One-Handed Gesture Design for Browsing on Touch Phone

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Abstract. The goal of this research is to understand how dual-surface touch gesture helps user interact mobile phone with one hand from user experience perspective. Hence, we proposed a set of gestures and some design recommendations for enhancing the browsing usability. Finally we emulated the information seeking task on mobile phone. The results showed that, compare to traditional graphic user interface, browsing gestures eased the thumb fatigue, reduced the error rate and task completed time.

Keywords: one-handed interaction, dual-surface touch gesture, web browsing, touch phone.

1 Introduction

Smart phones have fulfilled the various multi-function needs of users, which require the showing of a large amount of information on limited screen space. 63% of the participants indicated that they are limited to two-handed operations due to the interface design, and that one-handed operation is preferred [1]. In the multi-mode research under a moving environment, it was found that users prefer to interact with phones using fingers or tilting plane motions [2]. Users tend to work with the convenience of different space using one-handed operation in order to leave the other hand free to hold other objects. Touch screens tend to have wilder displaying areas, but current touch interface designs of button space and positions have not put user experience into consideration. This often causes thumbs to operate back and forth when targets are too far away from the thumb, causing accumulated injury and fatigue. The single-thumb operation also eliminated the possibility and strength of multi-point touch screens, such as the intuitive motion of enlarging and zooming or rotating using two fingers. From the research background and questions, we found that the habit of one-handed holding and browsing the net under limited thumb movement range, error rate, and fatigue has caused unhappy user experience. However, users needs for mobile phone and desktop systems are differentiating, applying fixed internet application sequences directly onto mobile phones is outdated. Therefore, mobile phone interface design standards should be in accordance with user habits, mobility, and small displaying screens. The top three browsing behaviors of mobile web pages are: fact finding, information gathering, and browsing [3]. Researches pointed out that when users

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click on a target on the center of the screen, the thumb joint does not need to be bent under a big range, but is presented in a comfortable slanting plane position [4].

However, during experiments, users are prepared and tend to focus more on aiming at the button on the edge of the screen. This may cause experimental inaccuracy in longer task times and lower error rates [5]. The index finger presented fine touch performance on either side of the mobile phone, with a better result in horizontal shift than vertical. The thumb presented a generally less satisfactory result on the front side of the phone with an user expectation of the see-through effect on the reverse side [6]. Gestures are meaningful in our daily lives. They can be categorized into the following according to different movement forms: symbolic, indicative, metaphoric, rhythmic, and controlling. Amongst which the controlling gestures indicate constructing a closer relationship with the controlled object using hand movements [7].

2 Methods

In order to improve user experience of single-handed browsing tasks, new cooperating relationships between the thumb and four fingers on different touch screen surfaces are brought up. A balance needs to be achieved between gesture interactions and the physical restrain of single-handed operation. A set of assistive gestures are designed specifically for browsing functions and evaluated according to usability and objective index.

2.1 Selection of Browsing Commands

Five participants were recruited for this stage. Participants were target users between 20 and 25 years old who have at least 6 months of smart-phone experience and habits of browsing web-pages using touch phones in order to avoid the effect of familiarity on experiment performance. Users should also maintain a habit of browsing non-mobile version of web pages at least twice a day. The participants were asked to fill in their basic information, personal experience on multi-point touch screen products, and motives, frequency, and occasions for non-mobile version of web browsing. The experiment procedures were explained and participants were asked to adjust to a comfortable sitting position before starting. Participants were required to hold the mobile phone single-handedly with no time limit. After the experiment, the videotapes were examined and function numbers and user descriptions were charted for questionnaire design. Gestures were designed with reference to frequencies each function is used and selecting appropriate browsing functions. The experiment devices used were the phones used by the participants on a daily basis. Therefore, the existing mobile browsing function arrangement differences do not affect the various browsing functions used with high frequencies. Referring to the observing statistics of the browsing function clicking frequency, the average answering time for four questions is 750 seconds for the 5 participants with no fatigue.

The tab function in the observing chart could be categorized in more details into “open new tab”, “close tab”, and “tab tour” to be more conformed to the present browsing interface. The functions were then made into questionnaires and distributed to 20 participants to select the functions keys used with the highest frequency.

Intergrading frequency and importance, 7±2 items of the 5 gestures were found to match the human short-term memories [8]. These were taken to the next design stage of “back/next”, “zoom in/out”, “open new tab”, “close tab”, and “search”.

2.2 The Design of Browsing Hand-Gesture Samples

The size of the phone prototype is derived from the average size of the top 5 selling touch phones globally in 2011. The calculated average values were: 118.9mm x 62.1mm x10.4 mm, 138.4g in weight, and a 3.9 inch screen.

Six professionals with touch control hand gesture experience and more than 5 years of design experience were invited for a focus group discussion [9]. The host of the discussion was asked to avoid criticism and response directed towards concepts discussed. Related vocabulary was developed from the browsing functions selected in the first stage. Using the related adjectives, nouns, and verbs, the vocabulary was categorized into the portrait group, indication group, and the symbolizing group. The hand gesture design was then preceded. Six participants were invited to discuss using the Six-Three-Five thinking method, completing a design round every five minutes. Every five minutes, the participants pass the cards in their hands towards the right and so on, until their own cards are back in their hands. Participants can improve or use the design in their hands to produce various browsing hand gesture movement samples. This method is a combination of Brainstorming and the KJ card method. This ensures the communication of the completed design concept under limited language expression without being neglected during the verbal discussion of the focus group method. This also helps professionals to draw and present on the blank interface provided by the phone prototype using image mode, using speed to communicate design concepts and develop multi-interface design. Finally, according to the hand gesture design principles and finger movement restrictions mentioned in literature review, 5 hand gestures were selected from each function to enter the confusion matrix to evaluate hand gesture recognition level. During the selection of the final hand gesture samples, the cognitive confusion condition between various hand gestures and browsing commands were evaluated and improved. Considering the burden caused by the large sample during the matching of the conventional confusion matrix with the 25 hand gesture samples, Action Script 3.0 is used to write the experiment interface and the answers done on laptop computers. After the explaining of the experiment contents, participants were left to get used to the experiment application interface. Participants got to preview all the hand gesture images to ensure the understanding the meanings of all gestures, including clicking, sliding, pressing etc. Prototypes of the same ratio were given to participants for brainstorming. Thirty participants joined this stage of the experiment with only half of them experienced in touch-screen control. The experiment recorded the cognition time, error rate, and satisfaction rate of various hand gestures.

2.3 Browsing Gesture Usability Evaluation

The experiment system uses Arduino to control the touch panel and using Bluetooth to connect with Android phones as showing in diagram 3-8. The model web page interface was written by Flash ActionScript 3.0. The experiment phone was using the Android 4.0 system. The 2.8" TFT touch screen attached in the back was a 4-wire analog voltage control, allowing 4 GPIO to detect X and Y coordinates independently, used to identify gesture images or directions. According to the browsing hand gesture designed in the previous stage, the model web page browsing experiment procedure was planned. In the beginning of the experiment, participants were asked to sit comfortably to fill in their basic information and to listen to experiment details. Participants were also given enough time to familiarize the interface before starting. The experiment order of each group is random, with no time limit. Participants were asked to complete the objective questionnaire chart after all three groups are done.

The interface for the control group models the most popular Opera web browser [10]. Participants held the phone in two different ways (two-handed and single-handed) during operation. The browsing gesture interface for the control group does not include the assistive function tab, using single-handed touch control gestures to replace buttons. The browsing task and hand gesture performance under the three different models is compared. Twelve participants took part in this stage including 6 male and 6 female, all with touch phone internet browsing experiences, all right-handed with no hand injuries.

In order to model the finger movements of users during mobile phone browsing such as screen shifting and pointing-and-clicking links, participants were required to search on the screen to complete all valid target clicking. The target positions follow the Fitt's law to control the total shifting distance between targets. Fitt's law stated that the further the target distance the longer the shifting time, and the smaller the target, the longer the shifting time [11]. Upon selecting, the icons change color as feedback. There is no time limit for the experiment. The experiment tasks were designed with reference to the observation and calculation of the frequency of functions used during the first stage in order to be compatible with the actual browsing and hand gesture conditions. (1) The zoom in/out function: At the beginning, the icons were set to be 15 pixels. Participants were not able to recognize valid targets until they were zoomed in to the suitable size. The icons were able to be clicked on and the numbers accumulated anytime during the experiment. The error rate will be listed as part of the usability consideration as a reference for the browsing gesture system development and improvement. (2) The back/next function: Each tab represents a different icon, and each page shows 2 to 6 different targets randomly without repeating. Each tab includes 5 pages and 5 tabs include a total of 25 pages. Participants use the back/next gesture or click on the back/next function key to switch between pages. (3)The tab function: The system shows two random valid targets on the previous tab. Once more than three tabs are opened, participants need to close one tab before opening another one. (4) The search function: If users are lost or want to know their task progress, they are to click on the "search" button on the top right corner or use the "search" gesture. Therefore the participants will use the search function at least twice during the experiment. There are many ways to evaluate web browsing performances, such as recognition deduction, focus group, GOMS model, speed prototype, task analysis, interface investigation, and user tests [12, 13]. The index of learning possibility, recollection possibility, short-term memories, long-term memory load, and error and fatigue allowance were also objectively evaluated. Amongst which, task time and successful rate and user satisfaction are common interface design evaluation standards. These three indices have the same goal with the reaction time, error rate recognition, and confusion matrix in the laboratory regulations. Therefore the browsing gesture evaluation items for this experiment were set to be task time, error rate, NASA workload, and subjective assessment scales.

3 Results and Analysis

3.1 Browsing Gesture Sample Design

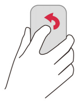
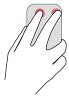
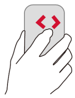
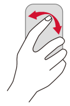
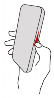
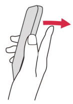
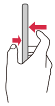
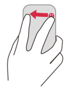
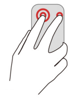
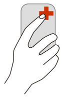
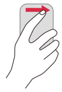
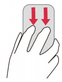
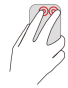
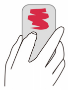
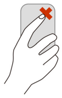
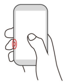
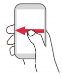
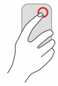
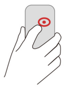
In this stage, six design professionals were invited for focus group discussions on the five functions derived from the observation and interview results from the first stage: back/next, zoom in/out, open new tab, close tab, and search. Adjective, noun, or verb association were done for the browsing functions and categorized into Table 1 for gesture design.

Table 1. Browsing function vocabulary association

	Portrait	Indicative	Metaphoric
Back/Next	cursor, back, skip	fork finger long/short (far/near), bottom left(back), top right(next), up(next), down(back), clicking frequency, arrow, direction	words, traffic lights
Zoom	magnifying class, balloon	distance between the index finger(far) and thumb(near), slanting angle, rotate, sound wave, forward and back dimensions, press/click, up to enlarge and down to shrink, compress	「+」 sign
New Tab	Homepage, home house, window	insert symbol, turn the page, flip up, divide, draw another circle, drag, pull page down, the feeling of paste, cut, check	plus sign, the number 2, N for new, H for home, A for add.
Close Tab	lock, seal, shut, close	trash can, throw, dump, cut, tear, completing a circle, period, shake, slide, invert, cover screen, outwards, flip away, eraser, cross out, paint	finish, 「×」 sign
Search	telescope, magnifying class	eye, fumble	S for search, Q for question, 「?」 sign

The 635 thinking method is used in stage 2 to design interface icon gestures. It is used to categorize a large amount of gesture interface in order to maintain the visibility of mobile phone reading. Movements require a big moving range such as those using arms will be excluded from the priority consideration list. Five feasible gestures were selected from each browsing function and redrawn on Table 2 using computers for the gesture recognition confusion matrix experiment in the following stage.

Table 2. Varies function gesture movement samples

Function	Gesture samples				
back/next	 1 portrait	 2 indicative	 3b portrait	 4 indicative	 5 indicative
zoom	 6 indicative	 7 indicative	 8 indicative	 9 indicative	 10 portrait
new tab	 11metaphoric	 12 indicative	 13 indicative	 14 metaphoric	 15 metaphoric
close tab	 16 indicative	 17 metaphoric	 18 portrait	 19 indicative	 20 metaphoric
search	 21 portrait	 22 metaphoric	 23 metaphoric	 24 metaphoric	 25 indicative

The results of confusion matrix refer to the confusion condition, recognition time, gesture satisfaction scores, and system recognition validity. The back/next gesture numbers 2 and 5 show no confusion, however, number 5 performed better in terms of time and satisfaction. The zoom gesture number 9 showed a lower confusion level than number 6 but similar user experience in terms of the zoom movement and touch-control in the back of the phone. Number 5 was chosen considering gripping stability of phone. The new tab gesture number 11 and the close tab gesture number 17 shared the same drawing shape in different angles (+and ×). The finger angles in the touch-control from the back of the phone were not as horizontal or vertical as the front, therefore was deleted due to system recognition difficulties. The search gesture number 23 was revised subtly, simplifying the question mark image into a hook shape for easier gesture recognition input. Browsing gestures number 5, 6, 14, 17, and 23 were selected.

3.2 Browsing Gesture Feasibility Evaluation

The original zoom function operated by moving the thumb up and down on the side of the phone was improved to be moving the index finger on touch-screen on the back of the phone considering the high-frequency requirement of the thumb in the front, the hardware limitation of the model system, and the original gesture design concept (Fig. 1).

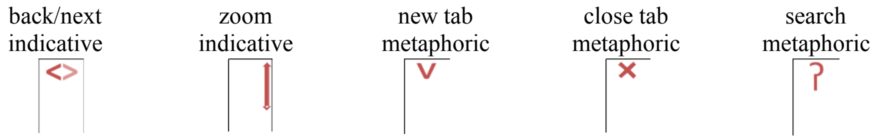


Fig. 1. Browsing gesture icon samples

The task completing time data of the three groups of operation models were analyzed using ANOVA. Under the condition of the test of homogeneity ($p>0.05$), this represents the reliability of the sample observation variance. A significant difference showed between the task completion time of the groups. In the post hoc analysis, a significant difference showed between the two-handed and the single-handed groups. There was no significant difference with either of the groups in gesture. The average task completion time for gesture was slightly lower than the single-handed group. Since the target size has an effect on the accuracy rate of the clicking, it was found from table 3 that there was no significant difference in size with any of the group during clicking. The main factor that affects the error rate should be the operation mode. The target clicking error data of the three operation modes were analyzed using ANOVA (Table 3) and significant difference shoed between the three gesture groups ($p<0.05$). In the post hoc analysis, there was a significant difference between the single-handed group and the gesture group. There was no significant difference between the two-handed group and either of the groups. The average error rate for the two-handed group was higher than the gesture group.

Table 3. ANOVA analysis result for the browsing gesture system

Item	S.S.	df	M.S.	F	Post Hoc
Task completion time	47256.72	2	23628.36	6.34*	Single-handed > two-handed, gesture
Target size	676.52	2	338.26	1.56	
Error rate	41.05	2	20.52	3.91*	Single-handed > gesture, two-handed

From the NASA workload scale ANOVA analysis results (Fig. 2), we found no significant difference in mental and physical strength used for task completion between the three groups ($p>0.05$). This shows no additional fatigue caused by gestures. The results match the analysis results for the operation mode subjective measurement scale. There was no significant difference in the wrist fatigue level between the three groups (p>0.05). From the average score we can see a lower level of haste and urgency when using two hands, with the highest time pressure felt by the gesture group. There was a positive relationship between the effort level, frustration, and gesture recognition rate. Integrating the above results, the browsing gesture input interface was less intuitive in operation performance than the conventional two-handed group, however showed a trend of better performance than the conventional single-handed group under situation simulation after learning. In terms of subjective evaluation, it scored better than the conventional groups, showing that the browsing gesture interface improves the operation feasibility of web page browsing.

The operation subjective scale ANOVA analysis results (Fig 3) showed significant difference between thumb fatigue, satisfaction, effort to use, effort to learn, and intuition. The post hoc analysis results show no significant difference between the usability of the single-handed and the gesture group. The gesture group showed a lower thumb fatigue level than the single-handed group.

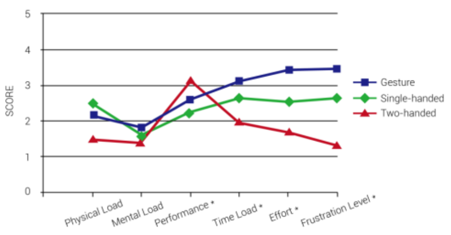


Fig. 2. NASA workload average score

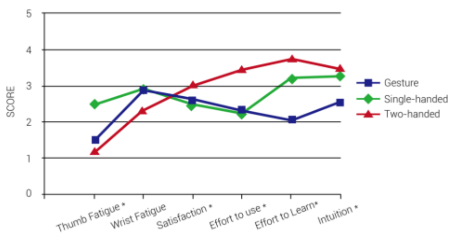


Fig. 3. Operation mode subjective average

As a whole, the lack of sensitivity of the gesture recognition of the system has resulted in a higher effort level and frustration. However, in terms of the objective performance items such as task time and error rate, the gesture group performed better than the single-handed group. In the future, the system hardware recognition rate needs to be improved in order to elevate user subjective satisfaction as a whole.

4 Discussion

The metaphoric "search" function in the non-confusion number 21 and 23 gestures each represents the "S" and the "?" symbol. Considering users with different language backgrounds and recognitions, the "?" symbol is able to lower the usability difference even more. Users prefer reversing the words and images in the back. This matches the "see through" expectation in literature review [6, 14].

When constructing the browsing simulation system, it is important to pay attention to the confusion compatibility between gesture icons. For example the × symbol may result in users starting the movement from different starting points. The system needs to be able to recognize that these are the same command. Due to the gripping posture, movements from top to bottom are easier than from bottom to top; horizontal finger movements are easier than vertical; however, strokes moving in the back tend to slant. This matches the information from literature review [15]. During the experiment, the two-handed group took the shortest time to complete the tasks. The single-handed group and the gesture group were limited by physical strains and took a longer task time. Amongst which the gesture group was slightly faster than the single-handed group. The gesture group is affected by recognition sensitivity. Users need to be trained and maintain the feel of the operation. This causes more obvious individual differences. Users who learned better showed a completion time close to the two-handed group.

During single-handed operation, the average clicking target size was 7.6mm, which matches the literature review [16, 17]. In error rate evaluation, although the single-handed and the gesture group both hold the phone with one hand and clicks with the thumb in the front, significant difference showed between the two groups. It is speculated to be caused by the thumb bending phenomena pointed out in the literature review [4, 18]. Since the mobile browsing function keys are often at the bottom of the screen, the thumb in the single-handed group has a bigger moving range on the screen and higher frequency of joint movement. These factors increase user fatigue and error rate. Although the users express doubts in the gripping stability, there was no significant difference between the wrist fatigue levels of the three groups. This shows no increase in the wrist load of users using the new gesture system. Other than that, during the experiment we found that the gesture group does not need to click on the function key at the bottom of the screen. Therefore, to match the touch control gesture from the back, users changed the gripping posture, moving thumbs closer to the center of the screen. This decreased the thumb moving distance and hence improved operation performance. The high error rate of the two-handed group resulted from touching invalid targets. This represented the actual situation of operating the zoom gesture but often touching wrong links while browsing websites.

Finally, from the subjective scale we can see that users think that the gesture group lowers thumb fatigue. However, low scores showed in categories of effort to learn, frustration, time load, and effort. These indexes are affected by the system recognition sensitivity. Users need to spend more time learning the "correct" gesture icons in order to avoid system confusion. If gesture icons were designed to be too similar, the system may recognize them as the same gesture, creating a low recognition rate, increasing user frustration. Although practice could improve on the feel of the operation, hardware system support should still be improved to lower the icon error rate.

5 Conclusion

This research begins with user experience, aims at improving operation performance with single-handed gripping mobile phones, developing a series of gestures to compare to conventional icon interfaces in order to work out gesture design principles and ways for improvement. There is no most correct or the best icon for various innovative gesture designs. We aim at lowering individual subjective differences from the most objective angle. From the observing stage, gesture design procedures, and the interface analysis results, we found the following phenomena: (1) The browsing function selected by the gesture system is able to fulfill the mobile web needs of users. (2)

The function type affects the gesture design development direction. (3) Browsing gesture lowers thumb fatigue level, error rate, and task completion time.

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