Design and Evaluation of Innovative Chord Input for Mobile Phones

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Abstract. Text message is one of the most popular functions of mobile phones, apart from talking through the phone. This study focuses on how chord input is being used on mobile phones, as well as operating phones with chord input. We propose two new mobile phones: Tri-joint key and Four-corner key, which combines with the chord input and the natural finger localization. There were 14 male participants and 6 female participants that participated in this research; after 9 days of practice with the content of numerals, English characters and English phrases. The result shows the performances of the participants have increased, including the speed of completing tasks and accuracy. There is no significant difference between these two new styles of phones and the ordinary type concerning the user satisfaction chart. This also means users could accept new kinds of input devices.

Keywords: mobile phones, keyboard, chord input, input device, innovation.

1 Introduction

Mobile phones have been in our lives for the past decades, however the design of its buttons have barely changed. In terms of English alphabets, the 26 alphabets and other numerals have to be fitted into 12 buttons for input purposes. Therefore a button is used for the input of three or four alphabets by pressing the button multiple times. This input method is inefficient and causes burden on your muscle and bones. Different systems for different languages furthermore use different input methods on the buttons.

People want and need a bigger display screen. If the buttons occupy a big area of the mobile phone, then the size of the screen will be limited. Minimizing the buttons will cause inconvenience for input purposes. The need to increase its function and decrease its size of an electronic product will cause point of pain in the field of Ergonomics [1]. In terms of electronic products, the user interface can be divided into two types: GUI (Graphic User Interface) and SUI (Solid User Interface). SUI emphasizes on the importance of the control, signs, buttons and knobs; whether they fulfill the size, position, sense of sight, hearing and touch in Ergonomics. Due to the increased usage of mobile electronic products, and yet we are still using the traditional input

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keyboard. There are many keyboards that are defined this way; the size of the mobile cannot be decreased which in result is not suitable for mobile products. Using two of our hands on a keyboard has also further caused injury on one's finger, wrist and forearm [2].

Baumann and Thomas also pointed out that most electronic products require multi-functional purposes; the idea of one button for one function is not viable anymore [3]. This will lead to a large number of buttons occupying a large area of the interface, raising the production cost and increasing the burden of the user. The rate of error will also increase. The buttons of a mobile phone is an important factor influencing the control of the phone; if the phone is placed on the palm of the user, it will efficiently enhance the posture and increase stability.

Fitts' Law [4] is also an important law to refer to when designing buttons. This has been used as the standard of measuring accuracy and speed [5]. There were many scholars that used this Law to investigate the results of this influence [6][7][8][9][10][11]. Various results show the distance in between will influence the time it takes to key in and this is a very valuable principle that should be referred to when designing or evaluating keyboards. This is more relevant when the efficiency is the criterion that is investigated.

Chord keyboard integrates and lessens the buttons on the keyboard, thereby decreasing the movement of the user's hand. This will lessen the burden and improve working posture, ultimately lessen the harm accumulated through operating on the keyboard [2]. This study investigates the popular input device of modern mobile phones and proposes possible innovative designs for text and number input. The focus of the design will emphasize on integrating chord input onto the design of mobile phone buttons and combining natural finger positioning. The main purposes of the study are as follows:

1. Through literature review and discussions with professionals, propose new input methods for chord input mobile phones.
2. Study current user behavior of mobile phones and base it as the principles of the new mobile phone.
3. Produce prototypes of the new mobile phone chord input design.
4. Learning curve of users using the new chord input and input efficiency comparison.
5. Propose suggestions for mobile phone chord input design.

2 Method and Evaluation

This study consists mainly of three stages: observe current user behavior, design new conceptual product and verify the comparison experiment. The process will be supported by statistical analysis and user questionnaires and complete evaluation of results. In order to control the result of the experiment, the users are required to familiarize with the experiment equipments under a certain amount of time until they are under the same level of understanding with the equipment. In order to understand the psychological level of the users, continuous scale is used to undergo psychological choosing task. According to RPE (Rating of Perceived Exertion) proposed by Borg [12], using satisfaction estimation can evaluate the burden of the hand. As users are burdened when they are operating, the discomfort will increase accordingly.

2.1 Observation

Before the formal experiment, observation is made on the market and the natural holding posture of the hand; this is used as the reference of the new input design. The participants are 17 design-related students of undergraduate level or higher; 11 male and 6 female. No handicap on their hand and serious injury. Most of the participants are right-handed and have a long history of using mobile phones. The task is to input a paragraph consisting of 50 English words and 213 characters. Every alphabet occurs more than three times. After the inputting task, the subject fills in a subjective measurement that consists of performance estimation, comfort level and psychological satisfaction.

According to the observation results, the 17 users use both hands for support and their thumb for input. Three users use one hand for support and their thumb for input. One user uses one hand for support and the thumb of the other hand for input.

The result shows that most users like to use both hands for support and input via their thumb. Furthermore, in terms of using both hands for support, the four fingers behind the mobile phone can be categorized as three types: four fingers curled but not crossed, four crossed fingers and the forefinger locking the upper section of the mobile phone forming a “C” form.

Looking at the operation behavior of the available mobile phones, most users use their thumb for input because it has a higher mobility. The other four fingers are used for supporting the mobile phone. This will cause imbalance of the fingers and burden the thumb, causing muscle ache and sour muscles. While using chord input, it will increase the efficiency and the burden between the fingers.

2.2 Design Development

The first phase of the experiment observes existing mobile phone operation behaviors and designs eight different prototypes for different holding postures (Table 1).

Table 1. Eight different prototype models

1. 	2. 	3. 	4. 
5. 	6. 	7. 	8. 

The prototypes are designed for a right-handed person and divide the buttons as groups for the input of their five fingers. The burden of the muscles is divided onto all the fingers in accordance to the different fingers. The burden on the ring finger and pinkie is lessened. This is referenced from the previous study as the most efficient natural gesture and finger positioning [13].

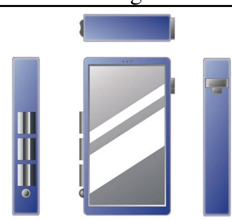
Evaluation of the holding posture and operation is made on the eight prototypes. A total of 10 participants consisting of 8 male and 2 female; all of them having an undergraduate level of education and more than three years of experience in using a mobile phone.

The highest scored prototype is number 1, a finer modeling is made on this prototype and design on the placement of the buttons is based on the position of the buttons on this prototype.

2.3 Evaluating Chord Input of Mobile Phones

According to the design principles of existing buttons, the numeral buttons are spread on the left hand-side of the mobile phone which is considered as grouped buttons. There are sub-buttons in grouped buttons; these buttons are operated by the four fingers other than the thumb. The function button is place on the right hand-side of the mobile phone that is operated by the thumb. The button itself has four sub-buttons that are used during input. Pressing different buttons will select different combinations to produce different numerals. Base on the above design, two prototypes are designed: Tri-joint and Four-corner (Table 2).

Table 2. Two designs of chord input for a mobile phone

Type	Three-view Drawing	Button placement
Tri-Joint		
Four-Corner		

Chord input is not applied in the input of numerals. In the input mode of English characters, the thumb operates on the function button and number buttons to select the characters desired through chord input. The alphabets use the placement of current mobile phones (Table 3).

Table 3. Corresponding chart of chord input

	1	2	3	4	5	6	7	8	9	0
A		a	d	g	j	m	p	t	w	
B		b	e	h	k	n	q	u	x	
C		c	f	i	l	o	r	v	y	
D							s		z	

2.4 Design Mockup

Tri-joint and Four-corner prototypes (Table 4), all sizes are referred from existing mobile phones. Length*width*height is 100mm*45mm*16mm.

Table 4. Information about two prototypes

Type	Prototype view and operating posture
Tri-joint	
Four-corner	

2.5 Participants

20 participants are chosen, aged between 20-30 years old. The average age is 25.05 years old. They consist of 14 male and 6 female, all having a higher educational degree of undergraduate level. All participants have more than 3 years of experience in using mobile phones and sending English text messages. There is not any hand injury at the time of participating in the experiment. They were willing to participate for the ten day course of the experiment.

2.6 Learning Sections

The formal experiment required the participants to input characters and numbers as part of their learning; which included numerals and English words and short sentences. The rate in which the numbers occurred is the same as the English characters. The experiment also recorded time and the error rate. The learning period of the experiment is nine days. All of the nine days included numeral input and English characters are added starting from the fourth day, and English short sentences are added on the seventh day.

2.7 Final Tasks

After all the participants have completed the learning stage and begins the formal experiment. They begin on two tasks: numeral and English characters input. The questions are displayed on the computer screen in the form of slides, each slide including 5 questions, each question including 5 words. Every task includes 3 slides. In terms of numerals, each question has five numbers, each slide has 5 questions and each number on a slide is displayed randomly. Each task includes five questions, which is 75 numbers. The English character includes 15 English words consisting of five characters, displayed on three slides and every alphabet will be displayed more than twice. Every mobile phone is tested first on numerals followed by English characters. In the formal experiment, the subject completes one usability questionnaire and evaluate according to the efficiency, physical comfort and psychological comfort of mobile phones. The numeral and English characters are discussed separately.

3 Result

The experiment measures the time taken and the number of errors occurred that are transformed to input speed (CPM) and accuracy (%) for further evaluation and analysis.

3.1 Results of Numeral Part in the Final Tasks

One can see from the figure that the fastest input rate is an ordinary mobile phone, 82.07 characters per minute. This is followed by Tri-joint of 66.73 characters per minute and lastly Four-corner of 51.43 characters per minute. The correctness is also the ordinary mobile phone leading the other two new mobile phones. The correctness of an ordinary mobile phone is 99.33% compared to Tri-joint's 98.07% and Four-corner's 97.33%. Compared with the achievement rate of the current mobile phones; Tri-joint can reach 81.31% of the current mobile phone's rate, Four-corner can reach 62.67% of the current mobile phone's rate. In terms of correctness, Tri-joint can reach 98.73% of current mobile phones and Four-corner reaching 97.99% (Table 5).

Table 5. Formal experiment numerals statistical numbers

	Group	Mean	SD	Achievement rate
Speed (CPM)	Tri-joint	66.73	16.00	81.31%
	Four-corner	51.43	9.26	62.67%
	normal mobile phone	82.07	19.46	
Accuracy (%)	Tri-joint	98.07	20.65	98.73%
	Four-corner	97.33	23.78	97.99%
	normal mobile phone	99.33	12.69	

The Homogeneity Tests before undergoing ANOVA analysis, the P value of numbers in terms of input speed and accuracy is 0.080 and 0.059 respectively, bother larger than 0.05. Therefore an ANOVA analysis is proceeded and the result shows significant differences between the three mobile phones both on the speed [F(2, 57) =19.539, P<0.001*] and the accuracy [F(2, 57) =5.322, P=0.008*<0.05].

Duncan multiple comparison tests is proceeded and the figure shows that the input speed cannot be grouped. In terms of accuracy, Tri-joint and Four-corner can be groped in the same category.

3.2 Results of English Characters Part in Final Tasks

The figures below shows that the current mobile phone has the fastest average input rate, 23.37 characters per minute. Tri-joint has the rate of 18.51 characters per minute and Four-corner has 16.78 characters per minute.

Table 6. Formal experiment English characters statistical numbers

	Group	Mean	SD	Achievement rate
Speed (CPM)	Tri-joint	18.51	3.06	79.2%
	Four-corner	16.78	3.10	71.8%
	normal mobile phone	23.37	9.46	
Accuracy (%)	Tri-joint	95.80	2.42	97.69%
	Four-corner	94.80	2.93	96.67%
	normal mobile phone	98.07	1.65	

The correctness of the current mobile phones leads the other two, being 98.07%. Tri-joint has a correctness rate of 95.8% and Four-corner being 94.8%. Compared with the achievement rate of the current mobile phones; Tri-joint can reach 79.2% of the current mobile phone's rate, Four-corner can reach 71.8% of the current mobile phone's rate. In terms of correctness, Tri-joint can reach 97.69% of current mobile phones and Four-corner reaching 96.67% (Table 6).

The Homogeneity tests before undergoing ANOVA analysis, The P value of English characters in terms of input speed and accuracy is 0.032 and 0.157 respectively, only the P value of accuracy larger than 0.05. Therefore an ANOVA analysis is proceeded and the result shows significant differences between the three mobile phones on the accuracy [F (2, 57) =9.808, P<0.001*].

Duncan multiple comparison test is proceeded and shows that in terms of accuracy, Tri-joint and Four-corner can be grouped in the same category.

3.3 Participants Satisfaction

Subjective Measurement will be divided as efficiency rating, physical comfort and usability satisfaction. There are seven, eight and five questions respectively. Each question is compared on the three mobile phones and a score is given on the continuous scale for the mobile phone. There is no numbers on the scale, only the length of the starting point to the end point. The length is 10cm and the length marked is measured afterwards. The score ranges from 0 to 10, calculated to one decimal point.

In the efficiency and comfort rating, all three mobile phones did not pass the Homogeneity tests, be it numerals or English characters. Therefore ANOVA analysis is not preceded. The usability satisfaction rating did pass the Homogeneity tests, the P value for numerals and English characters are respectively 0.1 and 0.133, both larger than 0.05. Therefore ANOVA analysis is preceded and the results shows that there are no significant differences between the three mobile phones in either numerals [$F(2, 12)=0.704$, $P=0.514>0.05$] or English characters [$F(2, 12) =1.753$, $P=0.215>0.05$].

4 Discussion

The learning stage is divided into three sections. The participants faces many mistakes when they tryout the new input device, whether it is the numerals or English alphabets. The participants with the best scores ended up as the best in the end. Although the one's with lower efficiency progressed but they did not surpass the participants with better results in the end. This can be concluded that the selection of the participantts did benefit this research. In the statistical numbers, Tri-joint is better than Four-corner in the final practice, whether it's the speed, accuracy or overall progress. However, in terms of the range of progress, Four-corner is better than Tri-joint on some aspects. This shows that Four-corner did not perform as well as Tri-joint yet there is a bigger space for progress. The numbers on numerals and English characters showed there are significant differences; meaning that learning has a remarkable effect on the users, except English short sentences, this can be speculated as the lack of practice.

The formal experiment shows significant differences on the current mobile phones both in the sense of efficiency and accuracy, they are both better than the chord input mobile phones. In terms of numerals and English characters both showed significant differences. Through the Duncan tests one can see that the ordinary mobile phones have better input speed than Tri-joint or Four-corner. Based on the result of the subjective measurement the problem is pointed out that Tri-joint mobile phone has the same placement as the current mobile phones. Therefore the participants can feel with their fingers during their input to find the corresponding buttons. This improved the input of English characters for Tri-joint mobile phones.

The subjective measurement is divided into two sections of numerals and English characters. It is focused on efficiency, comfort rating and usability satisfaction. No significant findings were made after the ANOVA analysis. This can be explained as the participants having no significant ratings on the efficiency, comfort rating and satisfaction rating of the three mobile phones; whether it is numerals or alphabets. In other words, the participants can input according to different devices. Furthermore, the participants expresses that the original input system is so deeply rooted in their minds so Tri-joint is better memorized than Four-corner. However, some participants expressed that Four-corner's placement is either top or bottom, left or right; it would be a better device in the long run. It is possible that it will be better than the three rows used in current mobile phones. The efficiency and comfort rating is not as good as current mobile phones because the prototypes differs from current mobile phones, causing operational difficulties. The lack of learning from the chord input also causes psychological burden on the users during their usage of this new input method.

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References

1. Hare, C.B.: Redefining user input on handheld devices. 3G Mobile Communication Technologies, 388–393 (2002)
2. Rose, M.J.: Keyboard operating posture and actuation force: Implications for muscle over-use. Appl. Ergon. 22(3), 198–203 (1991)
3. Baumann, K., Thomas, B.: User interface design for electronic appliances, London (2001)
4. Fitts, P.: The information capacity of the human motor system in controlling the amplitude of movement. J. Exper. Psychol. 47, 381–391 (1954)
5. Jagacinski, R.J., Repperger, D.W., Ward, S.L., Moran, M.S.: A test of Fitts' law with moving targets. Human Factors 22, 225–233 (1980)
6. Card, S.K., Moran, T.P., Newell, A.: The psychology of human-computer interaction. Erlbaum, Mahwah (1973)
7. Drury, C.G., Hoffmann, E.R.: A model for movement time on data-entry keyboards. Ergon. 35(2), 129–147 (1992)
8. Hoffmann, E.R.: Effective target tolerance in an inverted Fitts task. Ergonomics 38(4), 828–836 (1995)
9. Danion, F., Duarte, M., Grosjean, M.: Fitts' law in human standing: the effect of scaling. Neurosci. Letters 277, 131–133 (1999)
10. Sörensen, K.: Multi-objective optimization of mobile phone keymaps for typing messages using a word list. European Journal of Operational Research (2005)
11. Wu, F.G., Luo, S.: Performance Study on Touch-pens Size in Three Screen Tasks. Appl. Ergon. 37(2), 149–158 (2006)
12. Borg, G.: An introduction to Borg´s RPE-Scale. Movement Publications, New York (1985)
13. Eilam, Z.: Human engineering the one-handed keyboard. Appl. Ergon. 20, 225–229 (1989)