Fifth International Workshop on Computational Intelligence & Applications
IEEE SMC Hiroshima Chapter, Hiroshima University, Japan, November 10, 11 & 12, 2009

Basic Study for Development of Web Browser suitable for Eye-gaze Input System - Identification of Optimal Click Method -

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Abstract— **In this study, alternative methods of mouse click operation were discussed. The eye-gaze input system was used. The effectiveness was compared among three alternative methods of mouse click operation. The alternative methods in the eye-gaze input system included the eye fixation, the press of space button, and the wink (blink). The percentage correct recognition, the pointing time, the subjective evaluation of usability was used as evaluation measures. The arrangement of targets (vertical or horizontal) and the age were also considered as experimental factors, and it was explored how these factors affected the pointing performance. The percentage correct recognition of the horizontal direction was higher than that of the vertical direction. The pointing time became longer as follows: eye-gaze input system with eye fixation, mouse, eye-gaze input system with press of space button, and eye-gaze input system with wink. The age factor was found not to affect the pointing time so remarkably.**

1. Introduction

There are many reports suggesting that older adults exhibit deficits in various cognitive motor tasks [1]-[2]. Spatial abilities, that is, the capacity to acquire, manipulate, and use information on Web pages, have been shown to decline with age[3]. Kelly and Charness [4] showed that spatial abilities may be important for mediating the effects of age on computing skills. Processing speed refers to the ability to acquire, interpret, and respond to information quickly and accurately. Salthouse [6] pointed out that reductions in processing speed are a common explanation for many age-related deficits in task performance. Therefore, it is expected that decreasing motor function in older adults hinders the successful use of input devices such as a mouse and generally leads to a relatively longer pointing time and lower pointing accuracy in comparison with young counterparts. The development of a new input device that compensate for such declined ability of older adults would be essential.

As one solution, the technology for measuring a user's visual line of gaze in real time has been advancing. Appropriate human-computer interaction techniques that incorporate eye movements into a human-computer dialogue have been developed [12]-[14]. These studies have found the advantage of eye-gaze input system. However, few studies except Murata [14] have examined the effectiveness of such systems with older adults. Murata[14] discussed the usability of an eye-gaze input system to aid interactions with computers for older adults. Systematically manipulating experimental conditions such as the movement distance, target size, and direction of movement, an eye-gaze input system was found to lead to faster pointing time as compared with mouse input especially for older adults. However, these studies cannot be applied to the real-world computer systems such as Internet Explorer. Moreover, different from a mouse, there exists no fixed method of click operation in the eye-gaze interface. Until now, a click method suitable for an eye-gaze input system has not been clarified so that the results is applicable the real-world computer application systems.

An optimal click method was identified as a basic study to develop a Web browser which is based on an eye-gaze input system and even older adults can use easily. The usability was compared among three alternative method of click (click methods based on eye-gaze, press of space bar, and wink). In this study, the aging factor was also selected as an experimental factor to clarify how aging factor affects the usability of eye-gaze input system.

2. Method

2.1 Participants

Sixteen participants took part in the experiment. Ten were male adults aged from 65 to 76 years (average: 68.9 years). All of the older adults had an experience of using a personal computer with an average of 9.9 years (1-21 years). Six were male undergraduate students aged from 21 to 23 years (average: 21.8 years). All of the young adults had an experience of personal computer with an average of 5.5 years (6-7 years). The visual acuity of the participants in both young and older groups was matched and more than 20/20. They had no orthopedic or neurological diseases.

(a)

(b)

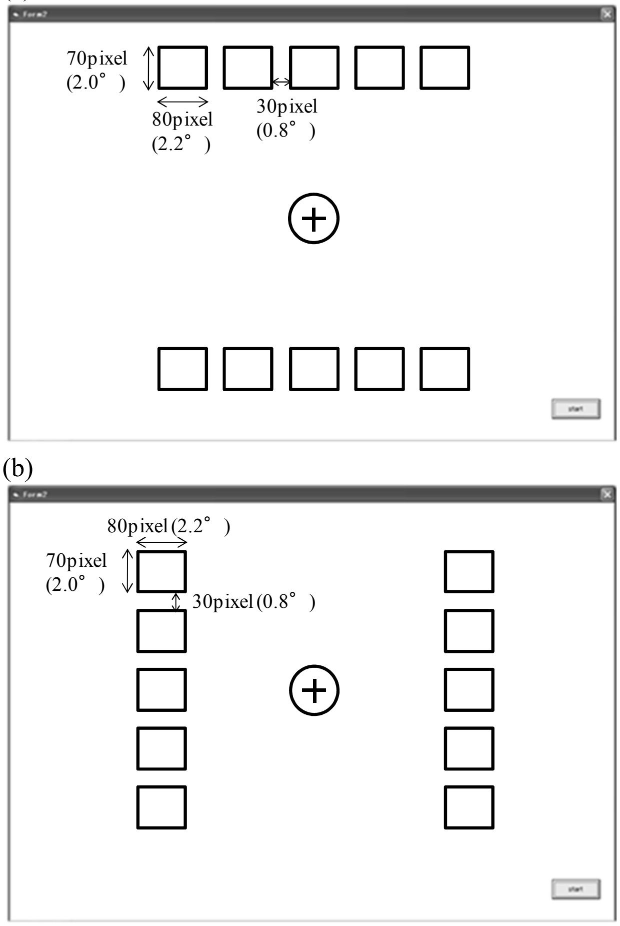

Fig.1 Arrangement of targets. (a) Vertical, (b) Horizontal

2.2. Apparatus

An eye-tracking device (EMR-VOXER, Mac Image Technology) was used to measure eye movements characteristics during the search task. This apparatus enables us to determine eye movements and fixation by measuring the reflection of low-level infrared light (800 nm), and also admits the head movements within a predetermined range.

The eye-tracker was connected with a personal computer (HP, DX5150MT) with a 15-inch (303mm x 231mm) CRT. The resolution was 1024 x 768 pixels. Another personal computer was also connected to the eye-tracker via a RS232C port to develop an eye-gaze input system. The line of gaze, via a RS232C port, is output to this computer with a sampling frequency of 60Hz. The illumination on the keyboard of a personal was about 200lx, and the mean brightness of 5 points (four edges and a center) on CRT was about 100cd/m^2. The viewing distance was about 70 cm.

2.3 Alternative method of mouse click

The following alternative methods of mouse click were used:

(1)Eye fixation:

When the eye-gaze fixated 10 times in a row, we regarded this as equivalent to mouse click. As the sampling frequency of EMR-VOXER was 60 Hz, 1/60 s was set up as a criterion of click.

(2)Press of space bar:

The movement of cursor was carried out using an eye-gaze input system, and the press of space bar was regarded as an alternative method of mouse click. When an eye-gaze entered within the target area and the space bar was pressed, this was regarded as a click operation.

(3)Wink (Blink):

An eye-gaze was used to move the mouse cursor, and the wink of a right eye was used as an alternative method of mouse click.

As a control condition, the pointing task using a mouse was also carried out.

2.4 Task

Ten targets were arranged as shown in Fig.1 (a) and (b). First, each participant was required to fixate the center of a circle (See Fig.1). After 3 s of fixation, the color of one of ten targets changed. Each participant was required to select this target using an eye-gaze input system or a mouse.

2.5 Design and procedure

The experimental factors were age (young and older adults), click method (4 levels), and arrangement of targets (2 levels: horizontal and vertical). Age was a between-subject factors, and click method and arrangement of targets were within-subject factors.

One session consisted of 8 conditions (2 arrangements of target x 4 click methods). For one condition, each participant carried out a pointing task 10 times. The order of 10 pointing tasks was randomized across the participants.

For each participant, a total of 5 sessions were carried out. After all tasks were exhausted, the following psychological rating was carried out using a 5-point scale:

a) Workload to upper body
b) Ease of entry

The evaluation measures were the percentage correct recognition and the task completion time.

3. Results

3.1 Percentage correct recognition

In Fig.2, the mean percentage correct recognition is shown as a function of age, arrangement of targets, and click method. A three-way (age by arrangement of targets by click method) ANOVA carried out on the percentage correct recognition revealed main effects of arrangement of targets ($\boldsymbol{F}(1,19)=7.566$, $\boldsymbol{p}<0.05$) and click method ($\boldsymbol{F}(1,19)=42.780$, $\boldsymbol{p}<0.01$). The following interactions were also found to be statistically significant: age by click method interaction ($\boldsymbol{F}(3,57)=3.227$, $\boldsymbol{p}<0.05$) and arrangement of targets by click method interaction ($\boldsymbol{F}(3,57)=4.276$, $\boldsymbol{p}<0.01$).

3.2 Task completion time

In Fig.3, the mean task completion time is shown as a function of age, arrangement of targets, and click

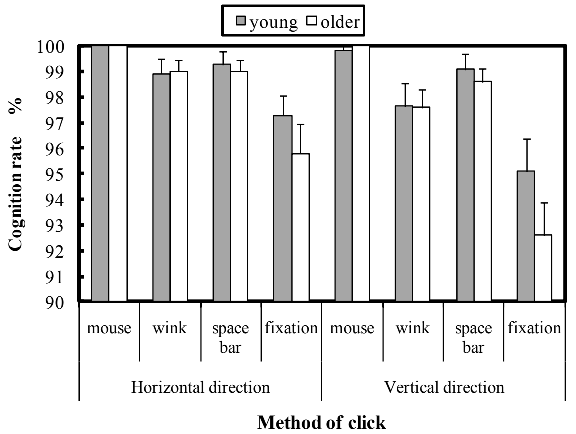

Fig.2 Mean percentage correct recognition as a function of direction of target arrangement, click alternative method and age.

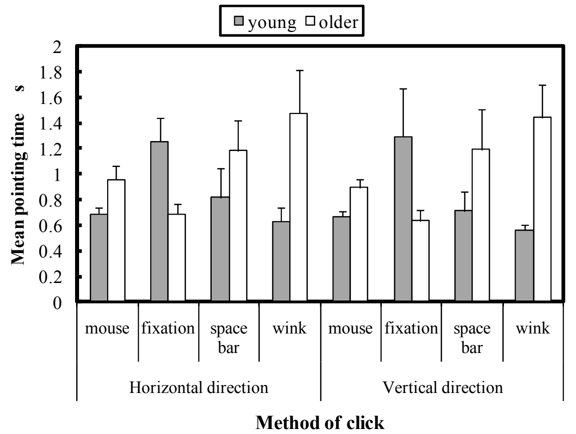

Fig.3 Mean pointing time as a function of direction of target arrangement, click alternative method and age.

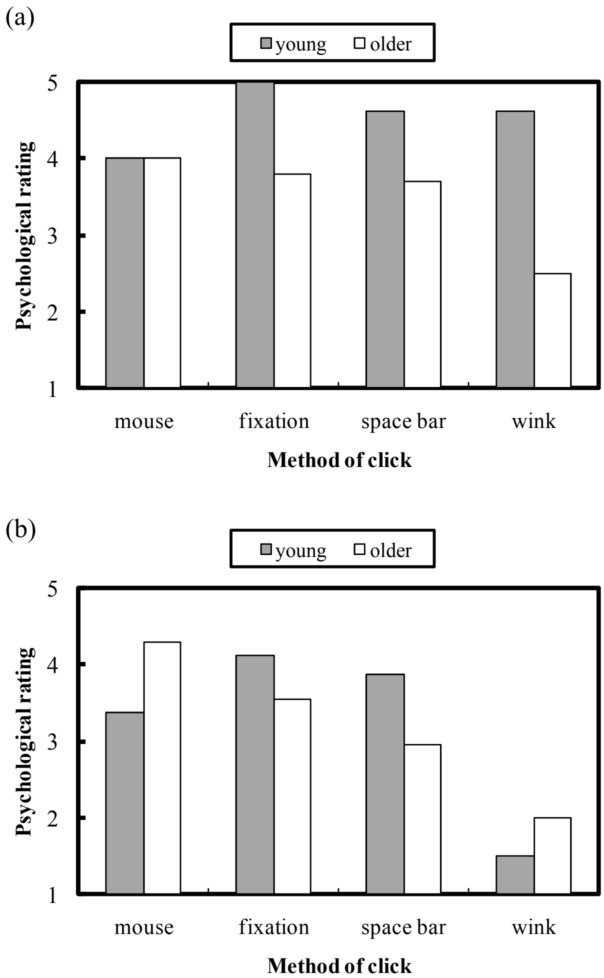

Fig.4 Mean rating score as a function of direction of target arrangement, click alternative method and age. (a) workload to upper body, (b) usability

method. A three-way (age by arrangement of targets by click method) ANOVA carried out on the task completion time detected main effects of age ($\boldsymbol{F}(1,19)=39.193$, $\boldsymbol{p}<0.01$) and click method ($\boldsymbol{F}(1,19)=90.563$, $\boldsymbol{p}<0.01$). A age by click method interaction ($\boldsymbol{F}(3,57)=8.675$, $\boldsymbol{p}<0.01$) was also found to be statistically significant.

3.3 Psychological rating

The mean rating scores of a) workload to upper body and b) ease of entry are shown as a function of age and click method in Fig.4 (a) and Fig.4 (b), respectively. As for a) workload to upper body, Man-Whitney non-parametric test (arrangement of targets) was carried out for both age groups. Kruskal-Wallis non-parametric test (click method) was also carried out for both age groups. Concerning young adults, no significant difference of score of (a) workload to upper body were detected between arrangements of targets and among click methods. On the other hand, a marginally ($\boldsymbol{p}=0.06$) significant difference of score of (a) workload to upper body were detected among click methods.

A similar non-parametric test conducted on (b) ease of entry revealed a significant difference among click methods for both age groups.

4. Discussion

4.1 Percentage correct recognition

For all click methods, the percentage correct recognition was more than 90%. The percentage correct recognition for the horizontal arrangement (Fig.1 (b)) tended to be higher than that for the vertical arrangement (Fig.1 (a)). This might be due to the knowledge that we can move our eyes more smoothly to the horizontal direction than to the vertical direction. The percentage correct recognition of (1) eye fixation was lower by 5-8% than that other click alternative methods and a mouse.

Irrespective of the arrangement condition of targets, the percentage correct recognition increased according to the following order: (1) eye fixation, (3) wink, (2) press of space bar. When the accuracy of entry is required, the eye-gaze input with the press of space bar is recommended. In the range of this experiment, the percentage correct recognition did not differ significantly between young and older adults. This means that the eye-gaze input system is desirable especially for older adults, because the eye-gaze input assure the accuracy equivalent to that of young adults.

4.2 Task completion time

For all of the four click methods (alternative click methods (1)-(3) and mouse click), the task completion time of young adults was shorter by 0.1-0.6s than that of older adults. Irrespective of age, the task completion time increased according to the following order: (1) eye fixation, mouse, (2) press of space bar, (3) wink. The task completion time of (3) wink was longer by 0.3-0.6s than other click methods. From the viewpoints of pointing time, the eye-gaze input with the eye fixation should be recommended. Although (3) wink was inferior to other click methods from the viewpoint of pointing speed, this is regarded as an effective click method, in particular, for disabled persons. Therefore, future research should make an attempt to reduce the task completion time of (3) wink, for example, by means of the faster image processing of wink.

4.3 Psychological rating

The workload to upper body of older adults was especially high for (a) workload to upper body. The declined motor function of older adults might be reflected in this result. As for (b) ease of entry, both age group felt that (3) wink was difficult to enter. Older adults were found to feel that a mouse click can be more easily carried out than other click alternative methods. If the percentage correct recognition of click alternative methods (1)-(3) was further enhanced, the psychological rating of (b) ease of entry for click alternative methods might be improved. Moreover, older adults evaluate (b) ease of entry of (1) eye fixation highly, although the percentage correct of (1) eye fixation was the lowest of all of three click alternative methods. The evaluated (b) ease of entry of (3) wink under which the task completion time was the longest. This might mean that older adults tend to pay more importance on task completion time than on percentage correct recognition.

4.4 General discussion

On the basis of the discussion above, it might be desirable to select a click alternative method depending on which of the two criteria (speed or accuracy) the participants pay importance on. When users put speed before accuracy, a click alternative method by (1) eye fixation would be recommended. When more importance is paid on accuracy, a click alternative method by (2) press of space bar would be recommended.

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