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An Ergonomic Study on Influence of Touch-screen Phone Size on Single-hand Operation Performance

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Abstract. Touch-screen smart phones have gradually occupied the market of traditional Qwerty Phones and become the mainstream products of mobile phone industry. However, few ergonomics research has been conducted on the touch screens of smart phones, while it has led to tendosynovitis among users owing to the overuse of thumbs. Sizes of smart phones in market range from 3.0 to 7.0 inches. What's more, 4.0 inches and above are the common size of current touch screens. Also, considering the users' habits, one-hand operation is preferred when the other hand is occupied. This paper has collected hand parameters of 80 subjects and has adopted an experiment which includes the performance testing and surveys of subjective evaluation by means of usability evaluation. After analysing correlation between touch-screen sizes and operation performances, the result indicates that under one-hand operation, the size of touch screen affects the operation performance significantly. However, it's hard to implement one-hand operation if the touch-screen size is over 5.7 inches. Additionally, the thickness of smart phones affects the degree of comfort remarkably.

1 Introduction

Nowadays, touch-screen technologies have been widely adopted in mobile phone industry and smart phones with touch screens have become the focus of commercial competitions among mobile phones manufacturers. The mobile phones sold in the market right now are mainly 4.0-sized and even larger ones. Research showed that the majority of users prefer to use phones' one-hand operation.

Many situations in daily life require users to handle with the cell phone on one hand, let's imagine that users standing in a bus or subway with only one hand left free when the other one has to hole the handrail to keep balanced. And if the users are holding a smart phone with a large screen, it will be rather difficult to operate, when fingers reach the untouchable area, the phone may just drop on the ground and resulting in property loss. In this situation, the large touch screen affects the user experience negatively [1].

However, the thumb is mostly likely to be used in the one-handed operation, while touching the screen, six muscles including adductor pollicis, flexor pollicis brevis, abductor pollicis brevis(APB), abductor pollicis longus, first dorsal interosseous(FDI) and extensor digitorum[2], are being used as shown in Figure 1. And these muscles get fatigue very fast on single-handed performance. Under this circumstance, most users will ignore the fatigue and keep on operating on their phones. Actually, the overuse of thumbs will cause health issues of users, such as tendosynovitis, in a slow process which cannot be observed easily.

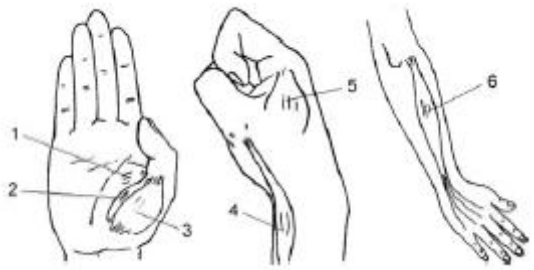

Figure 1. Six muscles being used in one-handed operation: 1. adductor pollicis 2. flexor pollicis brevis 3. abductor pollicis brevis 4. abductor pollicis longus 5. first dorsal interosseous 6. extensor digitorum.

Park and some other researchers, starting from the interface and operational usability, did some researches on the interrelationship of key position and one-hand operation performance. Oehl and others probed into the influence of screen sizes and difficulty levels of tasks on operation performances on small-screen devices. Besides, Perry analysed how operation performances are influenced by operational gestures on interfaces [3].

Nevertheless, according to the reference statistics in the ergonomics research area, most researches have been conducted to investigate the use of the thumb relating to the health issue. Up to now, there are few researches

about influence of mobile phone sizes on users' operation of touch-screen mobile phones. This paper firstly studies the mobile phone operation parameters collected from 80 college students, and makes analysis on mean parameter. Then, it designs some tasks for subjects to test their performance time and task completion rate. Also, their subjective evaluation results are collected through questionnaire. Finally, the paper made a research on the influence degrees of different parameters to each other based on correlation analysis.

2 Research method

2.1 Selection of subjects

80 test subjects (43 of them are males and 37 females) of this paper were selected randomly in Harbin Institute of Technology with the ages ranging from 18 to 27. All of these 80 selected students are physically healthy without any conditions on their hands and hands joints, and they were paid for the test.

After investigating their hands gestures of operation, we found that in one-hand operation, thumb was the finger most frequently used, and the functions of index finger, middle finger and little finger are to support or hold the phone. Therefore, in this paper, experiment collected the parameters about these three fingers, palm lengths and palm widths of the 80 test subjects.

The mean value of these parameters are as following (table 1): thumb (56.51±4.75mm), index finger (68.79±4. 54mm), middle finger (75.84±5.42mm), little finger (53.21±4.98mm), palm length (101.24±7.32mm), palm width (77.97±5.46mm). The K-S test for these 6 parameters through SPSS shows that all of them are within normal ranges (P>0.05).

Table 1. Mean value of selected fingers parameters.

Finger type	Mean value(mm)
Thumb	56.51±4.75
Index finger	68.79±4. 54
Middle finger	75.84±5.42
Little finger	53.21±4.98
Palm length	101.24±7.32
Palm width	77.97±5.46

2.2 Selection of mobile-phone samples

Table 2. List of mobile phone parameters.

	Length(mm)	Width(mm)	Thickness (mm)
Samsung C3300	96.3	53.8	12.9
Meizu M8	108	59	12
iPhone 4	115.2	58.6	9.3
Nokia X	115.5	63	10.4
iPhone 5S	123.8	58.6	7.6
Samsung S4 mini	124.6	61.3	8.94
Blackberry Z10	130	65.6	9
Nokia lumia1020	130.4	71.4	10.4
Samsung S4	136.6	69.8	7.9
Nokia lumia 930	137	71	9.8
Xiaomi Redrice	137	69	9.9
LG Nexus 5	137.84	69.17	8.59
iPhone 6	138.1	67	6.9
Blackberry Z3	140.7	72	9.4
Moto X	140.8	72.4	9.9
Moto G LTE	141.5	70.7	11
Samsung S5	142	72.5	8.1
Xiaomi 3	144	73.6	8.1
Xperia Z3	146	72	7.3
LG G3	146.3	74.6	8.9
HTC One M8	146.36	70.6	9.35
Samsung Grand2	146.8	75.3	8.9
Xperia Z2	149	73.3	8.2
Samsung note3	151.2	79.2	8.3
Samsung note4	153.5	78.6	8.5
HTC Desire 816	156.6	78.74	7.99
iPhone 6 plus	158.1	77.8	7.1
Moto X Pro	159.3	83	10.1
Moto Nexus 6	159.3	83	10.1
Samsung Mega 6.3	167.6	88	8

Considering that the phone brands selected should be popular among users, the experiment chose 10 best-

selling brands, including Samsung, iPhone, Blackberry, etc. To guarantee the diversity of the sizes of touch screens, the phones with largest, smallest and most welcomed touch screens have been selected in the experiment. While in some brands, the most welcomed sizes are the largest or smallest, the experiment has chosen the sizes between the largest and smallest ones.

In conclusion, 30 touch-screen mobile phones with differently branded are selected as test samples. The length of all samples ranges from 96.3mm to 167.6mm; the thickness ranges from 6.9mm to 12.9mm. Detailed parameters have been listed in the table 2.

2.3 Devising of performance tasks

Owing to different mobile phone brands and operation systems own various operation interfaces of phone calling and message. In order to eliminate influence caused by diverse interfaces, the test subjects are required to operate on WeChat app, considering the interface of WeChat is same on phones from different brands [4]. In addition, Sougou Input (QWERTY) is set up as unified input method [5].

In the performance test, the most often used postures like tapping, moving and typing are included. Detailed tasks are devised as following:

-**Tapping task**

In this task, the subjects are asked to open the "Setting" menu and switch "My account" status to "Protected" in the account protection menu.

Change the "WeChat ID" into "Human Factor" in the "Me" option.

-**Moving task**

The subjects are asked to find contact named "Mobile" in the "Contact" list, which requests the motion of moving.

-**Typing task**

Subjects are requested to open the chatting history with contact "Mobile".

Besides, subjects need to input the one hundred sentences given in the test introduction in the dialogue box.

In addition, the time cost as well as the completion rate to finish each task will be recorded in each task. And these records will be used for the following analysis.

2.4 Questionnaire of Subjective Evaluation

Subjective evaluation is a process that the sense organs, such as eyes, skin, and hands, collect information of objects. And these information are processed by brain, with subjective evaluation on the value of objects produced.

The method of subjective evaluation has been imposed on the automobile performance [6]. In the assessment, the professional users were asked to finish certain tasks, for example, driving the tested cars, maintaining the cars regularly. Then the users gave feedback of their experience.

In this experiment, the subjective evaluation is functional in form of questionnaire. The subjects are asked to mark the degrees of comfort, operation convenience and interface aesthetic these three elements of smart phone samples on the questionnaire. The grades rank from 1 to 5, in addition, 1 stands the lowest user experience while 5 does the best experience.

3 Data analysis

Work out the mean values of operation duration the subjects took and mean scores of subjective evaluation. Analyse all of these data with SPSS software and output the correlation analysis result.

3.1. Performance analysis

Table 3 indicates the correlation analysis results among touch-screen mobile phone sizes, completion rates and performance completion duration. Because the length and width of mobile phone are so linked to each other that their correlation reaches 0.954**（P=0.00）, which means there is an extremely close correlation between them and they can't be analysed separately but only to multiply two parameters and take the result (interface area size) as analytical parameter (the following correlation analysis adopted Spearman Correlation as analysing method).

Table 3. Correlations between size of mobile phone and task completion rate and performance time.

		Completion rate	Performance time
size	Pearson correlation	-.854**	.745**
	Significance (double face)	.000	.000
	N	30	30
Thickness	Pearson correlation	-.373*	-.391
	Significance (double face)	.043	.170
	N	30	30

The analysis result above shows that the correlation coefficient between completion rate and interface area size is -0.854**（P=0.000) which means the correlation between them is rather significant. However, the correlation coefficient between completion rate and thickness is only -0.373*（P=0.043) which indicates that the correlation between them is obscure.

The correlation coefficient between area size and performance is 0.745**, besides, correlation coefficient between mobile phone thickness and performance time is -0.391, which means area size has significant influence on performance duration and thickness has a limited impact on performance time.

To sum up, the completion rate and the time cost on each task are significantly affected by the area size of touch screens.

However, the influence of thickness on the completion rate and the performance time is limited and obscure.

3.2 Analysis of subjective evaluation

Table 4 demonstrates the results of influence of touch-screen sizes on operation convenience, comfort and aesthetic. The values of operation convenience, comfort and aesthetic ranges from 1 to 5.

Table 4. Correlation coefficient between size of mobile phone and operation convenience, comfort and appearance

		Operation convenience	comfort	Appearance
size	Pearson correlation	-.804**	-.408*	.237
	Significance (double face)	.000	.059	.208
	N	30	30	30
Thickness	Pearson correlation	.448*	.578*	.225
	Significance (double face)	.013	.081	.233
	N	30	30	30

It can be seen from table 4 that correlation between operation convenience and size is significant with the correlation coefficient of -0.804** (P=0.000); The correlation coefficient between thickness and operation convenience is 0.448* (P=0.013); The correlation coefficient between comfort and size is -0.408* (P=0.059), while the coefficient from degrees of comfort analysed with thickness possesses a value of 0.578* (P=0.081). However, there is no correlation between appearance and size or thickness.

In conclusion, the area sizes of touch screens affect the operation convenience more than degree of comfort, while it doesn't relates to the aesthetic degree of appearance; the thickness of smart phones influences the operation convenience, however, not so much as the area size does. Thickness also relates to the degree of comfort, of which extend is similar to the area size. Just as area size does, the thickness hardly influence the aesthetic degree of appearance.

Figure 2 is a curve reflecting correlation between operation convenience and area size produced by fitting interpolation method. From the curve line we can see that operation convenience decreases with the increase of area size, and when operation convenience reaches 3, the area size is 9547mm^2, which equals to the screen with 4.7 inches.

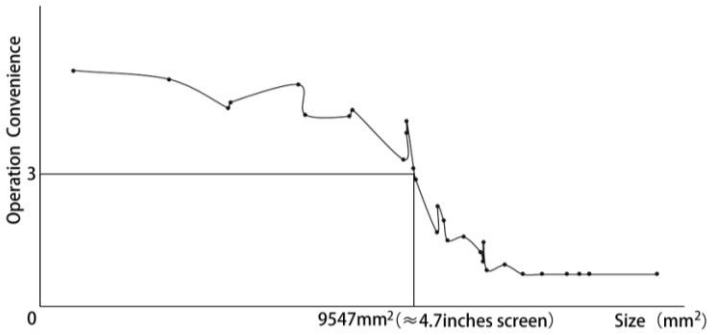

Figure 2. Curve of correlation between operation convenience and size.

4 Conclusion

The area size of touch screen has significant influence on operation performance, what's more, the complexity of one-hand operation increases along with the increase of area size. Especially, when the touch-screen size reaches to 150x80 which is actually around 5.7 inches, only 20% users can operate it with one hand.

The influence from the thickness of the mobile phone on performance is not significant.

The touch-screen area size has significant influence on operation convenience. In order to improve the convenience degree, the screen size of the mobile phone should not be larger than 4.7 inches, otherwise, it will bring obstacle.

The correlation between thickness of the mobile phone and comfort is significant, the thicker the mobile phone is, the more comfortable operation will be.

5 Retrospect and prospect

The ergonomics researches have done before were mostly about transportations like cars, planes [7]. And the motions being analysed are mainly large amplitude motion, such as driving, the action of firefighters [8]. As smart phones with touch screens become essential in our daily life, the health issue and the performance it brings cannot be neglected any more.

In this research, the experiment tests the performance including completion rate and time cost through tapping task, moving task and typing task. And the research concluded the correlation between area size of touch screens and the performance along with the subjective evaluation results.

However, the current researches mostly focus on finding ergonomic problems, while no solutions have been brought to eliminate or improve the certain parts of touch screens leading to unpleasant user experience. In the future research, hope the theory obtained from researches can be put into use of improvement to reach a completed closed-loop research.

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