Title	Exploring the Adaptation of Mobile GUI to Human Motion Status
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Source	IUI '23 Companion: Companion Proceedings of the 28th International Conference on Intelligent User Interfaces, / Association for Computing Machinery. New York, NY : Association for Computing Machinery, 2023, p. 145-147
Conference	IUI '23: 28th International Conference on Intelligent User Interfaces, Sydney, Australia, 27-31 March 2023
Version	Published Version
DOI	10.1145/3581754.3584155
Publisher	Association for Computing Machinery
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Exploring the Adaptation of Mobile GUI to Human Motion Status

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ABSTRACT

The changing of display content of a GUI has an intuitive impact on readability and usability. One of the examples is when people look at the screen of a wearable device (e.g., smartphone, smartwatch) while moving, and they are particularly sensitive to the size of the display elements. In this work, we provide an initial exploration of adaptive interface for different human motion states. Specifically, we conducted an empirical study to explore the relationship between 4 mobile GUI element (text, image, icon, and hybrid) sizes and 4 different human motion states (sitting, standing, walking, and jogging), based on the select-and-click performances for 15 subjects. Our findings show the possibility of utilizing these data for GUI adaptive adjustment in different human motion states for improving selecting efficiency.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**.

KEYWORDS

computational user interface; adaptive GUI; motion adaptation.

ACM Reference Format:
Yongquan Hu, Zhaocheng Xiang, Lihang Pan, Xiaozhu Hu, Yinshuai Zhang, and Aaron Quigley. 2023. Exploring the Adaptation of Mobile GUI to Human Motion Status. In *28th International Conference on Intelligent User Interfaces (IUI '23 Companion), March 27–31, 2023, Sydney, NSW, Australia.* ACM, New York, NY, USA, 3 pages. https://doi.org/10.1145/3581754.3584155

IUI '23 Companion, March 27–31, 2023, Sydney, NSW, Australia

ACM ISBN 979-8-4007-0107-8/23/03.
https://doi.org/10.1145/3581754.3584155

1 INTRODUCTION & RELATED WORK

With the advance of wearable technology, billions of people read for information every day on mobile devices such as smartphones. In order to facilitate people to interact with devices efficiently and effectively, the mobile Graphical User Interface (GUI) is vital [1, 10, 17]. Mobile or wearable devices usually have smaller screens and thus limited space for displaying, which would make it difficult for users to quickly and easily read too much information on their screens, leading to frustration and a negative user experience [3, 12]. Furthermore, mobile devices are often used on-the-go or in situations where users do not have a lot of time to spare [9]. For example, a person may be trying to read a message on their smartwatch while walking to work or checking the weather on their phone while running errands. In these cases, it is essential for the GUI to allow users to quickly and easily access the information they need. Hence, exploring the mobile GUI that adapt to different human motion states is important.

Although some advantages of the adaptive interface are still debatable, its necessity in some specific situations were already recognized since it could automatically adjust the interface in a intelligent, low-cost or even implicit way according to different factors [14]. External environmental factors (e.g., light, sound) are commonly considered as the basis for adaptive adjustment of the interface [15]. The user's behavior, such as the gesture or posture of the user's mobile phone, is also a crucial reference for the GUI deformation [8, 11]. Additionally, the adaptive GUI can also help to improve the user experience by adjusting the interface based on the user's preferences and history [16, 18]. Considering the existing research, the GUI adapts to different human motion states (e.g., speed, acceleration, height, height and angle of holding device) has been few explored. To the best of our knowledge, this work is the first to fuse these multidimensional sensor data and map them to different GUI element sizes to explore the adaptive design space and potential, which could facilitate more fine-grained interface adjustment and more novel application developments.

As a preliminary exploration, we present the results of a user experiment for exploring motion-adaptive GUI design for wearable devices. To this end, we conducted an empirical study with 15 subjects, examining the select-and-click performance of 4 mobile

GUI elements (text, image, icon, and hybrid) in 4 common motion states (sitting, standing, walking, and jogging). In particular, we capture the timestamp of each time the user correctly selects the target from the capacitive screen of the mobile phone, and use the length of time to reflect the reading efficiency. Meanwhile, we also collect 5 types of motion data (3-axis accelerometer, 3-axis gyroscope, 3-axis gravity, 3-axis linear acceleration, and 3-axis rotation vector) from the built-in Inertial Measurement Unit (IMU) of the mobile phone to comprehensively represent diverse motion states. The results of our study suggest that motion-adaptive GUI design has the potential to be a valuable tool for improving the effectiveness of the selecting task on wearable devices.

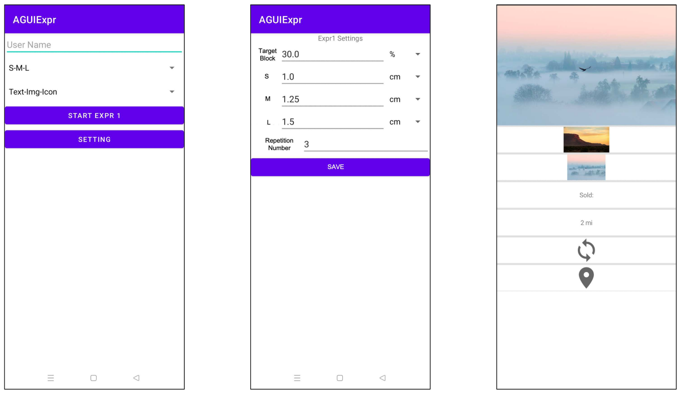
2 METHODOLOGY

2.1 Software Design & Development

Our goal is to determine whether there is a relationship between the size of GUI elements and human motion states that could be utilized to improve the efficiency of selecting task on GUI. In terms of recording data, we developed an Android program, taking into account several design details. Fist, given that people typically have limited interaction with mobile GUIs on the move [4], we're currently only taking the simple task of select-and-click. For such a task, the size of display content on the GUI has a direct impact on the usability of the device [7]. Furthermore, for the display content on the mobile interface, there have been literature to classify and summarize it. For example, Rico, as the largest mobile UI dataset so far, includes 27 different categories of GUI elements [5]. Since the mobile GUI usually has less space and few content to display, we select 4 of the most common GUI elements (text, image, icon, and hybrid), and randomly extract 100 samples from each of these categories from Rico. Then, those samples are randomly displayed in the Android program for users to select and click. The displayed target is not skipped until people choose it correctly. On the other hand, IMU, as a built-in sensor in smartphone, is a low-cost, safe way for collecting user data, especially motion data [13]. We collected 5 kinds of data (3-axis accelerometer, 3-axis gyroscope, 3-axis gravity, 3-axis linear acceleration, and 3-axis rotation vector) from the IMU, which can reflect the state of human motion in many ways such as the speed of people running or the posture of holding mobile phone. Finally, we visualize the results obtained from the experiment to explore whether the size of different interface elements needs to be changed under different motion states to improve the selection efficiency.

2.2 Data Collection & Analysis

In this preliminary study, we invited 15 subjects (8 males and 7 females, mean age = 23.4, SD=5.2) to participate in our experiment. Our Android program for recording data is shown in Figure 1. In the the setting page of Figure 1 (a), we need to first enter some parameters to start the select-and-click task. The information needed from top to bottom is: user name, display order, display type (text, image, icon or hybrid) and some more parameter settings. It should be noted that the display order refers to the order in which display blocks of different sizes are presented to the user for selection. We set three sizes in our program, i.e. small size (S), medium size (M) and large size (L). The significance of those sizes is that we could



(a) (b) (c)

Figure 1: Our Android application for data collection: (a) The first setting page is used to set various parameters (e.g., user name, display order); (b) The second setting page for more parameters (e.g., the values of S, M, L of display block); (c) An example of the task page for selecting and clicking on the correct target from the hybrid content (text+image+icon).

achieve count balance by adjusting their display order to eliminate the deviation between different users [2, 6]. What is emphasized that we provide three options for display order: S-M-L, M-L-S and L-S-M. Moreover, the specific values and units of these sizes of target and display block (e.g., the values of S, M, L of display block) are adjustable, as shown in Figure 1 (b). After some pre-experiments, we found that the fluctuating and more reasonable interval is between 0 and 3cm. Hence, we set 12 different size values (4 sets of {S,M,L}), and they are: {S1,M1,L1}={0.25, 0.5, 0.75}; {S2,M2,L2}={1, 1.25, 1.5}; {S3,M3,L3}={1.75, 2, 2.25}; {S4,M4,L4}={2.5, 2.75, 3}. In short, each user is asked to complete all the tasks corresponding to the 12 different size values, but with distinctive display order. In addition, the repetition number in (b) means that the display block corresponding to the same size value will reappear several times. In our test, we set it as 3. For the (c) of Figure 1, we present an example of the task page with hybrid display content. The gray area in the upper part of the figure is the target block for demonstration, and the lower part is the display block for users to select and click.

3 FINDINGS & DISCUSSIONS

The results of our experiments are shown in Figure 2. As mentioned above, we would like to figure out how sensitive people are to the select-and-click task in different motion states. Specifically, we establish a mapping relationship between the time it takes to select the correct target and the GUI display block size. Most importantly, On the whole, no matter what kind of motion state or what kind of display content, all the curves show a trend of falling first and then slowly rising. It is because due to the limited screen space of mobile devices, as the size of the displayed content continues to increase, it is impossible to display all the content on a static page and requires the user to scroll the screen to find the correct option. The increase in display content within a certain range helps to find the correct target faster and shorten the time, while the scrolling

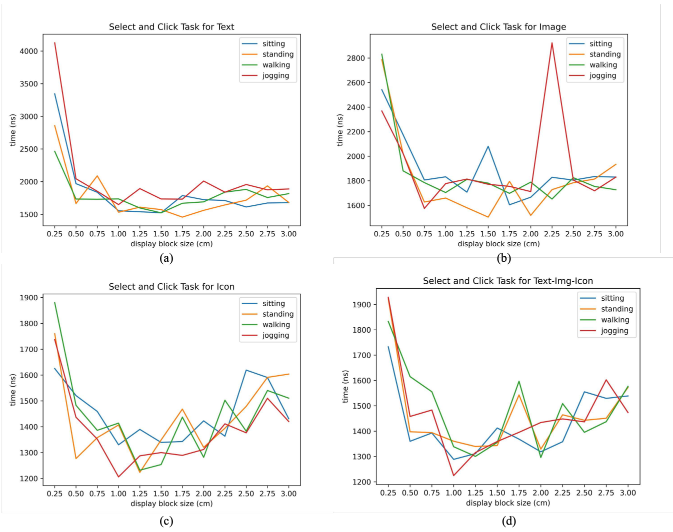


Figure 2: The relationship between human select-and-click efficiency (time taken to select the correct target) and display block size under different motion states: (a) The relationship curve of selecting text display; (b) The relationship curve of selecting image display; (c) The relationship curve of selecting icon display; (d) The relationship curve of selecting hybrid (text+image+icon) display.

caused by the oversize will add extra selection time. Therefore, there is a trade-off between the two, that is, there should be a theoretical "optimal solution" for this type of task. It is worth mentioning that the jogging (red) curve in the jogging state in Figure 2 (b) grows suddenly for the displayed block size of 2-2.5 cm, which indicates the size increase of larger images will rapidly cause the selection efficiency to drop. This phenomenon can be interpreted as compared to other display content, even under the same display block size, the image occupies a larger visual proportion, resulting in a larger screen space. Next, we notice that, for different motion states, the results of sitting and standing are usually similar, because both of them are stationary states and are less disturbed. However, the results for walking and jogging vary widely for multiple displays. For instance, for text display at smaller sizes, the walking (green) curve is substantially below the jogging (red) curve. However, the remaining three displays show that the green curve is generally higher than the red one. It reveals that human is more sensitive to changes in speed when recognizing smaller text characters. Finally, we found that all curves under text recognition have overall longer response times than those of image and icon task across the entire display block size. It suggests that text is a higher cognitive burden for human to identify and even comprehend than images and icons. Consequently, we recommend reducing the display content of the text category and presenting it more in the form of image or icon in the dynamic state of the body.

4 LIMITATIONS, FUTURE WORK & CONCLUSION

Currently, we have only taken the first step in exploring the adaptation of mobile GUI to human motion state, and there is still much follow-up that needs improvement and depth. First of all, our work only involves limited interface elements (four elements: text, image, icon and hybrid) and task (i.e., the select-and-click task), we will introduce more interface elements and more complex interactive tasks in the future. Secondly, our preliminary work point to the need for a motion-adaptive interface, but do not provide a concrete solution. We consider leverage machine learning or deep learning methods to understand the rules of the collected data and let the GUI automatically adjust according to different motion states based on the data we collect. Last but not least, more novel and unique application scenarios are required to be paid more attention for illustrating the potential value of this technology.

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