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Work Performance Comparison of Holding and Using Tablet

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***Abstract*—Tablet using is increasingly utilized in various working fields as a part of routine job. The interaction with tablet is usually handled as holding tablet with one hand while operating, dragging finger over the screen, by another hand. This study aims to study the working performance of four different posture conditions of using tablet. The using conditions are putting tablet on a table, holding tablet with flat hand, holding by thumb-extended with Thenar support, and holding as clipboard gripping posture. Consequently, each posture condition performance is measured by studying of radial dragging on the screen. Therefore, Steering law is applied. In addition, the fatigue occurring at lower arm, upper arm, wrist, and hand, which caused by holding a tablet for long period of time, is also considered and studied for its effect on work performance. In conclusion, the results from this study will be analyzed to express the best practice of tablet-using posture condition.**

***Index Terms*—Tablet, touch screen, steering law, fatigue**

I. Introduction

NOWADAYS, using of computer tablet is widely spread over not only for personal use but also for business. Globally, the demand of tablet is growing up year by year more than other computer device categories such as desktop PC and portable PC [1]. Many people all over the world are surfing their tablets as the entertainment gadget, listening to music, watching movie, playing game, etc. Human computer interaction (HCI) well described for this action. Therefore the producer designed to achieve a fit between the user, computer and task to reflect the performance [2]. Similarly, in term of service and manufacturing, the tablet also plays very important role as interface device to communicate within organization and to interact with a machine (in manufacturing use).

For service and manufacturing, the application of computer tablet is adapted in various areas. For example, in the warehouse of factory, tablet is used by staffs for checking the stock of their product and making order to production side. This application can smoothen of the work process in warehouse job, since the paper-based of document flow was applied in the past. In consequence, computer tablet is now being applied to many works because of its ability, mobility, and applicability. To study of the performance of using a computer tablet, 2 things are considered. The first is the task done on the tablet's screen. And, the second is the posture of using a computer tablet. The main task of using a computer tablet is that dragging on the screen. Dragging will be performed for measuring performance of using the tablet. Steering law is applied from Fitts' law [3] to measure performance. The guideline of International Standard (ISO 9241) - Ergonomics requirements for office work with visual display terminals in part 9 which specified for requirements for non-keyboard input devices also describe a performance test method for evaluating pointing task on computer interface by using Fitts' law to evaluate tapping task and using steering law to evaluate dragging task [3]. Steering law is a theory which relate to the relationship between movement time and Index of difficulty (ID) on human computer interaction. ID = $\log_2 (A+W)/W$ (see Fig. 1) is formulated as a target when conduct the activity of pointing task according to the condition as doing fast as possible and no out of path. Many studies concerned steering law such as comparison the difference of starting point of task [4] and the difference of input device usage [5].

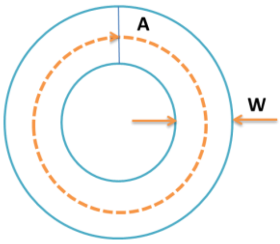

Fig. 1. Pointing task for circular dragging; A=Target amplitude, W=Target width.

While using a computer tablet, the most popular posture is that holding the tablet in one hand and let another hand to do the task as shown in Fig. 2. Certainly, this posture will lead the physical fatigue if the using period is long. This fatigue may result as injury of muscle and work performance. The ergonomics of holding computer tablet is therefore important that will affect to physical health of tablet users and also the performance of work.

Generally, the postures that usually applied for holding a computer tablet are Flat hand (FH), Thumb extended with Thenar support (TE), Clipboard grip (CB) which are demonstrated as Fig. 2. There is the study to investigate the role of the stabilizing hand, wrist, and forearm when using a multi-touch tablet by conducting the Flat hand and Thumb extended [6]. In addition, the tablet holding in clipboard grip by existing of lower arm support is suggested [7]. Using

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tablet was performed not only holding by hand but also putting on the table according to the condition of work.

Fig. 2. Tablet holding posture; Clipboard grip-CB (left), Flat hand-FH (middle) and Thumb Extended with Thenar Support-TE (right)

By studying of tasks and various postures of using tablet, the proper posture of using tablet could be determined. This is to optimize the most appropriate posture with the performance efficiently of doing the task on touch screen of a computer tablet for both short and long period of using time. In order to doing the task on touch screen is precise and rapid movement, the input device is also important to use properly with the right task. The input devices of touch screen by finger and digital pen were chosen to conduct in this experiment as a factor with tablet holding posture which can be affected the performance together.

II. METHODOLOGY

A. Task

The pointing task of this experiment which is measured the performance of user between human computer interface is circular dragging. We define the subject to do as the shortest lead time and the correctness of path (not out of path). The input devices are touch screen by finger and digital pen. There are totally four conditions which cross between the pointing task and the input device

B. Subjects

Seven subjects participated in the experiment. The aged is 18 to 35. All participants are healthy and no pain on hand, arm and upper arm. Normal sight or allowed to wear the glasses/ contact lenses for the abnormal one. The strength of body is normal that is not athlete. All participants are used to touch screen computing device on a daily and had an experience at least one year.

C. Apparatus

The tablet and digital pen was completed using Thinkpad tablet 2 with a 10.1 inch capacitive touch screen display and the full Windows 8 Pro operating system installed. The dimension is 10.3 x 6.5 x .39 inches and 600 gram of weight. Tablet comes with a digital pen which has a button that can be used to select options.

D. Design

In this experiment, the independent variable is the movement time which affected by the several of Index of difficulty as Table I. The main dependent variable that is significant for this research is tablet holding posture with one hand while using with another hand. Moreover the period of time to conduct the defined pointing task (short time ~10 mins. and long time ~30 mins.) and the input devices (finger and digital pen) are the factor of this experiment.

TABLE I
TARGET AMPLITUDE AND WIDTH USED FOR THE SEVEN LEVELS OF INDEX OF DIFFICULTY.

Width (W)	100	200	200
Amplitude (A)	80	80	30
ID	3.14	4.06	5.42

E. Procedure

The subjects are firstly briefed for the designated experiment. All of tasks conducted in this study are explained and demonstrated to subjects. The subjects are allowed to practice for 5 minutes prior to starting of experiment.

Thereafter, each subject perform 2 sets of experiment separated by posture of using a computer tablet; put tablet on the table (TB), Clipboard grip (CB), Flat hand (FH) and Thumb extended with Thenar support (TE) randomly.

In each posture, it consists of 2 patterns of workload which lead to the different of holding time affect to the fatigue stages (except "Put tablet on the table"); hold tablet while conducting the pointing task in short time (~10 mins.) and long time (~30 mins.).

In a stage, there are 6 experiments conducted. The matrix of 2 tasks (dragging by finger and dragging by digital pen) crossing with 3 Indexes of Difficulty (IDs) are created for recording the results of 1 pattern of workload.

In summary, the results consist of:

7 Subjects (participants) ×
4 Postures of using tablet ∈ {TB, CB, FH, TE} ×
2 Workload ∈ {Short time (~10 mins.), Long time* (~30 mins.)} ×
2 tasks ∈ {Dragging by finger, Dragging by digital pen} ×
3 IDs ×
= 294 trials*

(*Only one workload; No "Long time (~30 mins.)" for the posture of "Put tablet on the table (TB)")

After all experiments are finished, the results are collected and analyzed consequentially

III. RESULT

The results are presented as 2 mains of pointing task which are dragging by finger and digital pen. Performance of pointing task is determined as a relationship between Movement Time of pointing task (MT) and Index of Difficulty (ID). The standard deviations of MT are also analyzed for studying the steadiness of that pointing task.

A. Dragging by finger

The results of analyzed linear regression models and IP values for dragging by finger are shown in Table II. The linear regression equation (Y=bX+a) of each posture is determined which R-Square value is more than 0.98 for all postures and conditions. Steering Law models with all postures and conditions of dragging by finger are good ($R^2 \geq 0.98$).

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TABLE II
RESULTS OF LINEAR REGRESSION EQUATION, R-SQUARE (R^2) AND INDEX OF PERFORMANCE (IP) FOR DRAGGING BY FINGER AND DIGITAL PEN WHICH COMPARING BETWEEN SHORT TIME (~10 MINS.) AND LONG TIME (~30 MINS.)

Input device	Posture	Holding for short time (~10 mins)			Holding for long time (~30 mins)		
		Linear Regression Y = bX + a	R^2	IP=1/b	Linear Regression Y = bX + a	R^2	IP=1/b
Finger	Put on the table (TB)	y = 813.52x - 1271.4	0.99	0.00123	-	-	-
	Clipboard (CB)	y = 949.98x - 1803.6	0.99	0.00105	y = 894.54x - 1673.3	0.98	0.00112
	Flat hand (FH)	y = 845.48x - 1459.7	0.99	0.00118	y = 940.13x - 1649.8	0.99	0.00106
	Thumb Extended with Thenar Support (TE)	y = 696.81x - 1061.7	0.98	0.00144	y = 650.17x - 810.79	0.99	0.00154
Digital pen	Put on the table (TB)	y = 923.47x - 1624.8	0.99	0.00108	-	-	-
	Clipboard (CB)	y = 983.98x - 1960.6	0.99	0.00102	y = 972.89x - 1961.8	0.99	0.00103
	Flat hand (FH)	y = 892.16x - 1633.3	0.98	0.00112	y = 1157.3x - 2472.4	0.98	0.00086
	Thumb Extended with Thenar Support (TE)	y = 826.77x - 1506.2	0.99	0.00121	y = 789.21x - 1390.9	0.99	0.00127

As Table II illustrated, it is showing the relationship between the mean movement time and the Index of Difficulty (ID) as performed dragging task by finger for short time (~10 mins.) and long time (~30 mins.). The Index of Performance (IP, defined as 1/b) of TE is highest among the studied postures. Moreover, the Mean Movement Time (Y-interception, defined as a) of TE is also lowest. These results mean that TE is the most effective posture while TB, CB, and FH return the likely results to each other for short time tablet usage as displayed in Table II. Meanwhile, for long time tablet using, with three different holding postures, TE gives higher IP than CB and FH, respectively.

TABLE III
COMPARISON OF MEAN STANDARD DEVIATION FOR DRAGGING BY FINGER BETWEEN HOLDING FOR SHORT TIME AND LONG TIME

Posture	Index of Difficulty (ID)	Mean Standard deviation (SD)		ΔSD (ΔSD= SD'-SD)	SD trend
		SD Holding for short time (~10 mins)	SD' Holding for long time (~30 mins)		
Put on the table (TB)	3.14	296.08	-	-	-
	4.06	416.65	-	-	-
	5.42	596.07	-	-	-
Clipboard (CB)	3.14	294.24	331.97	37.73	Increase
	4.06	309.25	396.19	86.94	Increase
	5.42	948.03	991.52	43.49	Increase
Flat hand (FH)	3.14	231.17	315.17	84.01	Increase
	4.06	450.09	468.56	18.47	Increase
	5.42	575.92	750.99	175.07	Increase
Thumb Extended with Thenar Support (TE)	3.14	216.03	326.80	110.77	Increase
	4.06	207.48	311.57	104.09	Increase
	5.42	562.98	568.90	5.92	Increase

From Table III, this study collected the movement times of doing task (dragging) in specified condition. The results show the similarity among the studies over various postures and IDs. The longer period of holding a tablet leads the higher value of Standard Deviation (SD). It means that the accuracy of doing task is dropped as the tablet is held for longer period. This is the effect of fatigue that results in the deviation of moving time when doing task (dragging).

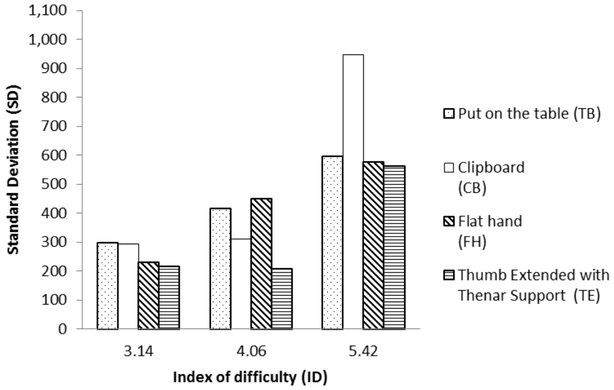

Fig. 3. Pointing task for drag by finger while holding for short time (~10 mins)

As shown in Fig. 3, the graph delivers the deviation of movement time used to do the task versus various IDs. It is found that Thumb Extended with Thenar Support (TE) is the most precise posture as the lowest value of SD is come out along increasing of ID. Nevertheless, the results of doing the task by put the tablet on the table do not show the better performance over any other postures.

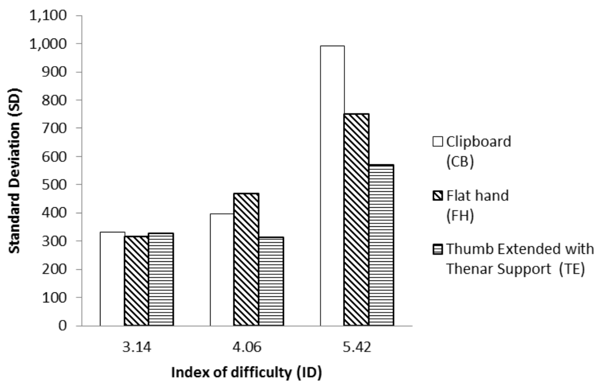

Fig. 4. Pointing task for drag by finger while holding for long time (~30 mins)

Fig. 4 is illustrating the results of doing task while holding the tablet for long. It is shown that the SD of Flat hand (FH) posture is smallest at ID of 3.14, while, Thumb Extended with Thenar Support (TE) results the smallest SD at ID of 5.42. This is showing that the posture TE is the most precise posture even the tablet is held for short (~10 mins.) or long time (~30 mins).

B. *Dragging by digital pen*

The results of performed dragging task by digital pen for short time (~10 mins.) and long time (~30 mins.) as Table II with all postures and conditions are also alike dragging task by finger that TE has the highest IP and the lowest Movement Time. R-Square value of the analyzed linear regression is more than 0.98 for dragging by digital pen which are essential for application of Steering Law model.

TABLE IV

COMPARISON OF MEAN STANDARD DEVIATION FOR DRAGGING BY DIGITAL PEN BETWEEN HOLDING FOR SHORT TIME AND LONG TIME

Posture	Index of Difficulty (ID)	Mean Standard deviation (SD)		ΔSD (ΔSD= SD'-SD)	SD trend
		SD Holding for short time (~10 mins)	SD' Holding for long time (~30 mins)		
Put on the table (TB)	3.14	336.26	-	-	-
	4.06	337.45	-	-	-
	5.42	594.37	-	-	-
Clipboard (CB)	3.14	299.53	354.88	55.35	Increase
	4.06	347.26	482.15	134.89	Increase
	5.42	984.64	952.39	-32.26	Decrease
Flat hand (FH)	3.14	302.41	331.81	29.40	Increase
	4.06	439.29	375.55	-63.74	Decrease
	5.42	524.38	1,021.39	497.01	Increase
Thumb Extended with Thenar Support (TE)	3.14	216.65	223.39	6.74	Increase
	4.06	270.11	310.53	40.42	Increase
	5.42	557.49	618.20	60.71	Increase

From Table IV, the results are showing that the using of Digital pen leads the SD of this result to be larger when the duration of holding tablet is longer.

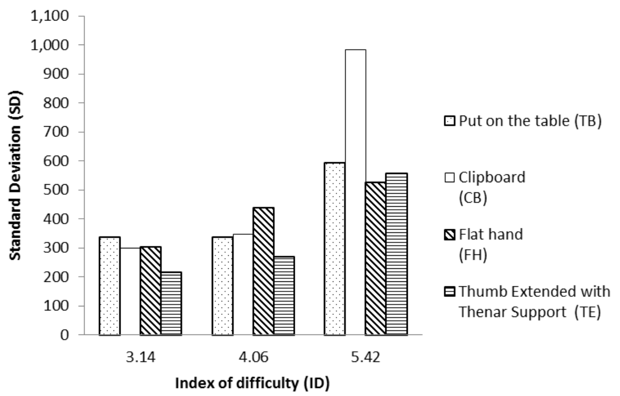

Fig. 5. Pointing task for drag by digital pen while holding for long time (~10 mins)

From Fig. 5, it is found that Thumb Extended with Thenar Support (TE) for short time (~10 mins) has the smallest deviation (SD) for ID of 3.14. This means this TE posture is the most stable posture. However, the results of doing the task by put the tablet on the table do not show the better performance over other postures.

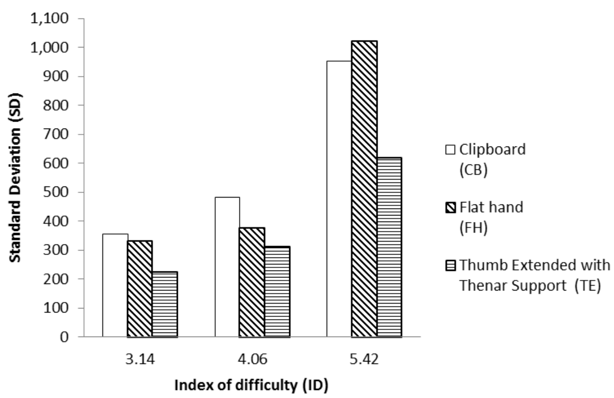

Fig. 6. Pointing task for drag by digital pen while holding for long time (~30 mins)

As shown in Fig. 6, Thumb Extended with Thenar Support (TE) also delivers the smallest SD value even the tablet is held for long time (30 mins). This result is similar for ID of 3.14 and ID 5.42.

IV. Discussion and Conclusion

From this study, it has found 4 main conclusions.

First, Thumb Extended with Thenar Support (TE) is the highest posture stability which implies the highest of data Index of Performance and the smallest of data deviation. This high stability comes from the position of a thumb and fingers of TE can tightly hold a tablet. And, TE also provides the proper display position for user. Meanwhile, Clipboard Grip (CB) is not flexible enough for user to adjust a tablet's position. For the Flat Hand (FH), the holding stability is not so good. So, the SD of FH is a bit larger than TE. Therefore, Thumb Extended with Thenar Support (TE) is recommended for using a computer tablet as its stability and performance on both short-holding (~10 mins) and long-holding (~30 mins). Despite this posture has several advantages in terms of wrist positioning, it requires strength to support digit opposition [6].

Second, using tablet on the table does not show the better performance over other postures as initial stage of work load which is not any fatigue concerned.

Next, for all SD trends which are compared between short-holding (~10 mins) and long-holding (~30 mins), the data of long-holding disperse increasingly due to the accumulation of fatigue from long-holding and difficulty to control the stability.

Finally, the input devices were applied for dragging task which also were compared of mean IP for all postures and conditions. Using finger is higher than using digital pen, mean IP_{finger} 0.00122 > mean $IP_{digital}$ pen 0.00111 (short time tablet using) and mean IP_{finger} 0.00124 > mean $IP_{digital}$ pen 0.00105 (long time tablet using). Furthermore, standard deviation of conducting pointing task by finger leads more stable of movement time than by digital pen. Although the deviation trends of finger task and digital pen task are in the same direction, as SD is increasing after long-holding of tablet, the deviation of digital pen task is averagely bigger. Nevertheless, IP of finger task is also greater than digital pen task. This can be concluded that conducting pointing task (dragging) by finger is providing greater performance than conducting by digital pen for both efficiency term (IP) and accuracy term (SD).

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REFERENCES

[1] Bob, D., Michael, S., and Ryan, R. (2012) Worldwide smart connected device market [Online]. Available: http://www.idc.com/getdoc.jsp?containerId=prUS23849612

[2] Dov, T., Jane, C., and Ping, Z., *Human computer interaction: developing effective organizational information systems* (Book style). United States of America, 2007, pp. 7.

[3] Scott, M. Fitts' law as a research and design tool in human-computer interaction. Human-Computer Interaction 7 (1992): 91-139.

[4] Xiaolei, Z., Xiangshi, R., and Yue, H., "Effects of start position on human performance in steering tasks" Paper presented at International Conference on Computer Science and Software Engineering, pp. 1098-1101, 2008.

[5] Cockburn, A., D. Ahlstrom, and C.Gutwin. "Understanding performance in touch selections: tap, drag and radial pointing drag with finger, stylus and mouse," International Journal of Human-Computer Studies 70 (2012), pp. 218-233.

[6] David, J., and Han, Z., "Holding a multi-touch tablet with one hand: 3D modeling and visualization of hand and wrist postures," Human factor and ergonomics society 56 (August 2013), pp. 1109-1113.

[7] Carolina, Z., Vicki, A., and Bonnie, K., "Human Factors Guidance for the Use of Handheld, Portable, and Wearable Computing Devices," Virginia: National Technical Information Service, 2005.