Effectiveness of the menu selection method for eye-gaze input system
- Comparison between young and older adults -

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Abstract— **Although the opportunity of older adults to use personal computer is increased more and more, the operation of a personal computer with a mouse is very annoying for older adults who cannot move his or her arm smoothly and effectively due to declined motor function. An attempt to move a cursor by an eye-gaze input system has been carried out as one solution to this problem. Until now, a menu selection method suitable for an eye-gaze input system has not been clarified. In this study, an effective menu selection for the eye-gaze input system was identified as a basic design parameter to develop a Web browser using an eye-gaze input system. Concretely, a menu selection method, that is, improved quick glance menu selection (I-QGMS) was proposed. The effectiveness was evaluated by means of the pointing accuracy, the pointing time, and the psychological rating on usability. On the basis of the evaluation experiment, the proposed I-QGMS was found to be effective especially for older adults.**

1. Introduction

Older people present an increasingly large portion of the population and are likely to be active users of IT. Issues surrounding IT and aging are, therefore, of much interest to not only researchers but also practitioner within the domain of human-computer interaction (HCI). Therefore, the development of an input device that is friendly to older adults and leads to higher performance is essential.

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], and this might account for the difficulties of older adults when navigating Web pages. 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 [5] 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 possibility of using the movement of users' eye or Electroencephalography (EEG) as a means of input to a computer has been investigated[6]-[9].Methods to use eye movements are mostly based on electrooculography (EOG)[7] or an eye tracking system [8],[9]. As well as EOG-based system, an input system based on EEG [10] cannot be used to carry out continuous pointing.

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 has been developed [11]-[18]. These studies have found the advantage of eye-gaze input system. However, few studies except Murata [18] have examined the effectiveness of such systems with older adults. Murata [18] 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. Until now, a menu selection method suitable for an eye-gaze input system has not been clarified so that the results is applicable the real-world computer application systems.

A menu selection method was identified as a basic study to develop a Web browser which even older adults can use easily. The usability was compared among five alternative method of menu selection. In this study, the aging factor was also selected as an experimental factor to clarify how aging factor affects the usability of menu selection system.

2. Menu selection method

The following six menu selection methods were used. While the methods (1)-(4) use both eye-gaze and press of a space key, the methods (5) and (6) use only eye-gaze. As for the methods (1)-(4), each participant carried out an experimental task suing both mouse and eye-gaze input. Only an eye-gaze input was used for the methods (5) and (6). The procedure for menu selection is summarized in Fig.1. The outline of each selection method is mentioned below.

(1)Vertical display (small target)

The method is outlined in Fig.2. This arrangement corresponds to a real-world menu selection system such as Internet Explorer. This method was selected to examine how an eye-gaze input system functions in a setting like a real-world situation.

(2)Vertical display (large target)

This method is different from the method (1) in that the targets size was enlarged so that a menu selection can be executed more easily. The outline of the method is shown in Fig.3.

(3)Horizontal display

The size of menu was the same with that of the method (2). It is generally known that we can more easily move our eyes to the horizontal direction that to the vertical direction. Therefore, we expected that this method would lead to higher performance than the method (2). In Fig.4, the outline of this method is depicted.
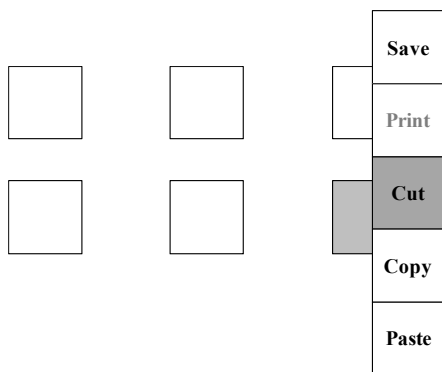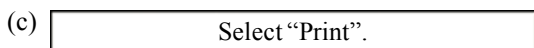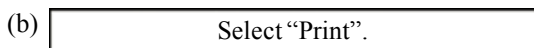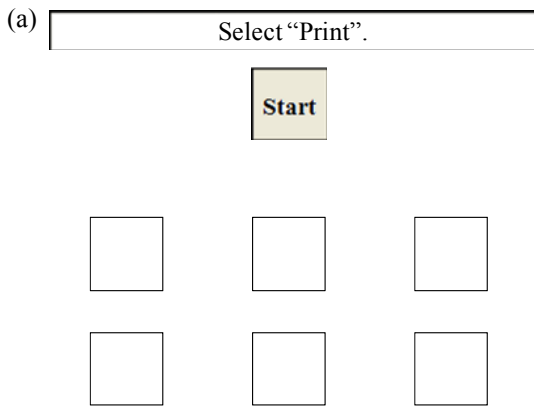
(a)

Select "Print".

Start

(b)

Select "Print".

(c)

Select "Print".

| Save |
| Print |
| Cut |
| Copy |
| Paste |

Fig.1 Procedure for menu selection.

(4)Circle display

As shown in Fig.5, the menu is displayed on the circle. The other methods are similar to the methods (1)-(3). This method enables us to carry out a minimum cursor movement.

(5)QGSM (Quick Glance Selection Method) [19]

The outline of this method is shown in Fig.6. Each menu is divided into two areas. The name of command is displayed on one area. The other area (we call this a selection area) is related to the selection of menu. The system judges that the menu has been selected when an eye-gaze stays within this area during more a predetermined period (In this study, this period was set up to 6/60 s). In such away, the menu selection by only
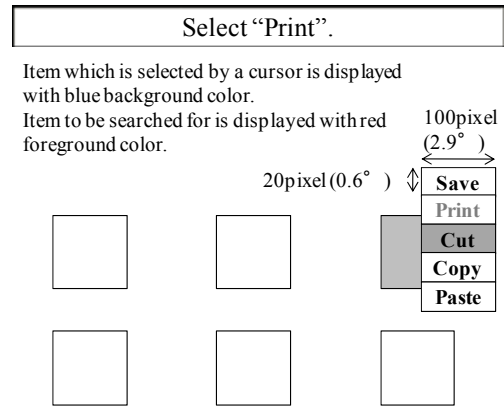
Select "Print".

Item which is selected by a cursor is displayed with blue background color.
Item to be searched for is displayed with red foreground color.

100pixel (2.9°)

20pixel(0.6°)

| Save |
| Print |
| Cut |
| Copy |
| Paste |

Fig.2 Menu selection method (1): Vertical display with small target size.

Select "Print".

Item which is selected by a cursor is displayed with blue background color.
Item to be searched for is displayed with red foreground color.

100pixel (2.9°)

100pixel (2.9°)

| Save |
| Print |
| Cut |
| Copy |
| Paste |
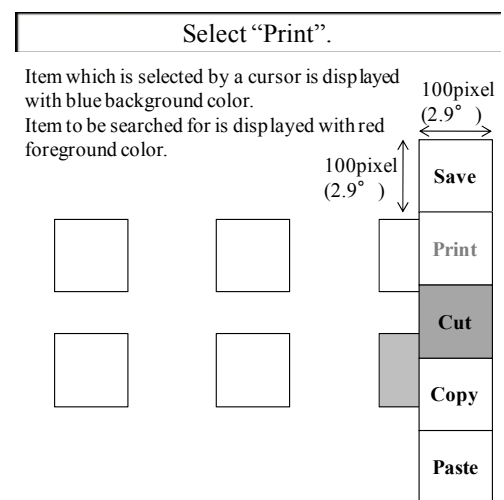
Fig.3 Menu selection method (2): Vertical display with large target size.

Select "Print".

Item which is selected by a cursor is displayed with blue background color.
Item to be searched for is displayed with red foreground color.
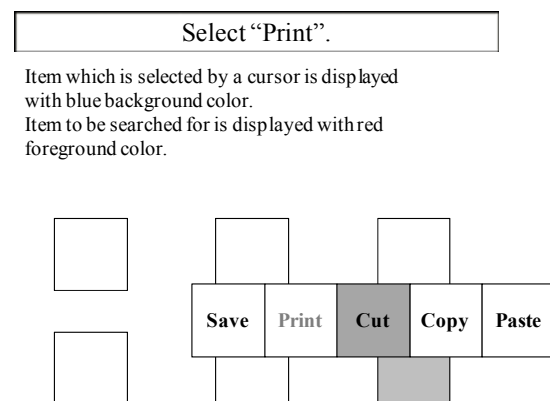
| Save | Print | Cut | Copy | Paste |

Fig.4 Menu selection method (3): Horizontal display.

an eye-gaze is possible. In this method, it is possible that Midas touch problem pointed by Jacob [11]-[13] might occur and lead to miss selections.

(6)I-QGSM (Improved- Quick Glance Selection Method)

This method improved a few disadvantages in QGSM, especially Midas touch problem. To prevent Midas touch problem from occurring frequently, this method regarded that the menu was selected only when the eye-gaze entered for the command area to the selection area. Moreover, the distance between menu
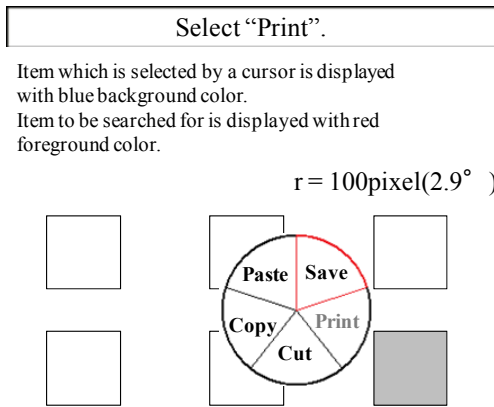
Select "Print".

Item which is selected by a cursor is displayed
with blue background color.
Item to be searched for is displayed with red
foreground color.

r = 100pixel(2.9°)

Fig.5 Menu selection method (4): Circle display.

Select "Print".

100pixel 50pixel
(2.9°) (1.4°)

Selection area

Save

Print ※

Selection mark

Cut

Copy

50pixel
(1.4°)

Paste

Fig.6 Menu selection method (5): QGMS.

Select "Print".

100pixel 100pixel
(2.9°) (2.9°)

100pixel
(2.9°)

Save

Print

Cut ※

Command Selection
area   area

Copy

Paste
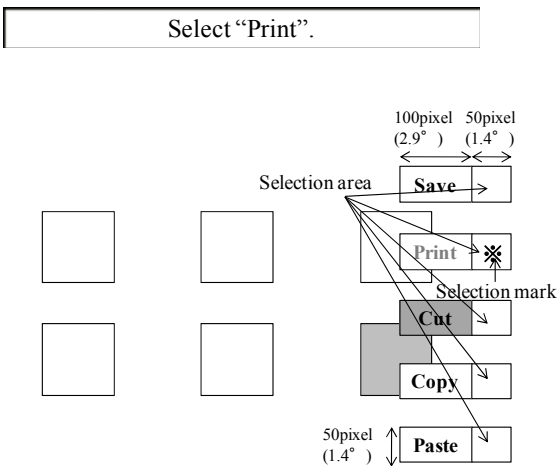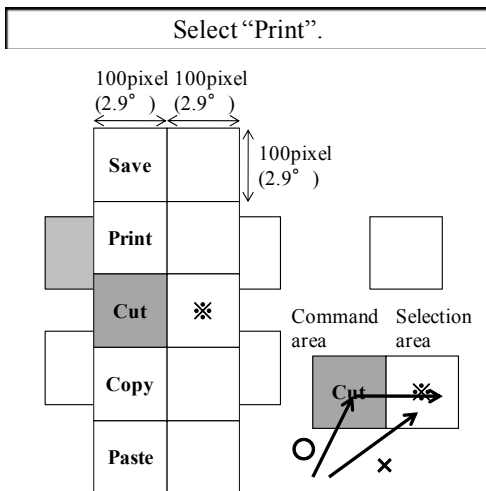
Cut ※

Fig.7 Menu selection method (6): I-QGMS.

items was set to zero and the size of each menu item was
enlarged in order to avoid Midas touch problem. The
outline of this method is shown in Fig.7.

Item to be searched for is displayed.

100pixel
(2.9°)

Start

162pixel
(4.3°)

102pixel
(2.9°)

40pixel (1.2°)

100pixel
(2.9°)

Fig.8 Arrangement of targets in experiment.

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.

3.2. Apparatus
An eye-tracking device (EMR-VOXER, Nac 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 768pixel.
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.

3.3 Task
Six targets were arranged as shown in Fig.8. First,
the menu item to be selected is indicated on the upper
area (See Fig.1). The menu items were "Save", "Print",
"Cut", "Copy", and "Paste." In Fig.2, "Print" was
required to select. After pressing a "Start" button, the
color of one of six targets changed. When selecting this
target, a pop-up menu appeared as shown in Fig.2, and a
participant was required to select a specified menu item.

3.4 Design and procedure
The experimental factors were age (young and older
adults), menu selection method (10 levels), and session
(3 sessions). Age was a between-subject factors, and
menu selection method and session were within-subject
factors.

One session consisted of 30 trials (6 target x 5 menu
items). In an eye-gaze input system, a total of 3 sessions
were carried out. As all participants daily used a mouse,
it was not necessary to examine the learning effect.
Therefore, only one session was carried out for a menu

3. Method
3.1 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
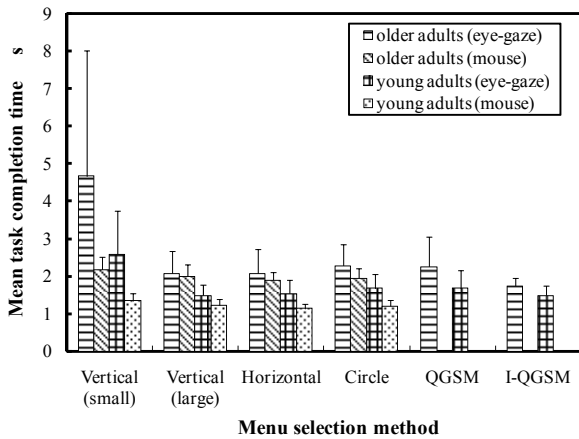
Fig.9 Mean task time completion time as a function of age, input device and menu selection method.
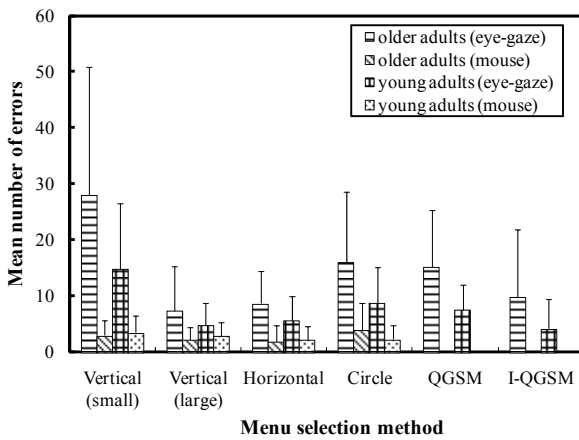

Fig.10 Mean number of errors as a function of age, input device and menu selection method.

selection task using a mouse. The order of 10 selection methods was randomized across the participants.

After all tasks were exhausted, the following psychological rating was carried out using a 5-point scale:
 (1) Workload to upper body
 (2) Usability
 (3) Comfort when using
 (4) Understandability of operation
 (5) Visibility of menu display

3.5 Evaluation measures
The following evaluation measures were used.
(1) Mean task completion time
The task completion time was defined as time from the selection of start button until the selection of specified menu item. When calculating the mean task completion time, the error trials were excluded.
(2) Mean number of errors
The selection of target or menu item that was specified by the software system was regarded as an error trial. The number of error which each participant committed until the completion of selection of a specified menu item was measured. Therefore, it is possible that more errors than the total number of trials in each session (30 trials).

4. Results

4.1 Mean task completion time
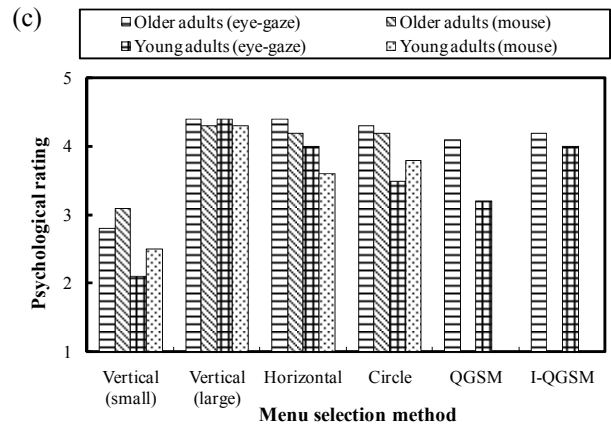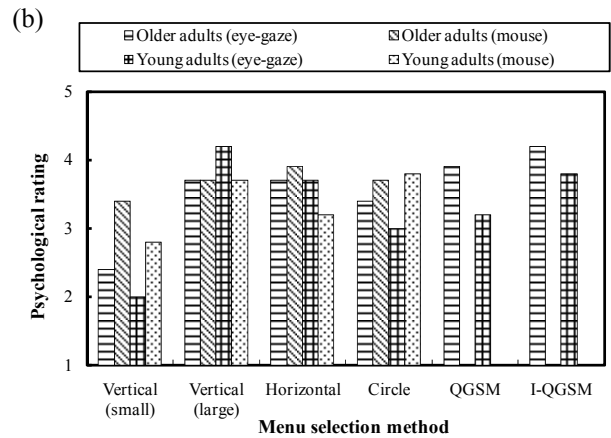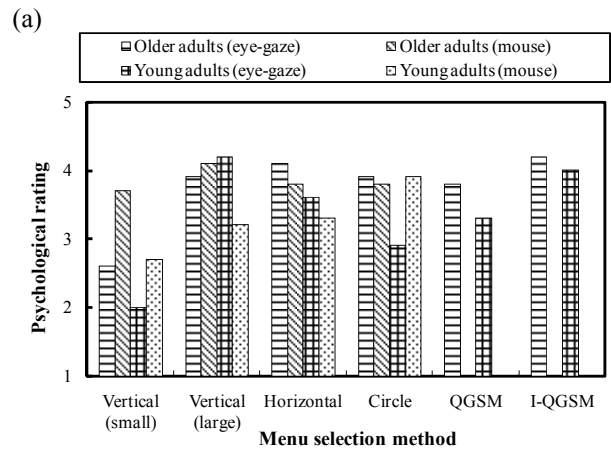In Fig.9, the mean task completion time is plotted as

(a)

(b)

(c)

Fig.11 Psychological rating as a function of age, input device and menu selection method. (a) usability, (b) comfortable operation, (c) visibility

a function of age and selection method. A two-way (age by selection method) ANOVA conducted on the task completion time revealed significant main effects of age ($F(1,18)=20.436$, $p<0.01$) and selection method ($F(9, 162)=15.557$, $p<0.01$), and a significant age by selection method interaction ($F(9,162)=2.248$, $p<0.05$).

4.2 Mean number of errors
In Fig.10, the mean number of errors is shown as a function of age and selection method. A two-way (age by selection method) ANOVA conducted on the task completion time revealed significant only a main effect of selection method ($F(9,162)=27.375$, $p<0.01$).
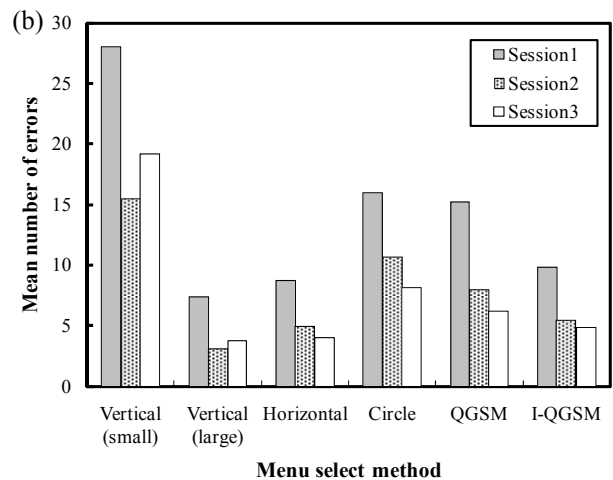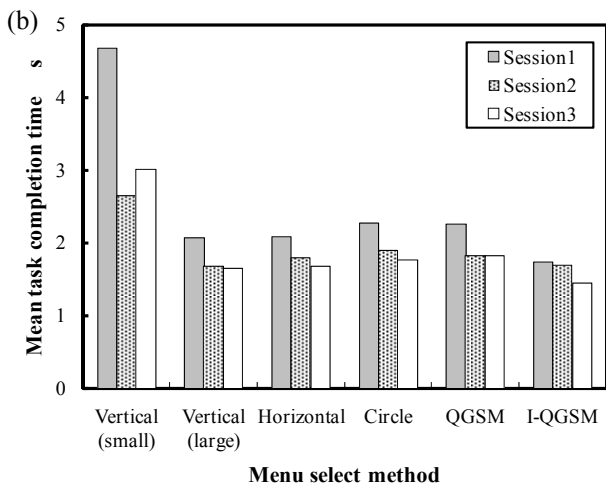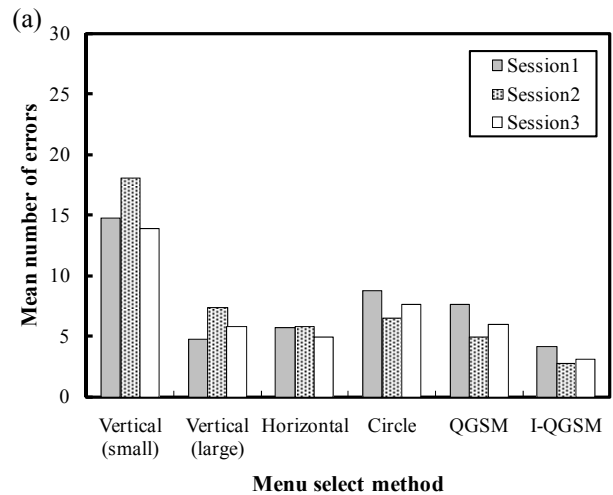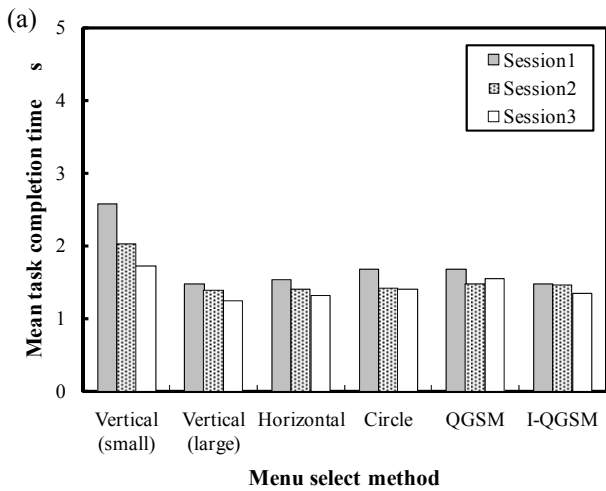
(a)

(b)

Fig.12 Mean task completion time as a function of session and menu selection method. (a) young adults, (b) older adults

(a)

(b)

Fig.13 Mean number of errors as a function of session and menu selection method. (a) young adults, (b) older adults.

4.3 Psychological rating

In Fig.11 (a)-(c), the results of psychological rating of usability, comfortable operation and visibility are shown as a function of age, and selection method.

4.4 Learning effect

In Fig.12 (a) and (b), the mean task completion time is plotted as a function of session and selection method for each age group. As a result of a two-way (session by selection method) ANOVA carried out on the task completion time, significant main effects of session ($F(2,27)=5.341$, $p<0.05$) and selection method ($F(5,10)=11.433$, $p<0.01$) were detected for older adults. A similar two-way ANOVA revealed only a main effect of selection method ($F(5,10)=17.586$, $p<0.01$) for young adults.

In Fig.13 (a) and (b), the mean number of errors is shown as a function of session and selection method for young and older adults, respectively. A two-way (session by selection method) ANOVA conducted on the number of errors revealed significant main effects of session ($F(2,27)=4.958$, $p<0.05$) and selection method ($F(5,10)=16.530$, $p<0.01$) for older adults. A similar two-way ANOVA for young adults revealed only a main effect of selection method ($F(5,10)=29.639$, $p<0.01$).

5. Discussion

5.1 Mean task completion time

The mean task completion time for the (1)vertical display (small target) was the longest for both age group. Therefore, it is impossible to use an eye-gaze input system under (1)vertical display (small target) for a real-world standard display such as Internet Explorer. This might be that the small target is difficult to select due to the effects of miniature eye movement.

Although it was predicted that the horizontal display leads to the faster task completion than the vertical display, no significant difference of task completion time was detected between (2)vertical display (large target) and (3)horizontal display. A circle display (4) was also predicted to lead to shorter task completion time, because moving distance was the shortest. Contrary to this prediction, the mean task completion time for this display was the second longest. This might mean that the small movement distance induces miniature eye movement and delays the pointing movements.

Except for (1) vertical display (small target), as for older adults, the task completion time of the eye-gaze input system was nearly equal to or shorter than that of the mouse. This is indicative of the eye-gaze input as a potential promising device for older adults. I-QGSM was the fastest of all selection methods for both age groups (See Fig.9), which indicates that I-QGMS is the

most suitable selection method from the viewpoint of selection speed.

5.2 Mean number of errors

Except for (1) vertical display (small target), for both age group, the number of errors did not differ significantly among five selection methods using an eye-gaze input. Moreover, it tended that the number of error for the eye-gaze input was larger than that for the mouse. Future research should make an attempt to reduce the number of errors for the eye-gaze input system. The number of errors for I-QGSM was larger than that for QGSM. This also supports the validity of I-QGSM.

5.3 Psychological rating

Concerning (1) workload to upper body, (2) usability, (3) comfort when using and (4) understandability of operation, I-QGMS tended to be rated higher than other eye-gaze selection methods. However, the rating of (5) visibility of menu display was lower than other eye-gaze selection methods. Therefore, the visibility of menu display should be enhanced further.

5.4 Learning effect

Learning effects of task completion time and number of errors were not observed for young adults. As for older adults, learning effects were detected for each selection method. The difference of learning effects between young and older adults might be due to the difference of cognitive function [1]-[5] between both age groups.

5.5 General discussion

On the basis of discussion above, a few design guidelines would be proposed. When using an eye-gaze input for menu selection tasks, (1) vertical display (small target) should be avoided. This means that it is impossible to use an eye-gaze input system under this condition for a real-world standard display such as Internet Explorer. Such a usage would increase entry errors and lead to longer task completion time.

The best means of entry for older adults was I-QGSM. The best means for young adults was I-QGSM or mouse entry. It must be noted that I-QGSM increases error entries when using an eye-gaze input and also increase entry time as compared with a mouse input. As the direction of display did not affect the performance, both vertical and horizontal directions would be recommended. When using I-QGMS method for older adults, we must pay attention to the learning effects. Therefore, enough learning period must be required to older adults so that I-QGMS can be used effectively.

Future research should device a method that should reduce error entries due to Midas touch problems. The effectiveness of I-QGMS should be verified using a more real-world situations.

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