Index Finger Zone: Study on Touchable Area Expandability Using Thumb and Index Finger

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Abstract
This paper evaluates how the "index finger zone" on the back of a smartphone could compensate for the limitations of the "thumb space." We conducted two experiments to investigate how to reach to a distant point comfortably with one hand. First, we gave the participants four typical tasks while using mobile phones (tapping, texting, calling, and scrolling). In these situations, we measured the position of the index finger and the thumb with the natural hand posture. Consequently, the index finger was primarily positioned in the upper left side. Second, the main experiment was to determine how a touchable area could be extended using the index finger zone on the back side. 1) Randomly selected tiles were touched 84 times with a thumb and 42 times with an index finger. 2) Each tile's preference was evaluated with a 5-point Likert scale. As a result, we found that the "comfort zone" could be expanded by 15% by using index finger zone.

Author Keywords
Back Touch Interface; Touchable Area; Reachability; Limitation of Thumb-space

ACM Classification Keywords
H.5.2 User Interfaces–Interaction styles:

Introduction

Currently, 4.5 to 5-inch-sized smartphones have entered the mainstream in the field. For instance, the recently released iPhone 6 also has a 4.7 inch-sized big screen. Previously, Apple had maintained an appropriate screen size for holding the iPhone with one hand on principle. However, because increasingly more people tend to prefer a large screen to a smaller one, many mobile manufacturers including Apple released smartphones with large screens to meet customers' needs.

Nevertheless, despite mobile industry trends for larger screens, big screens have the inevitable problem that they are difficult to carry. Despite portability issues, people prefer a large screen to a smaller one. Additionally, people have a tendency to perform their interactions on the screen with one hand. In particular, the thumb is the most commonly used finger for touching the front screen with one hand. Statistics have revealed that 49% of people use their thumb when they operate their smartphone.

However, there are some issues related to hand size and easily operating a smartphone with one hand. While the length from the wrist to the thumb is 110–120mm on average in South Korea, the vertical length of the iPhone 6 is 138.1mm[4][9] The larger size of smartphone makes it uncomfortable for some people to touch the screen using the thumb on "Stretch Zones and OW Zones [10]." To compensate for these problems, Apple attempted to introduce a function called "Reachability" in iPhone 6, which enables people to easily use the large screen of their smartphone with one hand.
Although the "Reachability" function of iPhone 6 was a new feature that focuses on handling the big screen with one hand, it has disadvantages in that the display is hidden partially when it moves down. Apple's new approach did not reflect actual situations involving the use of smartphones.
Furthermore, other approaches such as utilizing "thumb space" [2], have been suggested by researchers to enable users to easily operate the smartphone with one hand. However, related works on "thumb space" do not consider the other touchable areas of the smartphone. For this reason, first, we investigate how people use their smartphone when doing specific tasks, and we planned to conduct an exploratory study to compensate for the limitations of the unreachable zones on the front screen. To verify the value of the index finger zone on the back side, we set the following research questions.

- Is there a limitation of "thumb space" on the front screen of a smartphone?
- How can "index finger zone" be defined?
- Can the limitation of "thumb space" be compensated for using the "index finger zone on the back side of the device?

To justify these research questions, we reviewed related works regarding the validity of using the index finger zone on the back of a device. After verifying the research questions through two experiments, we also found that the touchable areas on the screen could be expanded through the index finger zone. This study will provide some implications for the "index finger zone," such as doing interactions more easily with the index finger and presenting extra privacy-related functions.

Related Work

We conducted a literature review focusing on three points to examine whether the index finger zone can compensate for the thumb space limitations on the front screen. First of all, research was carried out on the holding position of the hand to determine how the thumb and index finger are placed on the front screen and back of a smartphone. Secondly, we performed preliminary research on the thumb area on the front screen when people use a smartphone with one hand. Thirdly, from the literature review, we tried to determine whether touching the back side of the phone with an index finger would enable users to overcome the thumb space limitations.

Holding grip position on smartphone

Mauro Pelosi found the typical mobile phone grip styles in talk mode and data mode [7]. The index finger location was confirmed to be in the back region of the handset in most cases, and "single-hand" grip style and "both hands" grip style were exhibited in data mode. "Hand Grip Pattern Recognition for Mobile User Interfaces" presents a novel mobile device interface using an array of capacitive touch sensors to identify grip patterns and launch appropriate applications [5].

Thumb space

Research on the thumb area has been conducted using terms such as "thumb zone" and "thumb space." "Thumb zone" is a term that was coined by Steven Hoober in "Designing Mobile Interfaces," which refers to "the most comfortable area for touch with one-handed use"[2]. Additionally, Amy K. Karlson created "Thumb Space," a software-based interaction technique that provides general one-handed thumb operation of touch screen-based mobile devices [3]. Based on these terms, the results of experiments on the thumb area involve three zones: Natural, Stretch, and OW. Therefore, this paper will try to make design guidelines to solve the problems caused by one-handed thumb space in that it is hard to touch the stretch or OW areas with one hand.

Back touch interface of mobile devices and index finger

Supplement the thumb space with a back touch interface using the index finger can improve task efficiency. In terms of accuracy and movement, Khalad Hasan et al. made all areas of the trackpad within reach of the index finger, so users would be able to reach targets easily and precisely [1]. Markus Löchtefeld et al. obtained the meaningful result that there is a higher error ratio for front touches with the thumb than that for back touches with the index finger [6]. Studies of back touch interface are still in progress. Karsten Seipp devised a technique called Backpat to support the operation of the phone with one hand by using the back of the device as a touch input area [8]. Markus Löchtefeld et al. evaluated how a combination of front and back-of-device touch input can be used to overcome difficulties when using a mobile device with one hand [6].

Study design

To verify whether the index finger zone could be defined to compensate for the limitations of thumb space, we conducted two experiments. Above all, in the preliminary experiment, we tried to discover whether there is a common area on the screen when touching the screen in the typical four situations of using a smartphone. Next, based on the findings from the preliminary experiment, the main experiment aims to

1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	32	33	34	35
36	37	38	39	40	41	42
43	44	45	46	47	48	49
50	51	52	53	54	55	56
57	58	59	60	61	62	63
64	65	66	67	68	69	70
71	72	73	74	75	76	77
78	79	80	81	82	83	84

Figure 1: In four different tasks, the common area that a thumb primarily located is existed in near 60 and 61.

1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	32	33	34	35
36	37	38	39	40	41	42
43	44	45	46	47	48	49
50	51	52	53	54	55	56
57	58	59	60	61	62	63
64	65	66	67	68	69	70
71	72	73	74	75	76	77
78	79	80	81	82	83	84

Figure 2: In spite of four different tasks, the common area that the index finger primarily located is existed in 24 and 25.

sophisticatedly define the thumb space on the front screen and the index finger zone on the back side.

Preliminary experiment

The purpose of the preliminary experiment was to identify where the thumb and index finger are located on the screen. The participants of the preliminary experiment were five graduate students (M:3, F:2). Because the preliminary experiment involved recognizing the approximate location of the thumb space and index finger zone, it was considered sufficient to recruit a relatively small number of participants. Regarding the experimental method, we gave the participants four typical tasks: 1) Tapping an app icon, 2) texting a message, 3) receiving a call, and 4) scrolling through a list on a web page of a news portal. We required the participants to conduct each task with the natural grip posture. In these four situations, we measured the positions of the index finger and thumb.

To carry out the experiments, we attached tracing paper to the back of the iPhone 6, and then outlined the participants' handgrip with latex gloves using blue and red ink. We used different ink colors to calculate the maximum and minimum ranges in the four different situations. Figure 1 and 2 illustrate that there is common area that a thumb or an index finger usually located in despite four different tasks. The following results about four tasks could be understood with reference to Figure 1 and 2. The description about front screen is related to Figure 1. Also, the explanation about back side is connected to Figure 2.

1) Tapping an app icon

- Front screen: The thumb was located in 29, 30, 31, 34, 35, 36, 37, 38, 39, 40, 41, 42, 44, 45, 46, 47, 48, 49, 52, 53, 54, 55, 56, 60, 61, 62, and 63.
- Back side of device: The index finger was located in 15, 16, 17, 18, 22, 23, 24, and 25.

2) Texting a message

- Front screen: The thumb was located in 57, 58, 59, 60, 61, 64, 65, 66, 67, 68, 72, 73, 74, and 75.
- Back side of device: The index finger was located in 24, 25, 26, 30, 31, 32, 33, 37, 38, 39, and 40.

3) Receiving a call

- Front screen: The thumb was not located in any particular area.
- Back side of device: The index finger was located in 11, 16, 17, 18, 22, 24, and 25.

4) Scrolling through a list on a news portal site

- Front screen: The thumb was located in 18, 19, 20, 25, 26, 27, 28, 32, 33, 34, 35, 39, 40, 41, 42, 46, 47, 48, 49, 53, 54, 55, 56, 60, 61, 62, 63, 67, 68, 69, 70, 74, 75, 76, 77, 82, and 83.
- Back side of device: The index finger was located in 15, 16, 17, 18, 19, 22, 23, 24, 25, and 26.

Consequently, we found that there are common areas covered by each thumb space and index finger zone when people grip their smartphones during four specific tasks, as shown in Figure 1 and Figure 2. In particular, the index finger was primarily positioned in the upper-left side and the thumb space was located in the lower-right side. In spite of the four different situations, the possibility that a common thumb space and index finger zone exists was discovered through the preliminary experiment. Moreover, the index finger zone did not

overlap with the thumb space when the participants performed the given tasks.

Main experiment

Based on the results derived from the preliminary experiment, we conducted the main experiment. The purpose of the main experiment was to determine how the thumb space could be extended using the index finger zone on the back of the device. The main experiment was divided into two processes: A first experiment to define the thumb space and a second experiment to define the index finger zone. First, we investigated which area was comfortable to touch depending on the participants' preference scores for the thumb space. After dividing the front screen into 84 tiles, we classified the thumb space specifically by calculating the participants' preference scores for each tile. Second, we also identified which area was preferred by participants when touching the back of the device with the index finger. Similar to the first experiment, the back of the device was divided into 84 tiles and each tile was scored based on the participants' preferences. However, in the second experiment, different settings, such as tile numbers, were considered, because people tended to experience problems touching the lower 42 tiles. Therefore, we considered the upper 42 tiles as meaningful for use in the experiment, and the second experiment was carried out for the upper 42 tiles.

Participant Recruitment

Participants were chosen who had a strong association with the IT industry, because IT employees tend to adjust well to recently released large screens and have high proficiency with them. We recruited 10 graduate students (M:5, F:5) related to the IT industry. The mean age of the participants was 27.7 years old, and the average length of their hands was 17.83cm.

Method

Each participant was required to touch 84 tiles on the front screen in the first experiment. Additionally, 42 tiles on the back side were touched in the second experiment. The number of tiles touched by one participant was 126 (84 tiles on the front screen, 42 tiles on the back of the device). The experimenter wrote a certain number on each tile to communicate with the participants easily when asking them to touch a particular tile. The order of touching certain numbers on the screen was randomly distributed. We required the participants to touch certain numbers displayed on the tiles with the natural grip posture. Because we were trying to recognize how people touch their smartphone in actual situations, we did not order the specific position of gripping the smartphone. Participants were given five trials before the experiment to enable them to adjust sufficiently to the conditions of the experiment. After completing the trials, the participants were required to touch certain numbers on the smartphone screen. Once they had finished each task, the participants scored their degree of comfort on a five-point scale for each task. High discomfort while touching a tiled number was given 1 point, and high comfort was given 5 points.

The main experiment was conducted by tiling a 4.7-inch iPhone 6 screen into a 7x12 area by referring to the guidelines provided by Apple iOS. Based on the Apple iOS guidelines, we divided the smartphone screen into the smallest units that could be touched with by the fingers [11]. The experiment utilized the mirroring application "X-mirage." By using the video

1.4	1.5	2.4	2.3	2.7	3.3	3.3
1.8	3.1	2.5	3.5	3.4	3.7	3.5
2.2	3.1	3.2	3.7	4.0	4.1	4.1
2.2	3.3	3.6	4.3	4.3	4.5	4.4
2.7	3.4	4.0	4.6	4.9	4.8	4.8
3.0	4.1	4.1	4.9	4.9	4.7	4.3
3.2	3.8	4.6	4.5	4.6	4.8	4.1
3.7	4.0	4.7	4.9	5.0	4.7	4.2
2.7	3.8	4.7	4.9	4.7	4.6	4.2
3.3	3.6	4.4	4.4	4.6	4.2	4.0
2.2	3.5	3.8	3.8	4.6	4.0	3.1
1.7	2.2	2.7	3.1	2.9	2.5	2.1

Figure 3: Mean scores of the participants' preferences in the thumb space, which was composed of 84 tiles on the front screen.

4.0	4.1	4.0	3.9	3.8	3.5	2.8
4.3	4.2	4.3	4.6	3.5	3.5	2.8
3.8	4.1	4.2	4.4	3.5	2.8	1.8
3.8	4.0	4.0	3.7	3.4	1.9	1.5
3.0	2.9	2.8	2.6	2.4	1.7	1.3
2.4	2.4	1.8	2.3	2.0	1.4	1.1

Figure 4: Mean scores of the participants' preferences in the index finger zone, which was composed of the upper 42 tiles on the back of the device.

recording functions of X-mirage, we recorded all participants' interactions during the experiment, and the recorded interactions were used for the experimental results analysis.

Results

The investigated results were classified into three areas depending on the participants' preferences for thumb space in relation to the 84 tiles and for the index finger zone in relation to the 42 tiles: 1) Comfortable zone, 2) extended zone, and 3) unreachable zone. In the below figure, the colors are shaded according to the touchable comfort–discomfort scale. We assembled each participant's preference scores for the front screen of 84 tiles and the back screen of 42 tiles. In the main experiment, the average total degree-of-comfort scores were calculated for each tapping-of-the tile task. From the preference score, each tile is colored based on the mean point scale in Figure 3 and 4.

Figure 3 consists of the mean point score of the participants' preferences from when the participants touched numbers on specific tiles on the front screen. The findings confirm that the range of thumb space is located in the center of the right side. The range of thumb space defined by Hoober's research on the Thumb Zone [2] supports our findings. Additionally, an interesting point, the darkest spot, was found on Figure 3. The average preference point score for the spot is 5.0, which means every participant felt comfortable and gave the highest point for the specific tile. Figure 4 shows the mean point score of the participants' preferences when they touched the numbers on specific tiles on the back side of the smartphone. Following the preference score results for the back side of the smartphone, the index finger zone was positioned in the upper-left side of the screen. We found that the comfortable zones of Figure 3 and Figure 4 could be joined together, which means that the touchable areas could be extended by using the thumb space on the front screen and the index finger zone on the back side. Figure 4 shows how the touchable area is expanded by using the index finger zone on the back side of the smartphone. The "comfort zone" is extended from usually existing only on the center-right to include the upper-left. While the comfortable zone of Figure 4 could not be reached on the front screen, it is likely to be touched easily by using the back side by increasing the mean point score of preferences from 3.4 to 4.2. According to the main experiment, the comfort zone constitutes 48% of the front screen with thumb space.

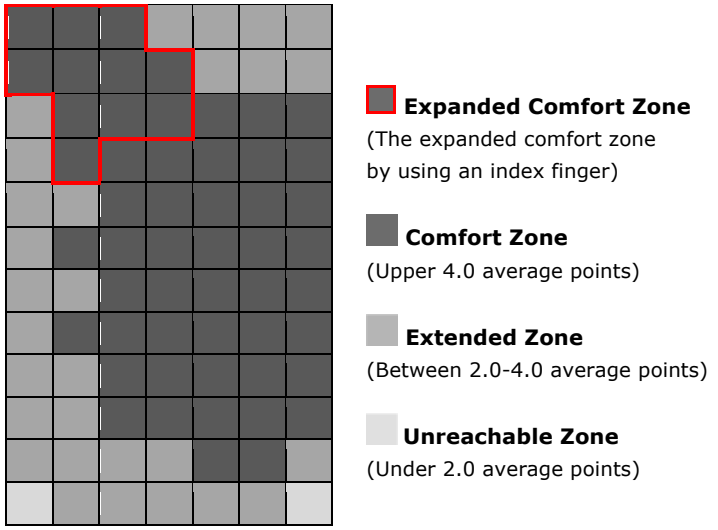

Figure 5: Comfort zone could be extended on the front screen when touching the back of the device with the index finger.

However, with index finger zone, it increased by 15%. Consequently, the extended comfort zone occupies 63% of the screen in Figure 5.

Conclusion

This study investigated the expandability of the touchable area by using an index finger. First, we identified that there is a limitation of "thumb space" on the front screen of a smartphone. Based on the preliminary experiment, the "thumb space" on the upper-left side is unreachable in any situation. Nowadays, the size of smartphone screens is increasing, and determining unreachable areas and expanding touchable areas is important. Secondly, we also identified that there is a touchable area using the index finger on the back side of the smartphone. We found that the index finger zone exists in the hard-to-touch area, including the extended zone and unreachable zone, which were difficult to touch in the thumb zone before. Lastly, we found that the index finger zone could compensate for the limitations of the thumb space. After the experiment, the comfort zone in front of the screen was expanded in the index finger zone. Hard-to-touch areas, such as the extended zone and unreachable zone, decreased by 15%, from 52% to 37%. In conclusion, this study will contribute to the creation of design guidelines for developing systems by making use of the index finger zone.

Future Work

Based on our findings, we plan to conduct further studies. In the future, we will focus on designing an integrated system that can provide an interface for the thumb space zone on the front screen and for the index finger zone on the back screen. For this goal, an elaborate design of experiments would be necessary. The direction of specific experiments to be additionally conducted for the realization of such an integrated system would be as follows. Firstly, a study concerning interactions, including scrolling and tapping, could be conducted efficiently in relation to the back side of the phone. A sophisticated experiment and qualitative research would be required to identify people's preferred functions regarding the index finger zone. Secondly, we also expect to determine which extra functions on the back side of the phone could be related to privacy issues depending on our findings. Because the back side is not easily recognizable, we also plan to verify whether the index finger zone could be used for personal authentication. Likewise, if we can complement the touch interface for the front screen by using the index fingers, it might be possible to effectively control touch interactions with one hand on bigger screens.

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