Usability Study on the Use of Eye Mouse Based on All the Functions of Conventional Mouse

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Eye mouse is an input device which uses a person's gaze and eye movements as input to operate a mouse cursor by using the eye tracking technology. Eye mouse is an input device which can reflect cognitive intentions of a user immediately from a user's eye(s). In this study, the functions of eye mouse, such as click, double-click, drag and scroll, was investigated and evaluated by supposing real computer interaction situation. In this study, usability of the different operation methods of eye mouse which correspond to the functions of conventional mouse was investigated and evaluated. The experimental result showed that there was performance difference between the different operation methods of eye mouse. The questionnaire result also showed that there was satisfaction difference between the different operation methods of eye mouse. The result of this study made us know what is the pros and cons about usability on the use of eye mouse. The result of this study can help to comprehend interfaces for eye mouse, and can contribute to the establishment of guidelines for development in interface design and operation methods for eye mouse.

Keywords: *human computer interaction (HCI), usability evaluation, eye tracking mouse, eye mouse, input device*

***Journal of Cognitive Science* 18-2: 153-173, 2017**
Date submitted: 05/08/17 Date reviewed: 05/21/17
Date confirmed for publication: 06/11/17

1. Introduction

Mouse and keyboard are typical and the most used input devices on the use of a computer. But there are also many other input devices on the computer interaction. Eye mouse so called eye tracking mouse is one of them. Eye mouse is an input device which is operated by a person's eye(s). The most remarkable feature of eye mouse is that it only uses a person's eye(s) to operate cursor. Eyes do an important role identifying person's cognitive process (Just and Carpenter, 1976). Because of this reason, naturalness of the use of eye mouse have been discussed before and eye mouse have been focused on as a promising input device. In the perspective of accessibility and universal design (Iwarsson and Ståhl, 2003), eye mouse can be a useful input device. Actually, eye mouse is superior to conventional mouse on the naturalness and the speed of cursor movement (Bednarik, Gowases and Tukiainen, 2009; Vertegaal, 2008). Eye mouse have been considered as a useful alternative input device for the people who have disability on their body (Bates and Istance, 2003), because of its characteristic of which gaze and eye movements are only needed to cursor operation.

Input methods of click, double-click, drag, and scroll by mouse are one of the most important input methods in the graphic user interface (GUI) of computer. Eye mouse is composed of eye detection device and specific software. Not only hardware but also appropriate software is needed to use eye mouse. Default input function of eye mouse is left-click. However, all the functions of conventional mouse such as click, double-click, drag and scroll can be performed using by functions of eye mouse's software. But there are a few differences about input methods to activate the functions, depending on eye mouse's software.

In this study, usability on the use of eye mouse based on the functions of click, double-click, drag and scroll was investigated and evaluated. This study investigated and evaluated usability on the functions of eye mouse by supposing real computer interaction situation. A function of mouse can be operated by different ways. Usability is important in the user interfaces. Minimizing a user's efforts for task performance is crucial on the user interfaces (Cockburn et al., 2007). Therefore, understanding which input operation methods by eye mouse are appropriate to each function of mouse will be help to gaze-based interface design.

2. Previous Works

Although eye mouse have been considered as a promising input device and a useful alternative input device, there are many problems on the use of eye mouse such as accuracy of eye tracking technology, fatigue of eyes following long time use of eye mouse and expensive price of hardware and software (Jacob, 1995; Jacob, 1993; Jacob, 1991). So, eye mouse is commercialized but is not generalized. Because of this reason, studies on eye mouse relatively have not been conducted than other input devices (Jacob, 1993).

Previous usability studies on eye mouse have been usually focused on the function of left-click (Kim et al., 2016a; Yeoh, Lutteroth and Weber, 2015; Schneider et al., 2008; Zhang and MacKenzie, 2007; Murata, 2006; Kim et al., 2003; Miyoshi and Murata, 2001; Sibert and Jacob, 2000; Ware and Mikaelian, 1987). Eye mouse has two methods for click – one is blink and another is dwell. Although eye mouse has two methods, most of the experiments were done only by dwell method (Schneider et al., 2008; Zhang and MacKenzie, 2007; Murata, 2006; Miyoshi and Murata, 2001; Sibert and Jacob, 2000; Ware and Mikaelian, 1987). Blink method, however, is a better method than dwell method except some situations (Kim et al., 2016a).

Of course, usability studies on eye mouse about double-click (Porta, Ravarelli and Spagnoli, 2010), drag (Kim et al., 2016b; Bates and Istance, 2003), and scroll (Kumar and Winograd, 2007) also exist. However, it is not sufficient to fully understand of eye mouse interfaces. Especially, most of the studies on eye mouse do not consider all aspects of usability. Although usability includes efficiency, effectiveness, and satisfaction (ISO, 1998), previous usability studies on eye mouse have been usually focused on efficiency and effectiveness. Therefore, in this study, we investigated and evaluated usability on eye mouse, considering all the aspects of usability. In this study, we investigated and evaluated usability on the functions of click, double-click, drag, and scroll of eye mouse, supposing a context in which different functions of mouse were sequentially needed.

3. Method

3.1 Prticipants

17 male and 10 female – all 27 paid volunteer participants - were recruited from the Seoul National University. Their ages ranged from 22 to 34 years (mean age of 26). They had normal vision or corrected visual acuity.

Participants did not have disability (Bednarik, Gowases and Tukiainen, 2009; Vertegaal, 2008). However, head movements of them were restricted during the experiment by using a head-fixed to enhance accuracy of the use of eye mouse (Zhang and MacKenzie, 2007). All of them were used to conventional mouse, but they did not have any experiences of the use of eye mouse (Murata, 2006).

3.2 Apparatus and Software

A laptop computer with 14 inch LG Electronics LCD screen, the resolution of 1920x1080 was used. The Window version 8.1 was installed.

Eye mouse was equipped with the laptop computer Eye mouse was placed at the bottom of the screen and as close as possible to the display. Eye mouse used in the experiment was TM5 mini of which size is 29x3x2.5cm from EyeTech Digital Systems Company (Figure 1). TM5 mini have infrared sensor and camera. There are two tracking indicators in the front of the eye mouse to detect a user’s eye movements.

The software of eye mouse used in this experiment was Quick Access, version of 1.6.2.27 from EyeTech Digital Systems Company. Basic layout was used as a UI mode of Quick Access. Pop-up menu about the functions of mouse was placed at the left side on the display and pop-up menu about the functions of size activation about window was placed at the right-up side on the display. The experiment was conducted with blink method. Blink time was 0.3 second and blink+ for double-click time was 0.9 second. The auditory feedback was offered to participants when click by eye mouse was activated.

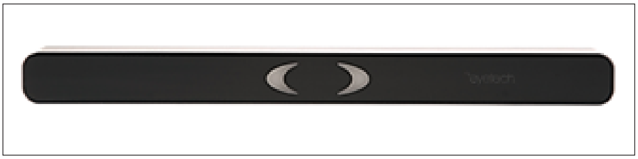

Figure 1. Eye mouse used in the experiment (Eyetech, 2016)

3.3 Experimental Environment

The table used in this experiment was a 730 mm height table (Shieh and Lee, 2007). The chair used in this experiment could be adjusted in a comfortable position depending on participants. Viewing distance was approximately 550mm. The angle of the display was 105° for the vertical axis (Lin et al., 2011; Lin et al., 2008). Experimental environment was controlled.

3.4 Experimental Design

In this study, the experiment was conducted with blink method based on the previous work (Kim et al., 2016a).

The experiment was conducted in within-subject design. After explained the experiment by an experimenter, participants conducted calibration process using a standard 16 points calibration function of Quick Access. Calibration process was repeated until standard level showed. Calibration process was also conducted during the experiment if sitting position of participants was changed to maintain accuracy consistently (Zhang and MacKenzie, 2007) and if participants wanted calibration process. Participants who failed the standard level of calibration were excluded (Bates and Howell, 2003) to control the deviation of calibration accuracy.

Icon and folders on the display were arranged as foursquare (Nakayama and Katsukura, 2007). Distance between each icon and folder was horizontally and vertically same (Sibert and Jacob, 2000). So, the icon and folder could be classified as four groups by the distance from the middle point, location 8 (Figure 2). A pdf file was placed at location 2 and a wastebasket folder was placed at location 3. At the other locations, normal folders were placed. Size of the targets was same, 0.94(W) x 0.89(H) cm. Visual angle of the targets was 1.67°. Starting point of a cursor in the experiment was at location 8, the middle of the display.

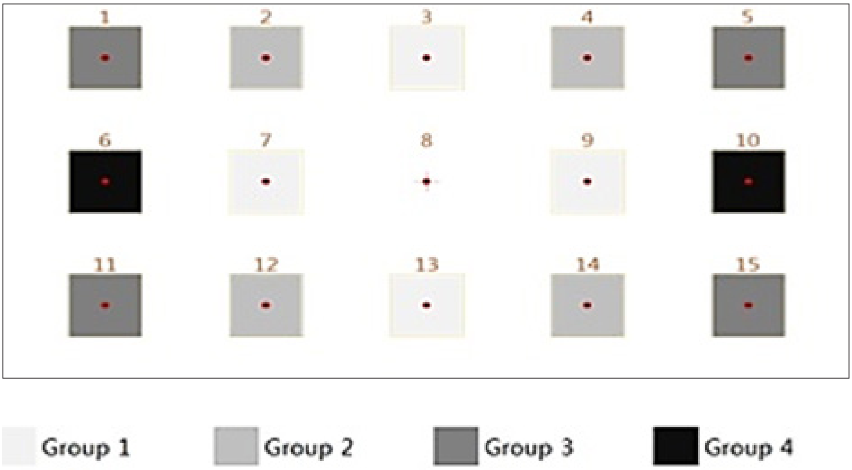

Figure 2. Arrangement of the computer display

3.4.1. Variable

The independent variables are functions of mouse and input methods of eye mouse. The tasks in the experiment consisted of four functions - click, double-click, drag, and scroll by mouse. Usability on click, double-click, drag, and scroll by eye mouse was investigated and evaluated. Two different input methods of eye mouse corresponding to the functions of double-click and scroll were used. The double-click function of UI menu and blink+ were used for double-click. The scroll function of eye mouse from Quick Access and clicking scroll-bar were used for scroll. Although it was not different methods, comparison drag & drop of a file and selecting a specified text by raking of drag was conducted.

The dependent variables are performance and satisfaction. Performance consisted of task completion time and error during the task. Task completion time is efficiency of usability and error during the task is effectiveness of usability. The task completion time was measured from the start of the task to the end of the task by video analysis that recorded time in 1/60 seconds. The error during the task was measured by counting wrong actions which are all the actions except a target action (Yeoh, Lutteroth and Weber, 2015; Bednarik, Gowases and Tukiainen, 2009). Satisfaction was measured by making participants fill in a questionnaire.

3.5 Questionnaire Design

Table 1. The questionnaire items used in this study

Satisfaction about the use of the functions of eye mouse	Workload	Physical effort
		Mental effort
		Temporal pressure
		Causing frustration, anxiety or irritation
		Task completion
		Overall
	Comfort	Eye
		Neck
		Shoulder
		Overall
	Ease of use	Accuracy
		Speed
		Naturalness
		Prior knowledge
		Expectancy
		Overall
Satisfaction about the overall use of eye mouse	Accuracy of calibration	
	Usefulness of eye mouse	
	Naturalness of eye mouse	
	Overall satisfaction	

The questionnaire was designed to measure satisfaction about the use of eye mouse. The questionnaire was based on the previous studies (Zhang and MacKenzie, 2007; Bates and Istance, 2003; Douglas, Kirkpatrick and MacKenzie, 1999; Brooke, 1996; Hart and Staveland, 1988), but it was modified for this study (Table 1).

The questionnaire items about the use of the functions of eye mouse consisted of workload, comfort and ease of use. Workload consisted of physical effort, mental effort, temporal pressure, causing frustration, anxiety or irritation, task completion and overall. Comfort consisted of eye, neck, shoulder and overall. Ease of use consisted of accuracy, speed, naturalness, prior knowledge, expectancy and overall. The questionnaire items about the overall use of eye mouse consisted of accuracy of calibration, usefulness of eye mouse, naturalness of eye mouse and overall satisfaction. The questionnaire was made based on 7 Likert scale (Bierton and Bates, 2000). The questionnaire was designed as high score meaning positive.

3.6 Experimental Procedure

The experiment consisted of five steps. The experiment was conducted step by step, by supposing a context in which different functions of mouse were sequentially needed to achieve all the tasks. Before starting the experiment, participants had a little time to be used to eye mouse's operation ways and had a little practice time about each step of the experiment.

Step 1 was for double-click. There are two operating methods for double-click by eye mouse. One is the double-click function of UI menu, and another is blink+ which is operated by a long blink. Step 1 was opening the pdf file placed at location 2 by double-click. This task was conducted by the two different methods. Which operating method for double-click is good was evaluated through this step.

Step 2 was for scroll. There are two operating methods for scroll. One is the scroll function of UI menu, and another is clicking the scroll-bar. Step 2 was scrolling the pdf text to 3/5 specified page. This task was conducted by the two different methods. The scroll function of eye mouse from Quick Access works by user's gaze – after the scroll function of UI menu activated, page is moved up & down by a user's gaze. Clicking the scroll-bar works by left clicking the scroll-bar repeatedly located on the light side of the page. Which operating method for scroll is good was evaluated through this step.

Step 3 was for raking by drag. Step 3 was selecting the specified text in the 3/5 page by raking by drag. The drag function of UI menu was use for the raking by drag.

Step 4 was closing the pdf file by the closing window function of UI menu. Just click is needed in this step. Although this step does not represent a specific function of mouse, closing a window is an essential task in the GUI.

Step 5 was for drag and drop. Drag and drop are also one of the essential task in the GUI (Jacko et al., 2002). Step 5 was dragging the pdf file to the wastebasket folder and dropping on it by the drag function of UI menu.

3.7 Data Analysis

SPSS version 23 was used to analyze experimental result. About the performance result analysis, the data got out of more three times of standard deviation from mean were excluded to reduce deviation of the performance result between participants. Wilcoxon signed rank test of non-parametric test was conducted to figure out whether there is a significant difference of experimental result. Significance level was α=.05.

To evaluate efficiency, task completion time on each task was analyzed. To evaluate effectiveness, error during the task was analyzed. Task completion time and error during the task of two different methods for the same function in step 1 and step 2 was compared to find which methods are more appropriate to the function. To evaluate satisfaction, the result of the questionnaire was analyzed to understand the use of eye mouse more deeply. Satisfaction of two different methods for the same function in step 1 and step 2 was compared. Satisfaction of the same function for the different tasks of step 3 and step 4 was also compared.

4. Result

4.1 Efficiency

The result about task completion time is presented in Figure 3. The result about task completion time corresponds to efficiency. If task completion time is fast, it means efficiency is good.

Scroll by clicking the scroll-bar in step 2 and selecting the specified text by raking by the drag function in step 3 took relatively long time compared with the other tasks. On the comparison of operation methods, double-click in step 1 (Z=-2.403, p=.016) and scroll in step 2 (Z=-4.015, p=.000) showed significant difference.

4.2 Effectiveness

The result about error rate is presented in Figure 4. The result about error rate corresponds to effectiveness. If error rate is low, it means effectiveness is good.

Scroll by clicking the scroll-bar in step 2 showed high error rate, 2.64, and other tasks showed error rate under 0.29. The scroll function of UI menu in step 2 showed 4 failure, scroll by clicking the scroll-bar in step 2 showed 2 failure, step 3 showed 3 failure, step 4 showed 2 failure, and step 5 showed 2 failure. On the comparison of operation methods, double-click in step 1 did not show significant difference (p>.05), but scroll in step 2 showed significant difference (Z=-3.580, p=.000).

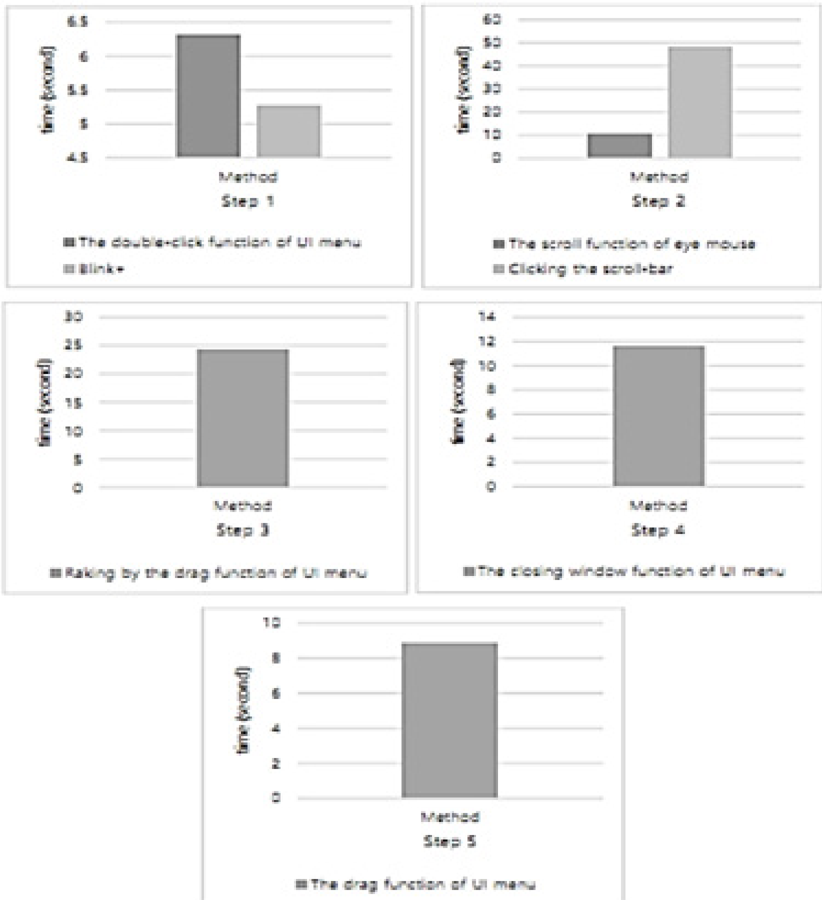

Figure 3. Efficiency result

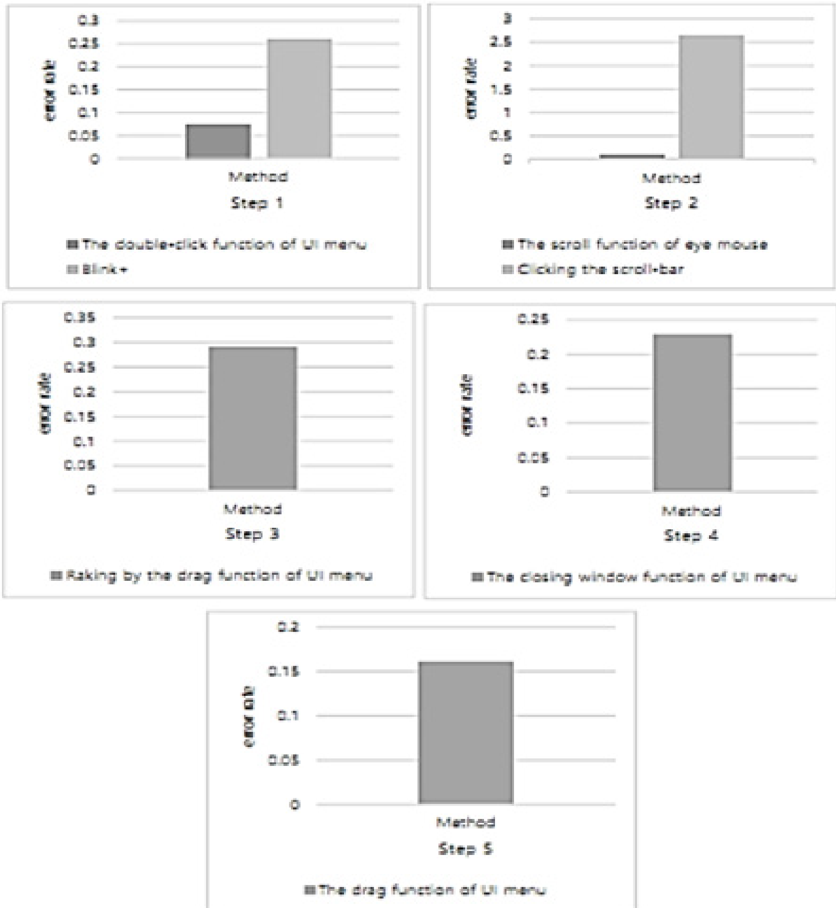

Figure 4. Error rate result

4.3 Satisfaction

4.3.1. Satisfaction about the Use of the Functions of Eye Mouse

The result about satisfaction of the click function is presented in Figure 5. All the results of click showed beyond 4 score value.

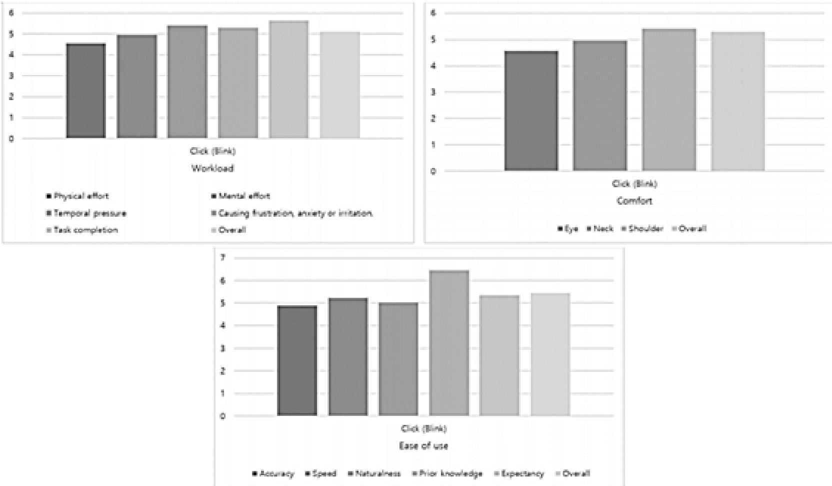

Figure 5. Satisfaction of the click function

The result about satisfaction of the double-click function is presented in Figure 6. All the results of the double-click function of UI menu showed beyond 3 score value. All the results of blink+ showed beyond 4 score value. On the comparison of operation methods about the double-click function, there was significant difference in all the items of workload (Physical effort (Z=-2.954, p=003), Mental effort (Z=-3.124, p=.002), Temporal pressure (Z=-2.357, p=.018), Causing frustration, anxiety or irritation (Z=-3.430, p=.001), Task completion (Z=-3.401, p=.001) and Overall (Z=-3.744, p=.000)). There was significant difference in Eye (Z=-2.483, p=.013) and Overall (Z=-2.028, p=.043) of comfort. There was significant difference in Speed (Z=-2.651, p=.008), Naturalness (Z=-2.873, p=.004) and Overall (Z=-3.192, p=.001) of ease of use.

The result about satisfaction of the scroll function is presented in Figure 7. All the results of the scroll function of UI menu showed beyond 4 score value. All the results of clicking the scroll-bar showed under 4 score value except one. Clicking the scroll-bar showed relatively low score value compared with the other functions. On the comparison of operation methods about the scroll function, there was significant difference in all the items of workload (Physical effort (Z=-3.736, p=000), Mental effort (Z=-

3.445, p=.001), Temporal pressure (Z=-4.129, p=.000), Causing frustration, anxiety or irritation (Z=-3.902, p=.000), Task completion (Z=-3.859, p=.000) and Overall (Z=-3.928, p=.000)). There was significant difference in all the items of comfort (Eye (Z=-3.940, p=.000), Neck (Z=-2.989, p=.003), Shoulder (Z=-2.971, p=.003) and Overall (Z=-3.496, p=.000)). There was significant difference in all the items of ease of use (Accuracy (Z=-4.137, p=.000), Speed (Z=-4.028, p=.000), Naturalness (Z=-3.613, p=.000), Prior knowledge (Z=-2.074, p=.038), Expectancy (Z=-2.525, p=.012) and Overall (Z=-4.129, p=.000).

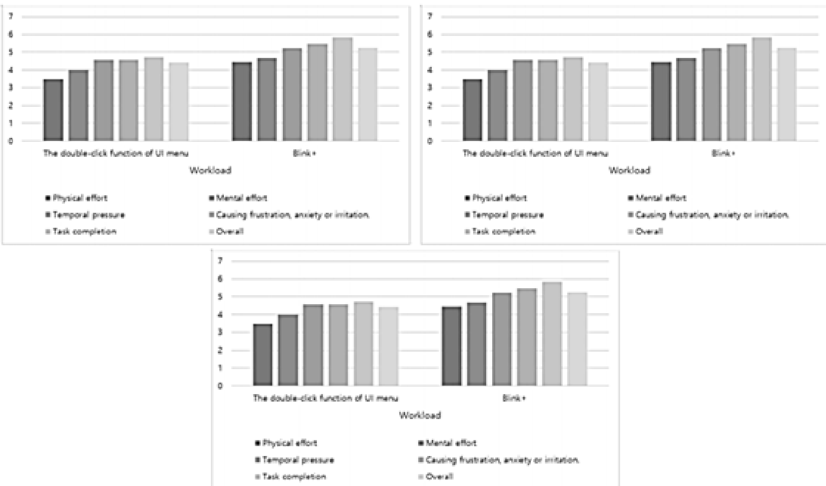

Figure 6. Satisfaction of the double-click function

The result about satisfaction of the drag tasks is presented in Figure 8. All the results of the raking task by drag showed under 4 score value except one. All the results of the file drag and drop task showed beyond 4 score value. On the comparison of the drag tasks, there was significant difference in all the items of workload (Physical effort (Z=-4.012, p=000), Mental effort (Z=-3.569, p=.000), Temporal pressure (Z=-3.661 p=.000), Causing frustration, anxiety or irritation (Z=-3.537, p=.000), Task completion (Z=-3.419, p=.001) and Overall (Z=-3.744, p=.000)). There was significant difference in all the items of comfort (Eye (Z=-3.658, p=.000), Neck (Z=-2.658, p=.008), Shoulder (Z=-2.970, p=.003) and Overall (Z=-3.168, p=.002)). There was significant difference in all the items of ease of use except Prior knowledge (p>.05) (Accuracy (Z=-4.075, p=.000), Speed (Z=-3.774, p=.000), Naturalness (Z=-3.566, p=.000), Expectancy (Z=-3.040, p=.002) and Overall (Z=-3.681, p=.000).

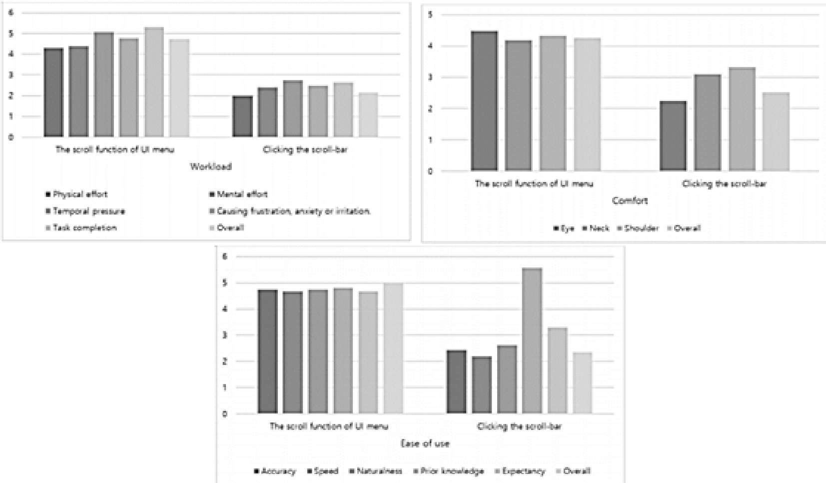

Figure 7. Satisfaction of the scroll function

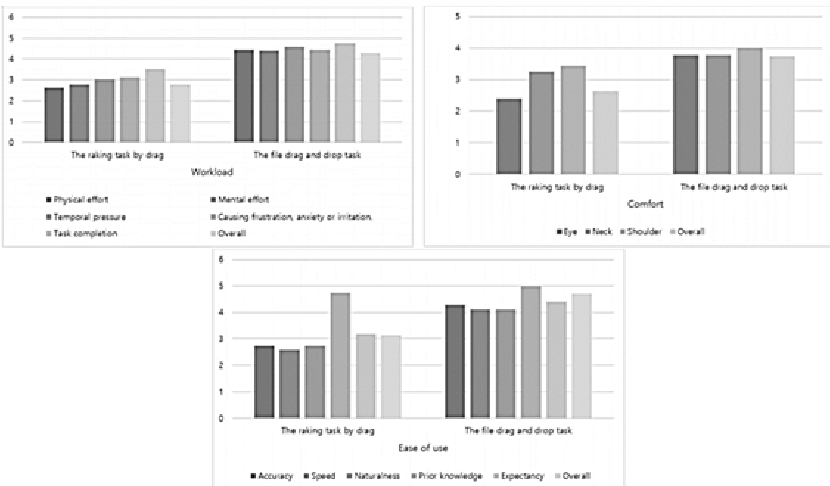

Figure 8. Satisfaction of the drag tasks

4.3.2. Satisfaction about the Overall Use of Eye Mouse

The result about satisfaction of overall use of eye mouse is presented in Figure 9. Accuracy of calibration and naturalness of eye mouse showed beyond 4 score value. Usefulness of eye mouse and overall satisfaction showed under 4 score value.

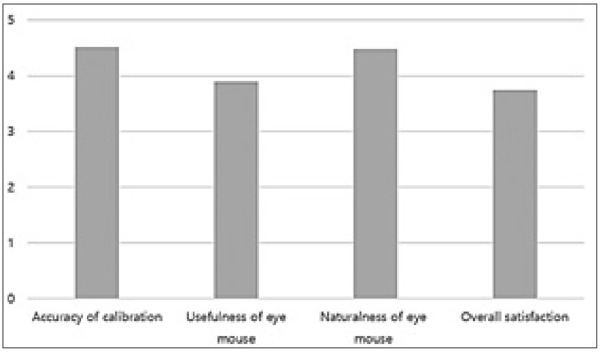

Figure 9. Satisfaction of overall use of eye mouse

5. Discussion

5.1 Performance

From this study, we could find out the fact that there was performance difference between the input
methods of eye mouse.

About the double-click function, blink+ showed better performance result than the double-click function of UI menu. Although there was not significant difference at the error during the task, there was significant difference at the task completion time. The reason of the result can be explained by simplified task process. Only 0.9 second is needed to activate double-click by blink+. But not only clicking a target but also clicking the double-click function of UI menu is needed to activate double-click by the double-click function of UI menu. We can think that double-click by the double-click function of UI menu needs much time to be activated, because it needs more processes to perform double-click than blink+.

About the scroll function, the scroll function of UI menu showed better performance result than clicking the scroll-bar. There was significant difference at the task completion time and the error during the task. The reason of the result can be also explained by simplified task process. Just seeing up and down is needed to scroll pages, after activating the scroll function of UI menu. But sequential clicks until reaching the page which he/she wants are needed to scroll pages by clicking the scroll-bar. Because of this, we can think that clicking the scroll-bar needs much time and makes more errors to perform scroll than the scroll function of UI menu.

About the drag tasks, selecting the specified text by raking by drag needed much time and made more errors than dragging and dropping the file during the task. We can think that it is because selecting the specified text by raking by drag is more precious task than dragging and dropping the file.

5.2 Satisfaction

From this study, we could also find out the fact that there was satisfaction difference between the input methods of eye mouse. About the double-click function, blink+ showed better satisfaction result than the double-click function of UI menu. About the scroll function, the scroll function of UI menu showed better satisfaction result than clicking the scroll-bar. About the drag tasks, selecting the specified text by raking by drag showed better satisfaction result than dragging and dropping the file. The satisfaction result about the use of the functions of eye mouse was corresponded to the performance result.

About the satisfaction results of overall use of eye mouse, although accuracy of calibration and naturalness of eye mouse showed beyond 4 score value which is beyond middle point, 3.5 score value, usefulness of eye mouse and overall satisfaction showed under 4 score value. It can be interpreted that although satisfaction of using eye mouse was not bad, but it was not also good.

The reasons of the satisfaction evaluation by the participants could be known by the free-answer method of the questionnaire. The reasons of the satisfaction evaluation could be divided into two categories – positive and negative. Some participants said that the basic interface of eye mouse was very intuitive. Especially, they said that the speed of moving a cursor was so fast and nature, and even faster than those of conventional mouse, because the cursor of eye mouse reflected their intention based on the gaze. However, some participants said that the accuracy of calibration and the accuracy of a cursor by position changes were less than their expectation. They also pointed out that eye mouse was not appropriate to complex task operations, because there were some problems when using the functions UI menu. And fatigue of eyes was also pointed out repeatedly.

5.3 Design Implementation

Taken together, usability on the use of eye mouse as follows.

Although the speed of moving a cursor was fast and nature, the accuracy of cursor movements was not satisfying. However, the naturalness and the speed of cursor movement of eye mouse is good, even better than those of conventional mouse, which is similar to previous studies (Bednarik, Gowases and Tukiainen, 2009; Vertegaal, 2008). If a target is big, the click function of eye mouse can be useful (Kim et al., 2016a; Murata, 2006; Bates and Istance, 2003; Miyoshi and Murata, 2001).

About the double-click function, blink+ showed higher usability result than the double-click function of UI menu. The double-click function of UI menu is useful. But, like blink+, an original input method of eye mouse for double-click should be also applied on eye mouse's software to enhance usability on the double-click function of eye mouse.

About the scroll function, the scroll function of UI menu showed higher usability result than clicking the scroll-bar. Clicking the scroll-bar for scroll is very exhaustive task. There is a possibility that a task of clicking the scroll-bar repeatedly may degrade usability on the whole use of eye mouse. The scroll function by a user's gaze is very useful and promising (Kumar and Winograd, 2007). The scroll function by a user's gaze must be applied to eye mouse's software to enhance usability on the scroll function of eye mouse.

About the drag tasks, selecting the specified text by raking was not satisfying than dragging and dropping. Selecting the specified text by raking by the drag function of UI menu of eye mouse may be not appropriate. The drag function of UI menu of eye mouse may be not appropriate for all drag tasks. It is needed that an original input method of eye mouse for drag should be developed.

From the result in this study, we can find what is the pros and cons about usability on the use of eye mouse which were not found in the previous works. New interface design for eye mouse based on this study can improve usability on the use of eye mouse. However although the experimental tasks in this study were conducted by supposing a real computer interaction situation, they were simplified through controlling many factors. And the participants did not have enough time to be used to using eye mouse perfectly. Further usability studies on the use of eye mouse with experienced users based on other input methods and complex situations are more needed. Further usability studies will make us know the pros and cons about usability on the use of eye mouse, which can enhance task performance and usability of eye mouse.

6. Conclusion

Previous usability studies on eye mouse have been usually focused on the function of left-click (Kim et al., 2016a; Yeoh, Lutteroth and Weber, 2015; Schneider et al., 2008; Zhang and MacKenzie, 2007; Murata, 2006; Kim et al., 2003; Miyoshi and Murata, 2001; Sibert and Jacob, 2000; Ware and Mikaelian, 1987). Previous usability studies on eye mouse have been usually focused on efficiency and effectiveness. Usability studies on eye mouse based on the other mouse functions are not sufficient. So, this study investigated usability on the use of eye mouse based on the functions of conventional mouse and input methods of eye mouse in terms of efficiency, effectiveness and satisfaction. The result of this study can be used to develop the establishment of guidelines for development in interface design and operation methods for eye mouse. The result of this study contributes to make us know what is the pros and cons of eye mouse.

Eye mouse is not a good input device to all yet. However, it is true that eye mouse is a useful alternative input device for the people who cannot use their arms and hands freely (Bates and Istance, 2003). It has a potential to be a useful input device, because its operation way can reflect cognitive intentions of a user immediately from user's eyes.

Although the experimental tasks in this study were conducted by supposing a real computer interaction situation, they were simplified through controlling many factors. And the participants did not have enough time to be used to using eye mouse perfectly. To reflect these factors, future studies will investigate usability on the use of eye mouse based on more diversified tasks and different input methods to understand its advantages and disadvantages more deeply.

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