“Just Like Blooming Fireworks, And Match With Function Perfectly”: Explore and Evaluate User-Defined One-Handed Gestures of Smartwatch

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ABSTRACT

One-handed gesture interaction is a more convenient input interaction method on smartwatches for some special scenarios, e.g. wearing a smartwatch when running or biking. To explore user-friendly one-handed gestures, what users are thinking when using the gesture, and what characteristic would make the user feel this one-handed gesture is friendly, we developed a series of one-handed gestures for 6 basic functions of the smartwatch. The end-user elicitation method resulted in 12 new one-hand gestures. We compared these 12 user-defined one-handed gestures with the Apple Watch one-handed gestures. We developed a Wizard of Oz model and evaluated these gestures by using qualitative and quantitative approaches. The results show that we generated a set of one-handed gestures that are more friendly than the existing Apple Watch one-handed gestures. Also, during the evaluation process, we collected quantitative data and interesting user perspectives. We also gave some design recommendations for one-handed gestures.

CCS CONCEPTS

• **Human-centered computing** → Human computer interaction (HCI); HCI design and evaluation methods; Heuristic evaluations.

KEYWORDS

Gesture generation, User-defined gestures, One-handed gestures

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1 INTRODUCTION

With the popularity of mobile Internet and smart devices, wearable products (e.g., smartwatches, smart bands) are becoming more and more mainstream [1]. The locations where these devices are mounted can provide instantaneous command input, and their continuous contact with users' skin enables embedded sensors (e.g., IMU[14], microphone[4, 6] and pulse sensors7, etc.) to record users' daily activities and monitor their health. Developers can take advantage of such hardware and combine it with computing algorithms to correctly recognize various one-handed gestures. At the same time, it is obvious that especially in mobile scenarios, users are more willing to use watches instead of mobile phones to complete some lightweight interactions (e.g. checking the time or reading social media messages while exercising) [8]. Therefore, interacting with the watch in a mobile scenario is a frequent scenario.

Like mobile phones, touch-screen interaction is the main interaction method for smartwatches. However, this interaction method has limitations in mobile scenarios. Specifically, the small screen size makes it difficult for users to tap accurately [15]. At the same time, some tasks require a series of click actions [9]. The whole process may take only a few seconds, but for the user to continuously move their eyes in a mobile scenario to make a series of clicks on the watch screen, requires an expensive behavioral cost.

To explore user-friendly one-handed gestures, we recruited a group of end-users to create 168 new one-hand gestures. After our consolidation and screening, we got 12 user-defined one-handed gestures for 6 basic functions of smartwatch, and each function has 2 gestures. We recruited another group of users to choose their preferred gesture for each 6 functions between 2 gestures. To focus on user behavior and thoughts, we want to eliminate the influence of fluctuations in gesture recognition. Therefore, we developed a Wizard of Oz model for users to experience one-handed gesture interactions. We designed two daily interaction flows to facilitate users understanding of the usage scenarios of one-handed gestures.

Participants learn 12 one-handed gestures and use them to complete the interaction flow on the prototype and the Apple Watch. After learning process, participants compare and evaluate the preferred user-defined one-handed gestures with existing Apple Watch one-handed gestures. We use Semantics, Effortlessness, Learning Costs, and Subjective Willingness 4 dimensions to evaluate the friendliness of a gesture. The user-defined one-handed gestures perform better than Apple Watch one-handed gestures. We summarized the experiment results and users' Interesting perspectives of these gestures. And we also propose some design suggestions as provide references for future one-handed gesture development.

2 RELATED WORK

One-handed gesture interaction only requires the user to use one hand to complete related interactive actions[24–26, 29, 23Schäfer,], while the other hand can complete other tasks at any time[1]. The one-handed gesture is a type of gesture without touching any tangible interface[7], similar to air gestures[3]. Some mid-air gestures require two-handed cooperation[17, 18], while one-handed gestures do not. Hence, one-handed is more simple than two-handed, and users are more inclined to learn simple gestures[2]. Some on-skin one-handed gestures allow the dominant hand to perform related gestures on the skin of another hand (for example, tap, draw, pinch, etc.) [5]. But some previous gestures are difficult for users to remember and distinguish from each other[28].

The one-handed gesture is useful for not only disabled users but also average users. One-handed gestures allow users with upper limb disabilities to use electronics without having to touch the display or watch the crown. For the average user, there is also a rising demand for interaction methods that can be used easily and quickly in mobile scenarios. For example, when running, the constant motion prevents runners from accurately tapping and swiping on the small screen of smartwatches.

There have been many previous studies proposing various techniques for recognizing one-handed gestures[11, 12, 22, 32–35], but few studies have focused on the user perspective of one-handed gestures. For eample, what one-handed gestures make users feel more user-friendly, and make users more willing to interact with the watch theough one-handed gestures. How users understand and remember a one-handed gesture. In order to explore user-friendly gestures, several previous studies have used user-defined[10] approaches to develop gestures [19, 20, 30, 31], which is a interesting way to develop gestures. Shimon et al. used user-defined approach to explore non-touchscreen gestures for smartwatches[21]. This study proposed 18 gestures. Some gesture can only be used in a specific software, for example, turning on the microphone in video conferencing software. But remembering so many set of matching relationships between the gesture and the relevant function of certain application is a big challenge for users. Fong-Gong Wu proposed a smaller set of one-handed gestures only for browsing on touch phone[27]. To match the human short-term memories, they found 5 gestures refer to 7±2 items refer to Miller's law[37]. Therefore, selecting universal functions that can be used in all applications can reduce memory costs of memory cost of gesture sets.

In 2021, Apple presented a one-handed gesture interaction based on Apple Watch, which includes 4 universal functions: previous/next/confirm/open the menu[16]. Users can operate all applications via several simple gestures. Such one-handed gesture set for smartwatch is simpler and friendlier than previous studies. Hence, we refer to these 4 basic functions of Apple Watch, then compare our user-defined collection of one-handed gestures with the Apple Watch's one-handed gestures. Explore whether the user-defined gesture set is more preferred by users than Apple's existing one-handed gestures.

3 METHODOLOGY AND EXPERIMENT DESIGN

The experiment included two stages. In stage 1, we used an elicitation study to generate and filtrate gestures. In stage 2, in order to help users experience the real feeling of gesture interaction, we use the experimental method of the Wizard of Oz and build a set of a prototype that can simulate the effect of gesture interaction. Another group of participants evaluated these gestures by using a prototype, quantitative surveys, and scales. Participants in stage 1 (gestures generation) and stage 2 (gestures evaluation) did not overlap.

3.1 Participants

We publish information and recruit users on three social platforms (Weibo, WeChat group, and Xiaohongshu). We pay ¥10 for each participant. We recruited 41 participants. The average age was 23.5 years. All participants had previous experience with the Apple Watch. Participant occupations included students, engineer, and product manager. In stage 1 of the generative gesture experiment, there were 12 participants, and 7 were female. In stage 2 of the gesture evaluation experiment, there were 29 participants, including 14 males and 15 females.

3.2 Stage 1: Developing the User-Defined One-hand Gesture Set

We want to collect users' preferences and opinions of one-handed gestures for basic features in the watch. Therefore, in stage 1, we asked 12 participants to design gestures for the seven most basic functions: confirm, previous Button, next Button, open Dock, return to Home page, return to previous interface, and open Control Center. Each participant designed two different gestures for these functions. We got 168 gestures, and each function heve 24 kinds of gestures.

Stage 1 Procedure: 1. Introduction: We describe the background and goals of the one-hand gesture design. **2. Designed gestures:** Participants designed the gesture they thought were natural and readily comprehensible for each function without a time limit. **3. Self Evaluation:** Participants used rated the gestures they just designed by three 5-point Likert-scale questions. The Likert scale includes three questions: The gesture I designed matches the expected function very well. I think this gesture is easy to perform. I think it's a little complicated to use this gesture to perform this function. **4. Selecting Gestures:** We use the scores of Guessability and Agreement to filter gestures. These two scores refer to the

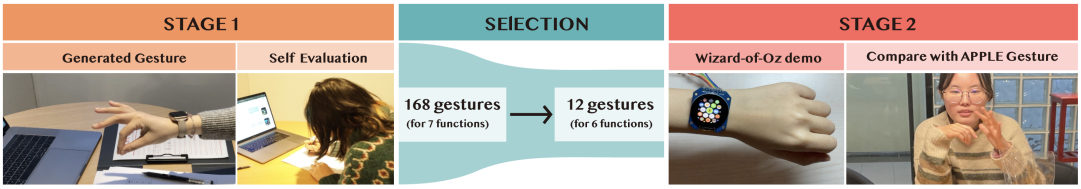


Figure 1: Experimental procedures

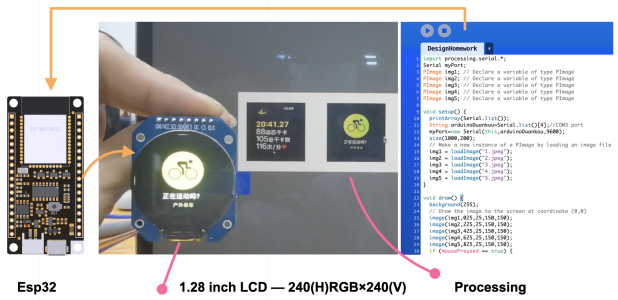


Figure 2: 1.3-inch LCD screen and Interface in Processing.

Wobbrock et al. [2, 13, 36]. The two scores are defined as follows:

$$G = \frac{P_s}{P}.100\% \tag{1}$$

$$A = \frac{\sum_{P_s \subseteq P} \left(\frac{|P_s|}{|P|}\right)^2}{1}.100\% \tag{2}$$

In equation 1 and equation 2, P is the amount of all user-generated gestures for a same function, and P_s is the amount of similar user-generated gestures. Based on prior work, guessability means the quality of symbols which allows a user to access intended referents via those symbols despite a lack of knowledge of those symbols. Hence, the higher G means the more participants have the same understanding for its semantics. The A means the the agreement among symbols
proposed by the participants. The A will be high when the different kinds of gesture for a function are unique, and it will be when they are unique. The function with low A maybe too abstract to indicate its sematics only by gesture.

Selection Result: We calculated the *Agreement* of all functions. The scores is: Confirmation(0.1875)> Previous Button(0.1597)> Next Button(0.1458) Opening Dock(0.1181)>Return to Homepage(0.1024)> Return to the Previous interface(0.0702)>Open the Control Center(0.0556). We remove the functions with the lowest scores. For each function, we combine similar gestures and calculated the *Guessability*. We selected the top two gestures with the highest *Guessability*.

3.3 Stage 2: Evaluating The User-Defined One-Handed Gestures Set

Apparatus: In developing a user-defined gesture set, we want to eliminate the influence of fluctuations in gesture recognition on users' behavior. Hence, we employed a Wizard of Oz approach. We implemented a Processing4 application[1] to control an ESP32-DevKit-Board and a 1.3-inch 240X240 HD LCD display as a watch screen. When a participant performs a gesture, the experimenter will control the appropriate interface on the watch. We finally selected 12 gestures for 6 functions.

Scenario design: In stage 2, we recruited 29 participants. Participants learn 12 gestures generated in stage 1, then use these gestures to complete two tasks. Participants compare the user-defined gestures set with the Apple Watch gestures set, select their favorite gesture and explain their reasoning. Then complete evaluation scales. To help participants imagine the scenario of using one-handed gestures, we designed two one-handed gesture task flows in two scenarios. The reason for setting these two scenarios is that wearing a watch for exercise is a common scenario for using a watch, and one-handed gestures can be more convenient than tapping the watch screen during exercise (e.g., doing anaerobic exercise).

Stage 2 Procedure: 1. Participants watched a tutorial video on one-handed user-defined gestures. 2. Participants imitated each gesture at least three times and used the prototype to complete the two task flows. Each user-defined gesture will be used in the task flows. 3. Participants selected the most preferred user-defined gesture and explained why. 4. Participants chose a task flow and completed it with an Apple Watch. 5. Participants use scales to rate the user-defined gesture they preferred and the Apple Watch. The scales have 4 questions and ranged from 1 to 7, from "strongly disagree" to "strongly agree", 4 is neutral. The questions were as follows, containing 3 forward and 1 negative question: 1. I think the semantics of this gesture match with the function well. 2. This gesture was easy for me to perform. 3(negative question). I think the learning cost of this gesture is very high. 4. I am willing to use this gesture to manipulate the interface. These four questions assess semantics, effortlessness, learning costs, and subjective willingness. Cronbach's α coefficient of the scales is between 0.7 and 0.9, showing good internal consistency. Scales have good content reliability.

4 RESULT

4.1 Data analysis

The scores of these four questions in all gestures were normally distributed, after the Shapiro-Wilke test. We calculated the average score of each question, then used matched T-test to analyze whether statistically significant difference between user-defined gestures and Apple Watch gestures on four dimensions (semantics,

[1]All necessary codes can be found at https://anonymous.4open.science/r/1035-supplementary-files-E5B3/1035-supplementary%20files.zip

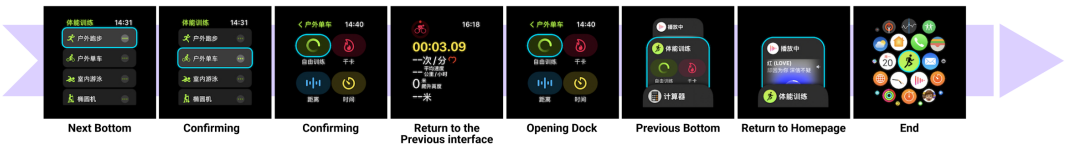


Figure 3: Task flow1 in Scene1- Open the Sports & Health app with one hand, then return to the Music app.

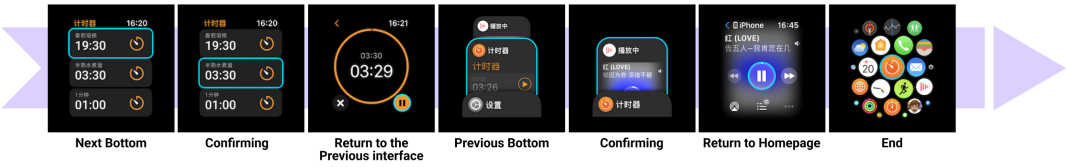
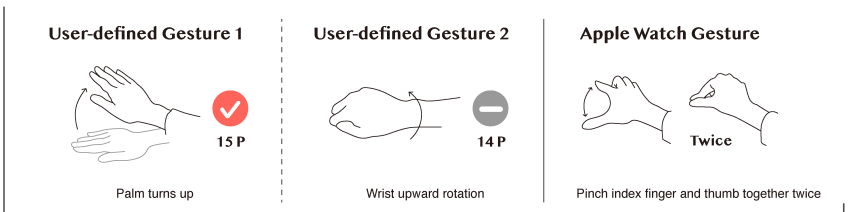


Figure 4: Task flow2 in Scene2- Open the Timer app with one hand, then return to the Music app.



Gesture	Preferred number	Semantics	Effortlessness	High Learning Costs	Subjective Willing-ness				
		Average	T-text	Average	T-text	Average	T-text	Average	T-text
User-defined Gesture 1	15 P	5.89	0.01<P<0.05	5.53	P>0.05	2.41	P>0.05	4.53	P>0.05
Apple Watch Gesture	——	4.29		4.94		2.94		4.35	

Figure 5: Comparison data between user-defined gestures and Apple Watch gestures in the "Previous Button" function

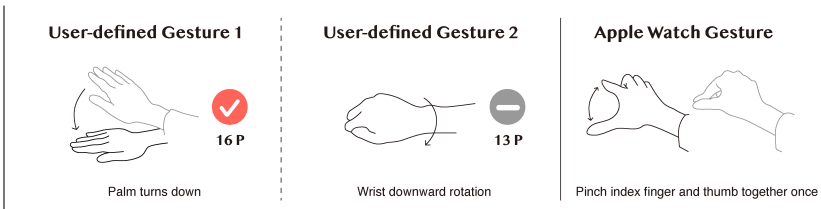
effortlessness, learning costs, and willingness). In questions 1, 2, and 4, a higher mean score means a friendlier gesture. In question 3, a lower mean score means a friendlier gesture.

4.2 "Previous Button" Function

Among the two user-defined gestures, 15 participants preferred gesture 1, more than the 14 participants who chose gesture 2. Obviously, in the "Previous Button" function, the average score of user-defined gesture 1 performs better than the Apple Watch gestures on all four dimensions. There is a significant difference between the scores of user-defined gesture 1 and Apple Watch gesture on semantics, while there is no significant difference in the scores of the other three dimensions.

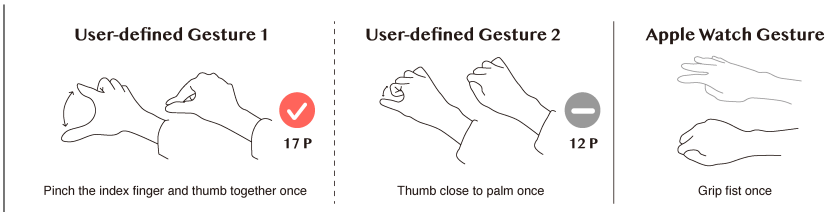
In the qualitative interviews, almost all participants mentioned that the Apple Watch gesture has confusing semantics, ***"For me, it's hard to associate this gesture with any function"***, and ***"Why does one pinch represent the next button and two pinches represent the previous button? I will easily confuse the gestures of these two functions with each other. I can't find a good reason to explain the difference in the number of repetitions. So I had to force myself to remember the correspondence between the number of times and function"***

Participants mentioned many advantages of the semantics of user-defined gesture 1, ***"My palm moves upward with the watch screen button move in the same direction, this interaction effect with a good sense of manipulation let me feel reasonable"***, and ***"The action is really like swiping a short video in TikTok"***. Regarding the effortlessness, participants generally felt that ***"Although the finger pinch seems to be a slight action, in fact, this movement is not as easy to do as the palm-up movement"***. Some participants criticize pinching, saying ***"Repeating this action makes me feel a muscle cramp "*** and ***"Pinching twice is really tiring"***. For palm-upward, the participants said ***"It is easier***



Gesture	Preferred number	Semantics		Effortlessness		High Learning Costs		Subjective Willingness	
		Average	T-text	Average	T-text	Average	T-text	Average	T-text
User-defined Gesture 1	16 P	5.82	P<0.01	5.35	P>0.05	2.65	P>0.05	4.82	P>0.05
Apple Watch Gesture	——	4.65		5.88		2.47		5	

Figure 6: Comparison data between user-defined gestures and Apple Watch gestures in the "Next Button" function



Gesture	Preferred number	Semantics		Effortlessness		High Learning Costs		Subjective Willingness	
		Average	T-text	Average	T-text	Average	T-text	Average	T-text
User-defined Gesture 1	17 P	5.53	P>0.05	6.47	P>0.05	2.17	P>0.05	5.18	P>0.05
Apple Watch Gesture	——	5.71		6.18		1.76		5.24	

Figure 7: Comparison data between user-defined gestures and Apple Watch gestures in the "Confirmation" function

than pinching" and "This gesture is very sprawling and easy to understand meaning"

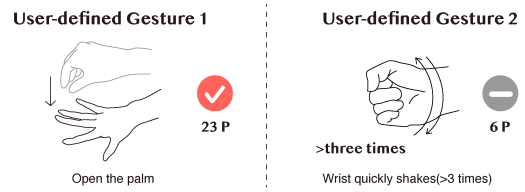
4.3 "Next Button" Function

More participants preferred user-defined gesture 1 than user-defined gesture 2. User-defined gesture 1 of the "Next Button" function has a much higher average of semantics than the Apple Watch gesture, and has a significant difference. It also got higher average scores of subjective effortlessness and willingness, and has a slightly lower average score of learning cost. In these three metrics, there are no significant differences between the two gestures. Considering that gestures of the "Next Button" function and the "Previous Button" function are a set of gestures, here omitted some qualitative comments similar to the "Previous Button" function. Interestingly, in the comparison between user-generated 1 and user-generated 2, participants mentioned that ***"Wrist rotation downward is too easy, which has no sense of control "***, and ***"Though turning palm up and down is a bigger set of gesture, more comfortable and easier to understand than wrist rotation".*** These reasons are similar to the next "confirmation" function. Though participants commented that the user-defined gesture 1 is more effortless than the Apple Watch gesture, they still preferred the latter, a gesture with greater action.

4.4 "Confirmation" Function

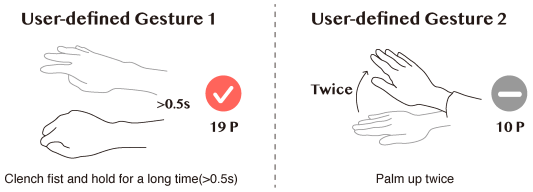
There are 17 participants who preferred user-defined gesture 1. Participants admitted that pinching of user-defined gesture 1 was less laborious than the fist of the Apple Watch gesture. However, the average scores of user-defined gesture 1 show that it performs slightly worse than the Apple Watch gesture in terms of semantics, learning cost, and subjective willingness. None of these scores were significantly different. Obviously, making a fist is more effortful, because it requires people to move the entire palm and all fingers. While pinch only needs two most commonly used fingers, that is the index finger and thumb. However, participants said that the fist gesture was ***"relaxed", "easy to do"*** and ***"can be done quickly"***, and the pinch was ***"Easy to use, but still more difficult than making a fist "***. We analyze that making a fist is used frequently enough in daily life. So that participants are already extremely familiar with it, and such familiarity brings a psychological feeling of ease that outweighs the actual physical exertion.

Participants state many semantic advantages of user-defined gesture 1: ***"Pinch looks like OK gesture", "It brings the feeling of grabbing something", "It is like snapping, and also like a 'Bingo'"***. While participants who preferred the Apple Watch gesture mentioned that ***"Making a fist has a determined feeling of confirmation function"*** and ***"The fist-clenching is stronger***



Gesture	Preferred number	Semantics	Effortlessness	High Learning Costs	Subjective Willingness
		Average	Average	Average	Average
User-defined Gesture 1	23 P	6.35	6.59	1.53	6.23

Figure 8: Comparison data between user-defined gestures and Apple Watch gestures in the "Opening Dock" function



Gesture	Preferred number	Semantics		Effortlessness		High Learning Costs		Subjective Willingness	
		Average	T-text	Average	T-text	Average	T-text	Average	T-text
User-defined Gesture 1	19 P	5.24	P<0.01	6.06	P<0.01	2.18	P<0.01	5.71	P<0.01
Apple Watch Gesture	——	3.24		3.18		5.12		2.71	

Figure 9: Comparison data between user-defined gestures and Apple Watch gestures in the "Return to Homepage" Function

and has more certainty ". Both two gestures have good semantics, but participants felt that the semantics of the Apple Watch gesture was stronger than the user-defined gesture 1. Our Analysis is that the "Confirmation" function is so frequently used and important, so that the corresponding gesture needs a strong sense. Another reason is, in a daily interface interaction flow, "Confirmation" usually means the end, staying in the current interface and without continuing interaction, this end meaning also requires a strong gesture.

4.5 "Opening Dock" Function

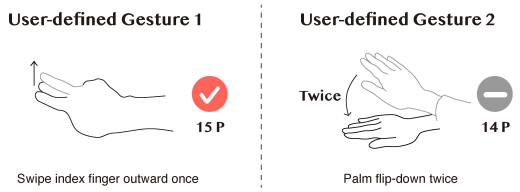
Apple Watch does not define a specific gesture for the "Opening Dock" function. And there is also no combination of gestures that can achieve this function, so this user-defined gesture 1 can not be compared with the Apple Watch gesture. This "Opening Dock" user-defined gesture 1 got the best scores among all the user-defined gestures. And the difference between the number of people choosing user-defined gestures 1 and user-defined gestures 2 is also the most dramatic. Many participants expressed their love for the gesture, offering a variety of interesting interpretations and associations.

"It makes me imagine the blooming fireworks, fireworks also have a semantic meaning of opening", "There is no any separation between the gesture and the operation, it matches perfectly and is easy to remember ", "It feels like all the applications are unfolding and displayed", "This gesture is very similar to the touchpad gesture to open the launch pad when I use Mac".

4.6 "Return to Homepage" Function

A total of 19 participants preferred user-defined gesture 1, and 10 participants chose user-defined gesture 2. As the previous function, there is no one gesture for the "Return to Homepage" function. Users need to use a combination of gestures to complete this function, the interaction process is 1. Open the control menu by making a fist twice, then the "Return to Homepage" button has been selected; 2. Then make a fist once which is the "Confirmation" gesture to click the "Return to Homepage" button.

Comparing the average scores of user-defined gesture 1 and the Apple Watch combination of gestures, gesture 1 performs better in all four dimensions, and there are significant differences between all these four sets of scores. Participants said, ***"When I use a smartwatch, I frequently need to back to the homepage to click other apps. It's too troublesome to use this combination of gestures every time"***. Participants mentioned many semantic advantages of user-defined gesture 1 ***" Slowly close all fingers, just as closing all applications and returning to the home page", "This gesture and the last Opening Dock gesture 1 looks like in the same***



Gesture	Preferred number	Semantics		Effortlessness		High Learning Costs		Subjective Willingness	
		Average	T-text	Average	T-text	Average	T-text	Average	T-text
User-defined Gesture 1	15 P	4.88	P<0.01	5.18	P<0.01	2.44	P<0.01	4.56	P>0.05
Apple Watch Gesture	——	1.56		1.94		6.38		1.31	

Figure 10: Comparison data between user-defined gestures and Apple Watch gestures in the "Back to the previous page" Function

system" and ***"This gesture is simple. And it is very effortless, well suited for such a function which be often used"***.

4.7 "Back to the previous page" Function

There is no specific gesture of this function in the Apple Watch. Can be replaced with a combination of gestures, the interaction flow is: Keep using the "Previous" button gesture until the "Back to the previous page" button in the upper left corner of the interface has already been selected, then use the "Confirmation" gesture to click the button. 14 participants chose user-defined gesture 1, which got better scores than the Apple Watch gesture in all four dimensions, with a significant difference.

Among all user-defined gestures, it has the largest average score beyond Apple Watch. Many participants agreed that this gesture is reasonable, as they said ***"Thumb outward gives a sense of getting out of the current interface",*** and ***"The direction of the thumb is the same as the direction of returning to the previous page on the phone. Easy to remember"***.

Interestingly, user-defined gesture 2 of the "Back to the previous page" (palm flip-down twice) and Apple Watch gesture of the "previous button" (pinch fingers twice) all need to repeat a gesture twice. However, about user-defined gesture 2 of the "Back to the previous page", repeating a gesture twice was not as criticized as pinching fingers twice. One participant offered this understanding, ***"Returning to the previous page means switching the entire interface. The previous button means selecting the button in the current interface. I think two repeated actions represent the interaction with a big change. So it is reasonable"*** .

5 DESIGN RECOMMENDATION FOR ONE-HANDED GESTURES IN SMARTWATCH

Based on qualitative and quantitative results, we present some design recommendations for the one-handed gesture.

Users prefer gestures that are simple and easy to associate, and user-defined gestures may have better semantics: There was some overlap between the inspiration from participants of stage 1 and the understanding of the stage 2 participants. For example, in stage 1, several participants who designed a pinching gesture for the "confirm" function explained that, ***"because it looks like ok"***. in stage 2, many participants said, ***"I think pinching looks like OK gesture and means confirmation"***. We found that participants can spontaneously and actively understand the semantics of the gesture to help them remember the mapping between gesture and function. Gestures with strong semantics were easier to remember and less likely to be confused between functions. There was a high degree of commonality in people's perception of semantics.

Less effort is not always better: The level of comfort is influenced by the user's experience and proficiency in using gestures. Good semantics help users remember and increase their willingness to use gestures. For frequently used functions, users prefer gestures with well-matched semantics and function, over effort-saving gestures. And good semantics can cover up the lack of effort-saving.

A typical example is the previous button function and the next button function. Apple proposed an extremely effortless solution of a simple finger pinch, but a large number of participants complained that the gesture was semantically weak and difficult to remember. Another similar example is the confirmation function, where participants felt that squeezing the finger saved effort, but clenching the fist was more consistent with the semantics of confirmation.

Shortcuts could be considered instead of a basic gestures combination interaction flow: In addition to the most basic gestures, users also need some gestures that correspond to the shortcuts function. This is because it is cumbersome for users to use several combinations of gestures to perform a commonly used function. Some participants mentioned, ***"For many scenarios, simple shortcuts can be useful, such as lock screen"***.

Avoid designing gestures that required repeated multiple times: We found that compared to touch screen interactions, one-handed gestures are a challenge for the user's memory. Because there are no visual cues to suggest how to operate. Of all the gestures evaluated in stage 2, users attach importance to the semantics of gestures because the good semantic means ***"easy to remember"***. However, "times" had no semantics and were therefore difficult to remember. In the "previous button" function, participants commented that a gesture with more than one action would be very problematic, ***"If I want to go forward to the fourth song, then I need to do eight pinches and that's too tiring"***. A gesture

that needs more than one action may result in too many repetitive actions in an interaction flow.

Gestures for "Continuous function": Some participants suggested, ***"I am tired of doing multiple gestures (such as selecting the last song in the list), I think it would be good to add a gesture for continuous "next button" function"***.

Transfer of experience: Consider transferring people's experience of using flat gestures on a phone or computer to one-handed gestures in the air. For example, participants mentioned ***"swiping the index finger outward, similar to going back to the previous page on the phone" and "opening the hand, similar to the gesture of opening an application with the MAC trackpad".***

Consider gender differences: Men and women may give different ratings about the level of effort cost of a gesture. Almost all male users think making a fist is a very effortless gesture, while some female users feel it is effortful.

6 LIMITATION

In this paper, all participants were young, under the age of 30. There may be differences in the understanding and preference of gestures among people of different ages. Therefore, in future work, we will consider participants with different ages e.g. participants aged 10-20, 30-50, and above 50.

The selection of appropriate and user-friendly shortcut functions is an issue worth exploring. The number of shortcut functions is often larger than the basic gestures, which can increase the user's memory burden. So developers should choose features that occur frequently and have relatively clear semantics. A negative example is the open Control Center function that we removed in stage 1. The meaning of this function is abstract, so people's understanding of the semantics is diverse. It is difficult to come up with a gesture that is universally understood by most users.

7 CONCLUSION

This paper presents a complete study and a complete analysis of one-handed gestures from generation to evaluation, combining user participatory design, qualitative methods, and quantitative methods. The main contributions of this paper are: 1. Demonstrating a new set of simpler and more user-friendly one-handed gestures. 2. Propose an experimental procedure, experimental prototype and scales to develop more user-friendly one-handed gestures. This process tests the semantics of gestures twice, increasing the possibility that the semantics of gestures will be understood by most users. 3. Gathering interesting user qualitative insights. 4. Extracting some design suggestions for future gesture design.

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