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Grasping Posture Study in One-Handed Touch Screen Operations Based on Posture Coding

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ABSTRACT

The ergonomic design of the thermal comfort of smartphones requires a greater understanding of the user's preferred grasping postures. This study examined the users' preferred grasping postures in three one-handed and high-heat-generating smartphone applications (short video browsing, video chatting, and video recording). The grasping postures of 50 participants in 3 smartphone application scenarios are photographed. The grasping position is encoded by the smartphone locations (left: L, right: R, top: T, bottom: B, front: F, back: K) and the number of fingers at each contact position. The grasping posture frequency distribution of smartphone application scenarios will be of use to guide the determination of the optimal thermal layout of smartphones in specific application scenarios.

Keywords: Smartphone, Grasping posture, Thermal layout, Thermal comfort, Posture encoding

INTRODUCTION

With the advent of the 5G era, the problem of overheating is well-known in the electronics sector. In a competitive smartphone market, manufacturers constantly enhance computing performance and diversify functionalities, which could result in generating a great amount of heat (Kang, S. et al., 2019). The integration of functions and the need for long periods of user use have placed higher demands on the thermal management of smartphones, and the thermal comfort of the user's grip has become a pressing issue in the ergonomic design of smartphones.

Smartphone devices are in close contact with the human hand and there are differences in heat sensation thresholds between different areas of the human hand. Hagander, L. G. et al. (2000) experimentally noted that the greater thenar eminence has a higher sensitivity than the rest of the hand and the fingertips have a lower sensitivity. The impact of smartphone heat issues on user experience in real-world scenarios can be reduced if heat distribution is based on the user's preferred Grasping posture information. Improperly designed locations of mobile phone hotspots may allow hand areas with high heat sensitivity to be in prolonged contact with the hotspot during use, leading to more intense thermal discomfort for the user at the same temperature level. Since the one-handed operation has more usability issues than the both-handed operation in terms of grip pressure and comfort. Therefore, the ergonomic design of smartphones for thermal comfort requires a greater understanding of the Grasping posture that users prefer when operating high-heat-generating applications with one hand.

Grasping posture was investigated by previous studies for the design of mobile devices., Choi, Y. et al. (2020) coded and clustered mobile phone gripping postures in a hard key operation scenario to obtain three main postures, and proposed that the enlarged grip of mobile phone size would favor one of the postures. Although previous studies have analyzed the main grasping postures of mobile devices, the grasping postures under real workloads of smartphones have not been systematically investigated. The present study was intended to identify the user's preferred grasping postures in one-handed smartphone applications. Grasping postures captured by cameras were encoded by the locations of a smartphone and the number of fingers at each contact location and the frequencies of grasping postures were analyzed.

EXPERIMENTAL METHODS

Participants

Fifty-one participants (25 males and 16 females; age = 23.1 ± 3.1; hand length = 180.6 ± 10.7 mm) were recruited. They were all smartphone users with more than one year's experience using their right hand primarily for one-handed manipulation and without a history of visual impairment or musculoskeletal disorders in the hand.

Apparatus and Experimental Applications

The experiments were carried out on a prototype mobile phone. The dimensions of the phone were 163.7 mm * 73.9 mm * 8.8 mm; it had a 6.7-inch touchscreen and weighed 218 g. It ran applications realistically in the experiment to provide a graphical user interface while participants simulated smartphone tasks.

Applications that require video encoding especially generate excessive heat quickly (Kang, S. et al., 2019). In addition, we considered experimental applications often In addition, we considered experimental applications often used in our daily lives, ranging from instant messaging to cameras. Therefore, short video browsing, video chatting, and video recording were chosen as representative high-heat task scenarios. For short-form video browsing, we chose Tiktok, which has over one billion daily active users worldwide (TikTok, 2021). For video conversations, we chose WeChat because it is the most popular video chat application in China. For video recording, we used the default app on the prototype smartphone.

Procedures

Introduction phase: Explaining the purpose and procedures of the experiment to participants, followed by obtaining written informed consent.

Task familiarisation phase: Participants used the prototype phone to operate three experimental applications to familiarise themselves with the size and weight of the prototype phone through exercises, as shown in Table 1.

Table 1. Major experimental applications and corresponding actions.

Experimental Applications	Actions
Short video browsing	1. Grasp the phone; 2. Swipe up and down to navigate through the tweeted video 3. Tap to pause/resume playback 4. Swipe left and right to adjust the progress of the video
Video recording	1. Grasp the phone; 2. Swipe to adjust the focal length of the camera; 3. Click to start/stop recording
Video chatting	1. Grasp the phone; 2. Click to start/stop recording

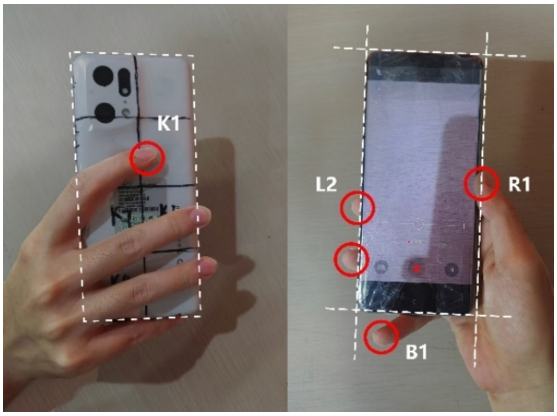

Figure 1: Encoding of smartphone grasping postures.

During the exercise, participants were required to perform a specified set of operations to familiarize them with the prototype phone. For example, a short video browsing scenario requires 4 actions to complete: (1) Grasp the phone; (2) Swipe up and down to navigate through the tweeted video; (3) Tap to pause/resume playback; (4) Swipe left and right to adjust the progress of the video.

Main experiment phase: Participants experienced three task scenarios in random order, each lasting 10 min, during which they could adjust their grip to their most comfortable position according to their usage habits. The participant's grasping posture was measured using a handheld camera immediately after each task scenario.

Posture Coding

The grasping posture was manually encoded by counting the number of fingers in each part of the device (left: L, right: R, top: T, bottom: B, front: F, back: K) (Choi, Y. et al., 2020). For example, the grasping posture captured for the one-handed video scene in Figure 3b was coded as L2-R1-B1-K1 (two fingers on the left, one finger on the right, one finger on the bottom, and one finger on the back of the model). A total of 153 images from 51 participants in three scenes were analyzed using the same method.

RESULTS

A total of seven different grasping postures were found for short video browsing. Three of the grasping postures (L3-F1-K1, L2-B1-F1-K1, and L2-F1-K2) dominated, accounting for a total frequency of use of 84.31%, as shown in Figure 2. In the measurement of the grip position for the short video viewing scenario, L3-F1-K1 (holding the left side of the smartphone with three fingers, the right side with the thumb, and the back with the index finger) dominated with a frequency of 50.98%. In addition, L2-B1-F1-K1 and L2-F1-K2 were the second and third most dominant grasping postures, accounting for 21.57% and 11.76% of the frequency of short video browsing operations respectively.

A total of ten grasping postures were identified from the experiment for short video recording, and of them, two grasping postures (L1-R1-F1-K2, L2-B1-F1-K1) make up the majority, accounting for 68.84%, as shown in Figure 3. L1-R1-F1-K2 (1 finger on the left side of the smartphone, 1 finger on the right side, thumb on the front side, and 2 fingers on the back side of the device) dominated, accounting for 45.31% of the total usage frequency. In addition, L2-B1-F1-K1 was the second most dominant grip position, accounting for 23.53% of the short video recording operation frequency.

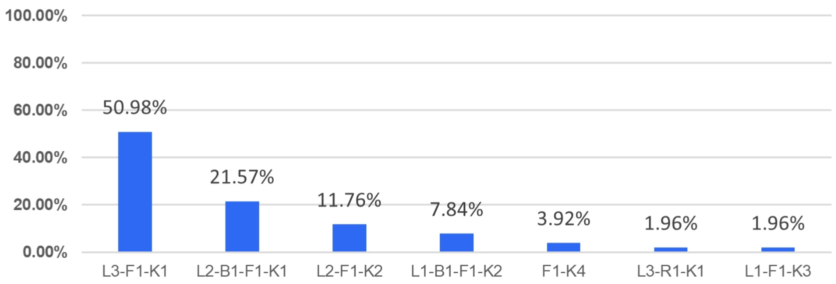

Figure 2: The use frequency distribution of grasping posture for short video browsing.

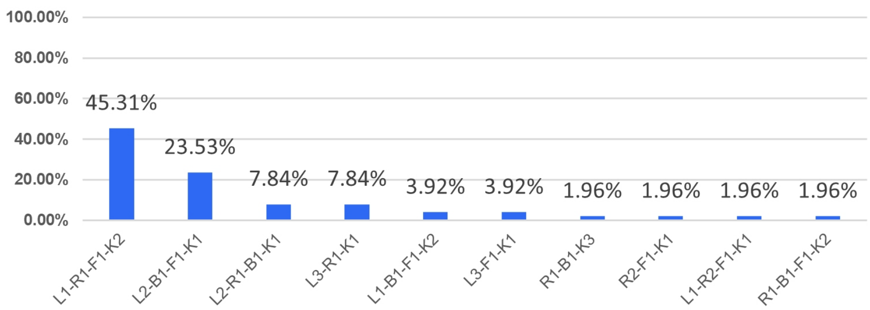

Figure 3: The use frequency distribution of grasping posture for video recording.

A total of 9 grasping postures were found for the video chat scenario. L2-R1-B1-K1 (27.45%) and L3-R1-K1 (25.49%) grasping postures accounted for more than half of the total and were identified as the predominant grasping postures (see Figure 4). L2-R1-B1-K1 is a grasping posture in which the user holds the left side of the smartphone with 2 fingers, the right side with the thumb, the index finger on the back, and the little finger supporting the bottom, while L3-R1-K1 is a grasping posture in which the user holds the left side of the smartphone with 3 fingers, the right side with the thumb, and the index finger on the back. The main difference between these two dominant postures is whether the bottom of the phone is supported by the little finger.

According to the frequency distribution of the grip postures in the three scenarios, L3-F1-K1 and L2-B1-F1-K1 are the two most popular grasping postures, as shown in Figure 5. Both postures allow the screen operation to be easily done by the thumb while the device is held firmly. In both postures, the thumb can be flexibly moved to the right side of the smartphone to quickly switch to L3-R1-K1 and L2-R1-B1-K1 when touchscreen operation is not required.

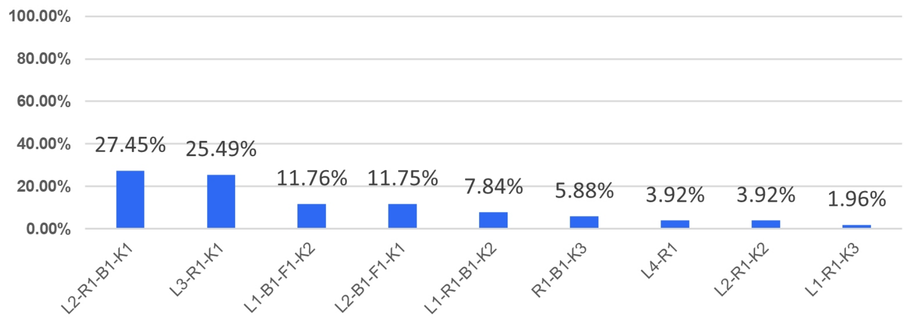

Figure 4: The use frequency distribution of grasping posture for video chatting.

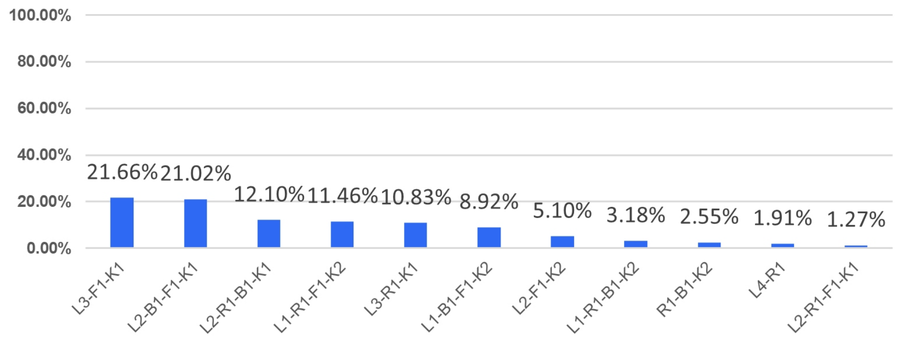

Figure 5: The combined frequency distribution of the grasping poses in all three scenes, excluding the poses with a very small percentage of frequency <2 times.

DISCUSSION

This study analyzes the preferred grip positions of users with different hand sizes and their frequency when operating three high heat-generating applications (short video browsing, video chatting, and video recording) with one hand, which is necessary to determine the optimal thermal layout of smartphones in specific application scenarios to improve thermal comfort. Based on the analysis of the user's preferred grip position, a rational design of the thermal location can reduce discomfort when the smartphone heats up at the same temperature level.

Of the two dominant grips in the video recording scene, L1-R1-F1-K2 (pinky on the left, index finger on the right, thumb on the front of the smartphone, last two fingers on the back of the smartphone) is a one-handed horizontal grip, L2-B1-F1-K1 (last two fingers on the left, pinky on the bottom of the smartphone, thumb on the front of the smartphone, index finger on the back of the smartphone) is a one-handed vertical grip. Both grips, while differing significantly in orientation, have the pinky finger at the bottom of the smartphone to support the device more firmly and thus allow the thumb to be flexible for touchscreen operations on the front.

In the short video viewing scenario, the two main grip positions, L3-F1-K1 (three fingers on the left side, thumb on the front of the smartphone, and index finger on the back of the smartphone) and L2-B1-F1-K1 allow the thumb to flexibly touch the screen on the front of the screen while the device is held firmly in place. In particular, L3-F1-K1 had the highest frequency of 50.98%.

The difference between the two dominant grips for video chatting, L2-R1-B1-K1 (27.45%) and L3-R1-K1 (25.49%), which are close in proportion, is whether the pinky is supported on the bottom of the smartphone, as the thumb in the video recording is barely required for touchscreen operations and can grip the phone firmly against the right side. Compared to the other two scenarios, the total percentage of non-dominant grip positions in the video chat scenario, excluding the top two dominant grip positions in terms of frequency, is 47.06% (27.45% for short video viewing and 31.16% for video shooting). This indicates that in the video chat scenario, users are freer to adopt their desired grip positions as they are hardly restricted by the position of the interface interaction components on finger positions.

Next, the results of this study need to be validated with a broader age range of users whose hand sizes may be outside the hand size range of this study, and in usage environments other than standing. This study measured the comfortable grip posture of users while sitting, but other use environments such as sitting, lying, and walking need to be considered to check whether the distribution of grasping posture varies with the use environment.

Finally, it needs to be investigated how the determined primary grasping posture can be used to determine the optimal heat generation layout of the smartphone. When using the identified primary grasping posture, the appropriate location of the phone's hotspot can be determined by identifying the actual area where the user is in contact with the smartphone, avoiding bringing areas of the hand with high thermal sensitivity into prolonged contact with the hotspot during use. The ergonomically determined location of the heat generating point can be evaluated based on the user-verified thermal comfort.

CONCLUSION

This study examined users' preferred grasping postures in three one-handed smartphone applications. short video browsing, video chatting, and video recording were chosen as representative high-heat task scenarios. Grasping postures were coded by the location on the smartphone (left: L, right: R, top: T, bottom: B, front: F, back: K) and the number of fingers at each contact location. The study identified three scenarios and the corresponding dominant grasping postures as follows: short video browsing (L3-F1-K1: 50.98%, L2-B1-F1-K1: 21.57% and L2-F1-K2: 11.76%); video recording (L1-R1-F1 -K2: 45.31%, L2-B1-F1-K1: 23.53%); video chatting (L2-R1-B1-K1: 27.45%, L3-R1-K1: 25.49%). The frequency distribution of grasping postures for smartphone application scenarios will be used to guide the development and evaluation of optimal thermal layouts for smartphones in specific application scenarios.

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