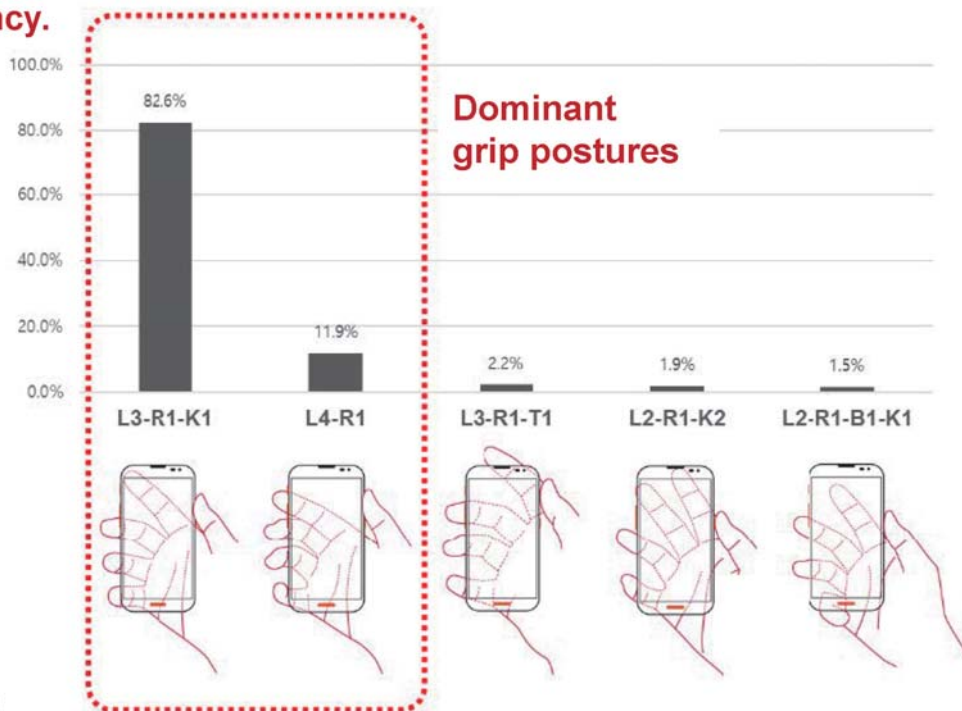


L3-R1-K1

| Location | Left (L) | Right (R) | Top (T) | Bottom (B) | Front (F) | Rear (K) |
|--------------|----------|-----------|----------|------------|-----------|----------|
| # of fingers | 3 | 1 | 0 | 0 | 0 | 1 |

Grip Postures for Hard Key Use

- ❑ **5 grip postures** were identified for operating **the power key and volume key**
- ❑ **L3-R1-K1 (82.6%) and L4-R1 (11.9%)** were found dominant with **94.5% of use frequency.**

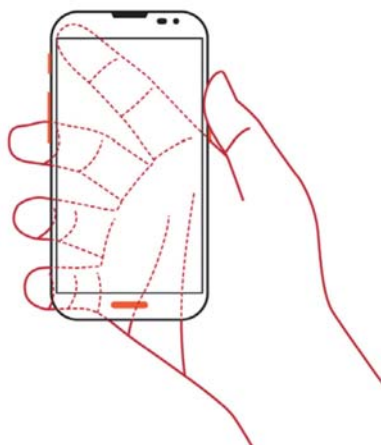


Dominant Grip Postures

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

L3-R1-K1

82.6%



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

L4-R1

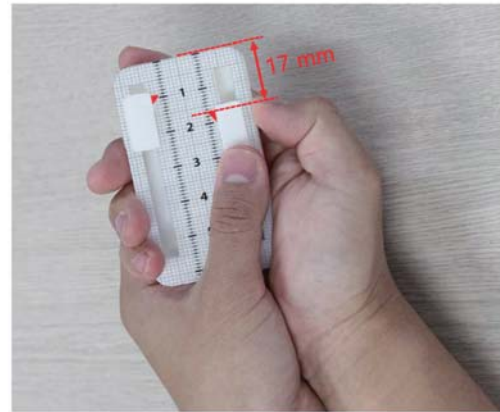
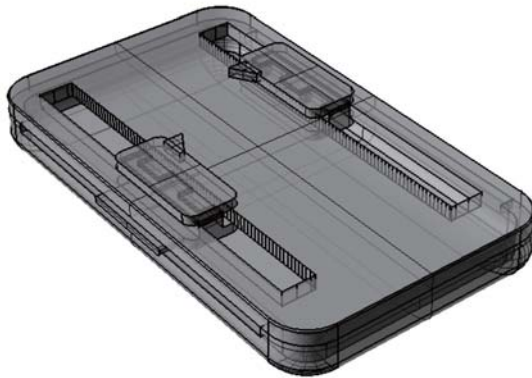
11.9%



Mockup for Preferred Control Range Measurement

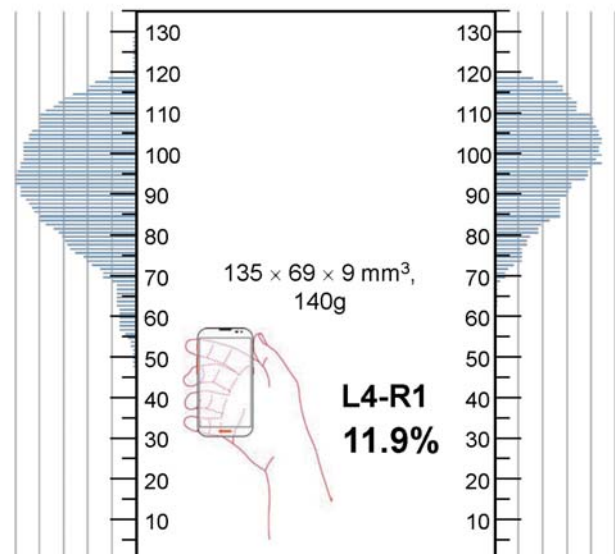
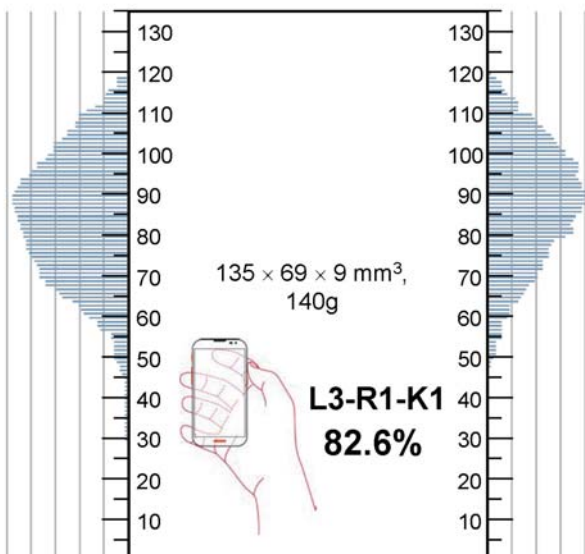
❑ Developed a **smartphone mock-up** of which **locations of hard keys can be adjusted effectively**

- **Two sliding hard keys** (left side: volume key, length = 20 mm; right side: power key, length = 10 mm) are placed **on the left side and right side** of the mock-up
- The locations of the hard keys can be easily measured by **grid scales printed on the mock-up**



Measurement of Preferred Control Range

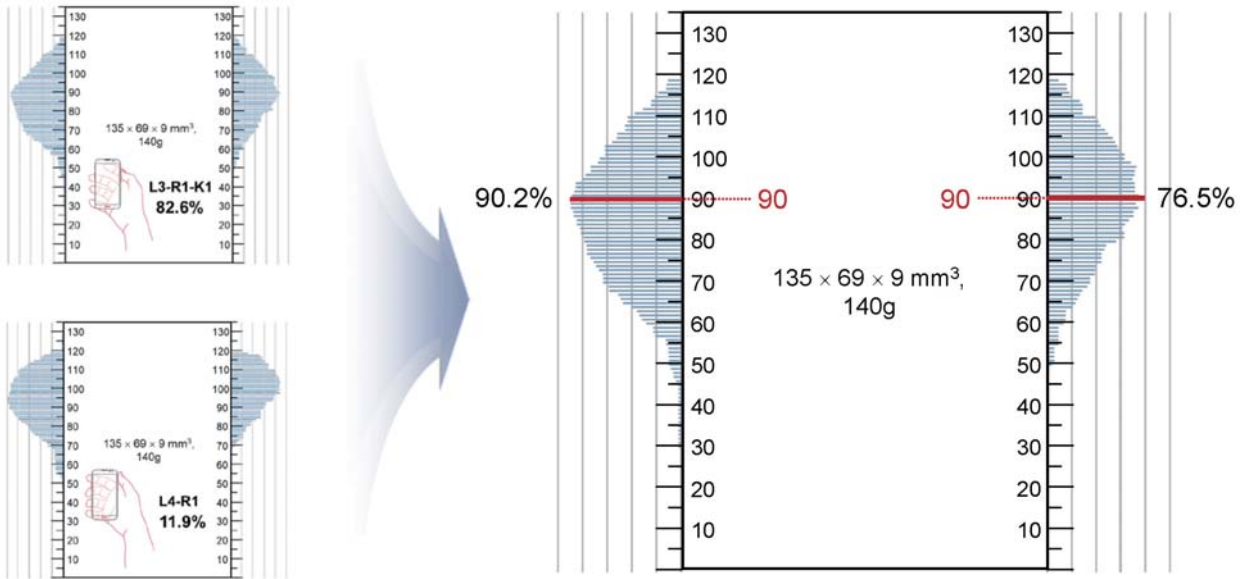
- ❑ Measured **preferred ranges for each participant** in the two dominant grip postures
- ❑ **Established the distribution of the preference** of each participant for each posture



Analysis of Preference for Control Locations

□ **Derived preference for each control location** by combining all postures

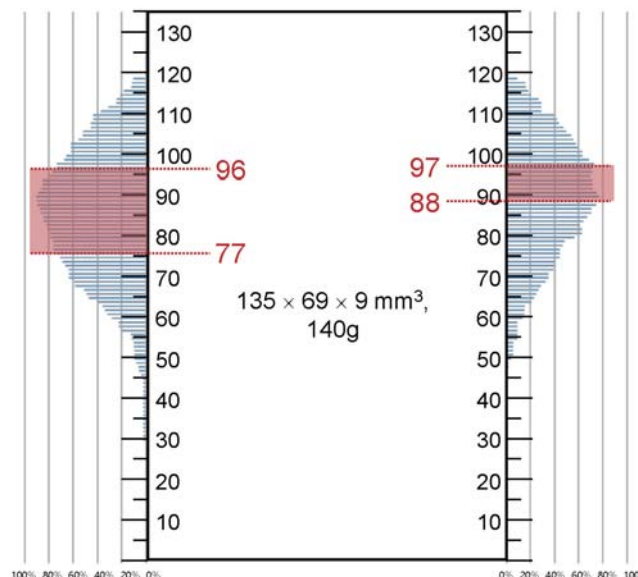
(L3-R1-K1: 82.6%; L4-R1: 11.9%)



Determination of Hard Key Locations

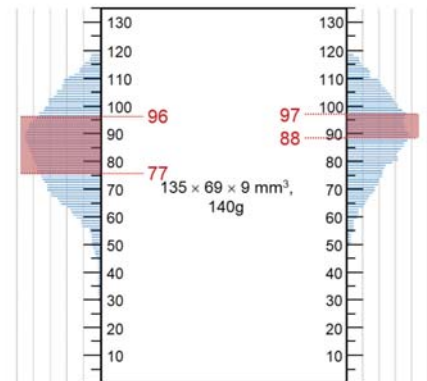
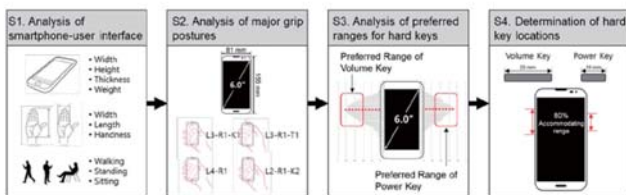
□ The locations of the two hard keys were **determined in highest preferences.**

- Left side: Volume key, 77 ~ 96 mm, 76.4% ~ 90.2%
- Right side: Power key, 88 ~ 97 mm, 71.6% ~ 76.5%



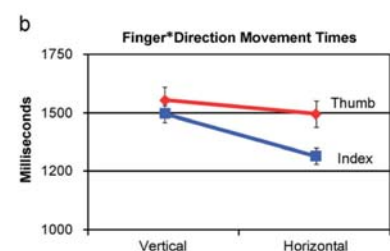
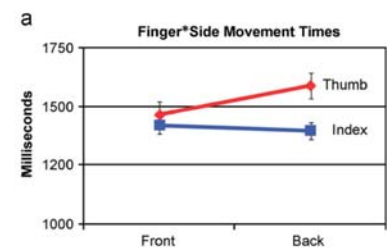
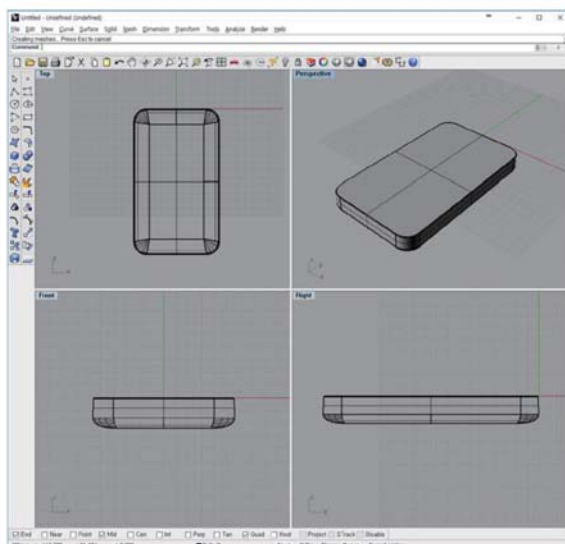
Discussion (1/3)

- ❑ Proposed a **method for determination of smartphone hard key locations**
 - Characteristics of **user, device, and use context** were considered
 - **Preferred grip postures** were applied to find the preferred hard key locations
- ❑ Applied the proposed method to determine the hard key locations of a smartphone with 5.0" screen size.



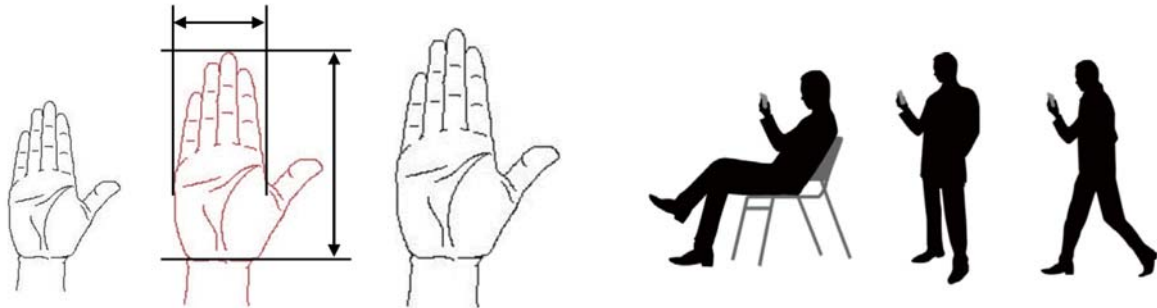
Future Research (1/2)

- ❑ Need to **compare the hard key locations** determined by the proposed process with those of an existing smartphone **in terms of task completion time, error rate, and subjective satisfaction for verification**



Future Research (2/2)

- ❑ Need to **validate the proposed determination process of hard key locations with users having more diverse hand sizes** than those of the present study and for use contexts other than standing
- ⇒ Users having **smaller and larger hand sizes** needs to be considered
- ⇒ **Sitting and walking contexts** can be considered



Q & A

Thank you
for your attention!

