Optimal Scroll Method for Eye-Gaze Input System

Comparison of R-E and R-S Compatibility

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Abstract. It is not clear which of the R-E and the S-R compatibility principles is proper for the eye-gaze input. This issue should be addressed for the development of more usable eye-gaze input system. The aim of this study was to explore which of the two compatibility principles was proper for the eye-gaze input system. For all scroll methods, the task completion time did not differ between R-E and S-R compatibility conditions (see Fig. 4). In other words, the speed of scroll did not differ between two compatibility conditions for all of three scroll methods. The number of errors per 90 trials significantly differed among scroll conditions and between R-E and S-R compatibility conditions. Judging from the accuracy of scroll, the error was less when the S-R compatibility like non-touch screen Microsoft Windows was applied than when the R-E compatibility like iPod or iPad was applied. In the range of this study, it seems that the S-R compatibility is dominant from the viewpoints of scroll accuracy for all of three scroll methods. The subjective rating on both usability and fatigue also supported the superiority of S-R compatibility over the R-E compatibility condition. In conclusion, the S-R compatibility was found to be superior for the eye-gaze input system.

Keywords: Eye-gaze input · Scroll · Auto scroll · Scroll icon · S-R compatibility · R-E compatibility

1 Introduction

The technology for measuring a user's visual line of gaze in real time has been advancing [1–9]. Appropriate human-computer interaction techniques that incorporate eye movements into a human-computer dialogue have been developed. It has also not been explored how the scroll location on Web browsers affects the performance. Although a few scroll methods have been proposed, these are not assumed to be used on Web pages. Murata et al. [9] made an attempt to determine empirically the optimal scroll method among the scroll methods (improved scroll-icon, auto-scroll, improved auto-scroll methods). The scroll-icon method was found to be not proper for use in an eye-gaze input system on the basis of the results of the task completion time, the error rate, and the subjective rating on usability. It was found that the improved auto-scroll

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method (quadratic and quadratic combination) with nonlinear relationship between the vertical scroll location and the scroll velocity was optimal from the viewpoints of the task completion time, the error rate and the subjective evaluation on usability.

Scrolling methods are mainly based on either R-E (Response-Effect) compatibility or S-R (Stimulus- Response) compatibility. The R-E compatibility a natural scrolling, and the responses are congruent with their forthcoming effects or consequences. This compatibility principle is used in iPod, iPad, and a variety of smart phones. The S-R compatibility is mainly used in Microsoft Windows. When the scrolling control goes one direction, the display content goes the other. The computer task by a mouse on Windows System adopts the R-S compatibility principle.

Chen and Proctor [10] compared the performance between two scrolling methods (R-E and S-R compatibility) on non-touch screen computer operating system using a keyboard, and showed that the responses were facilitated when the response direction was compatible with the forthcoming display-content movement direction (R-E compatibility). However, it is not clear which of the R-E and the S-R compatibility principles is proper for the eye-gaze input. This issue should be addressed for the development of more usable eye-gaze input system. The aim of this study was to explore which of the two compatibility principles was proper for the eye-gaze input system.

2 Method

2.1 Participants

Eight male undergraduate students aged from 21 to 23 years (average: 21.8 years) took part in the experiment. 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.

2.2 Apparatus

An eye-tracking device (EMR-AT VOXER, Mac Image Technology) was used to measure eye movement characteristics during the experimental task. The eye-tracker was connected with a personal computer (HP, DX5150MT) with a 15-in. (303 mm × 231 mm) CRT. The resolution was 1024 × 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 60 Hz.

2.3 Task

The task was to scroll and select a pre-specified item by scrolling up or down the display in Figs. 1, 2, and 3. The following scroll methods were used: (1) scroll icon method (see Fig. 2), and (2) auto scroll method (see Fig. 3) with nonlinear relationship

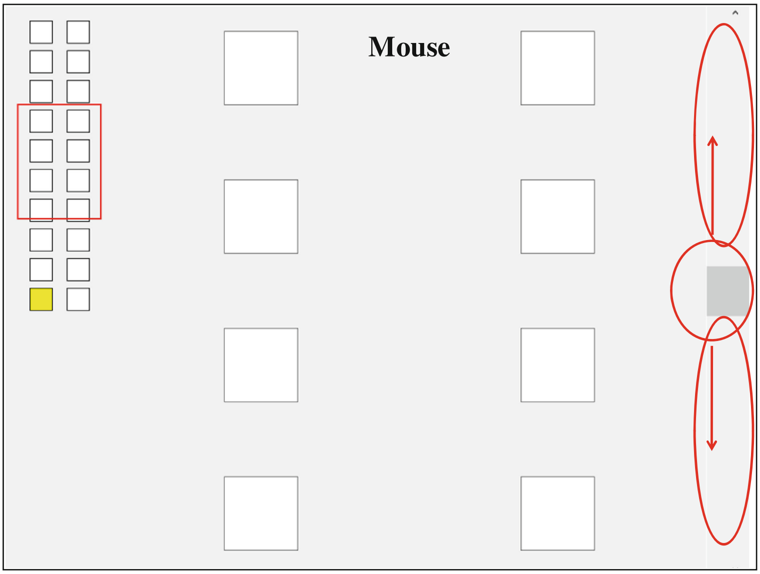

Fig. 1. Display for scrolling using a mouse

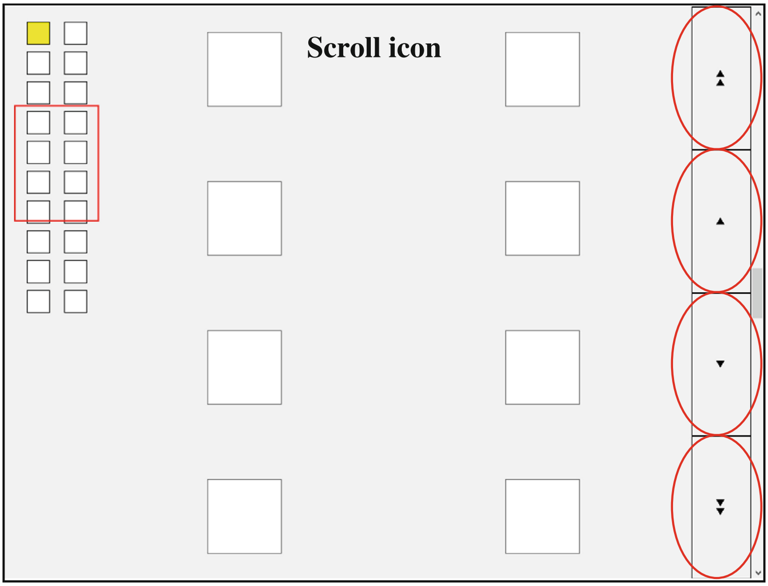

Fig. 2. Display for scrolling using a scroll icon

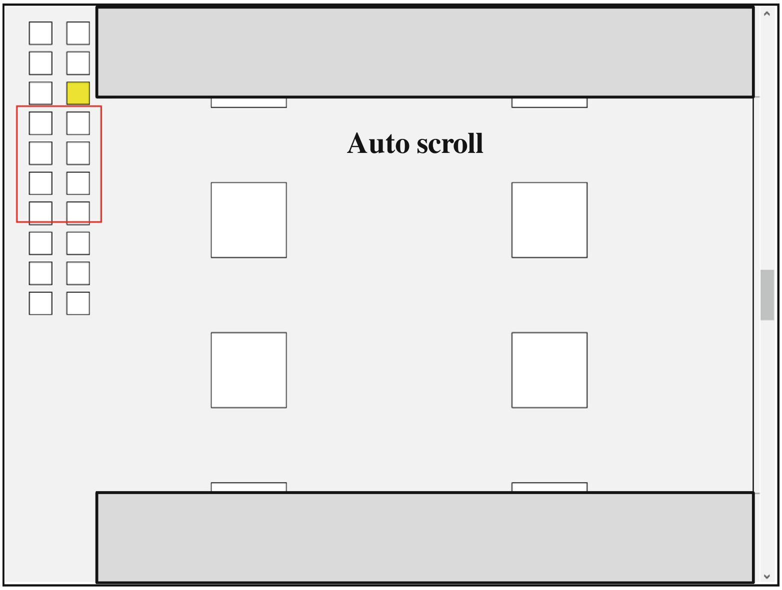

Fig. 3. Display for scrolling using a auto scroll method

between vertical scroll location and scroll velocity. For each scroll method, both of R-E and S-R compatibility principles were applied (a total of four combination), and it was examined what combination of scroll method and compatibility principle facilitate scrolling responses. Both scroll method (scroll icon and auto scroll) and compatibility principle (R-E and S-R compatibility) were within-subject factors.

2.4 Design and Procedure

The experimental factors were a scroll method (mouse, scroll icon method, and auto scroll method) and compatibility (S-R compatibility and R-E compatibility). Both were within-subject factors. There were six combinations of scroll method and compatibility.

The order of performance of six combinations (conditions) was randomized across the participants. For each condition, the participants were required to click a predetermined target using an eye-gaze input or mouse input 90 times. In the scroll conditions (scroll icon method, or auto scroll method), the participants were required to scroll the display to find a predetermined target using an eye-gaze input, and to click the target using a mouse. The performance measures were the task completion time, the number of errors (failure to click a predetermined target), and the subjective rating on usability (5-point scale: 1 = not usable at all, 5 = very usable) and the fatigue induced during the task (5-point scale: 1 = much fatigued, 5 = not fatigued at all).

The performance measures above were compared among the scroll methods and between S-R compatibility and R-E compatibility conditions).

3 Results

In Fig. 4, the task completion time is compared as a function of scroll method and compatibility. Figure 5 compares the number of errors per 90 trials among scroll methods and between S-R and R-E compatibility conditions. Figure 6 plots the subjective rating score on usability as a function of scroll method and compatibility. In Fig. 7, the subjective rating score on fatigue is compared among scroll methods and between S-R and R-E compatibility conditions.

A two-way (scroll method by compatibility) ANOVA (Analysis of Variance) conducted on the task completion time revealed a significant main effect of scroll method ($F(2,14) = 20.709$, $p < 0.01$). No significant main effect of compatibility and significant scroll method by compatibility interaction were detected. A similar two-way ANOVA conducted on number of errors per 90 trials revealed significant main effects of scroll method ($F(2,14) = 17.576$, $p < 0.01$) and compatibility ($F(1,7) = 8.710$, $p < 0.05$). No significant scroll method by compatibility interaction was detected.

As a result of Krusakal-Wallis nonparametric test conducted on the subjective rating score on usability for the S-R compatibility condition, a significant difference was detected among scroll methods ($H = 11.149$, $p < 0.01$). A similar nonparametric test conducted on the subjective rating score on usability for the R-E compatibility condition revealed a significant main effect of scroll method ($H = 9.084$, $p < 0.01$).

As a result of Krusakal-Wallis nonparametric test conducted on the subjective rating score on fatigue for the S-R compatibility condition, a significant difference was detected among scroll methods ($H = 15.365$, $p < 0.01$). A similar nonparametric test conducted on the subjective rating score on usability for the R-E compatibility condition revealed a significant main effect of scroll method ($H = 12.414$, $p < 0.01$).

As a result of Man-Whitney nonparametric test conducted on the subjective rating scores on both usability and fatigue for the mouse scroll condition, no significant

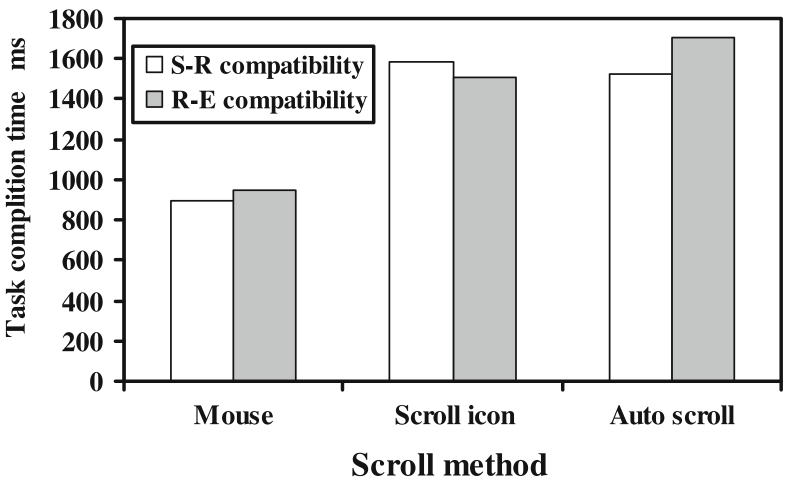

Fig. 4. Task completion time as a function of scroll method and compatibility

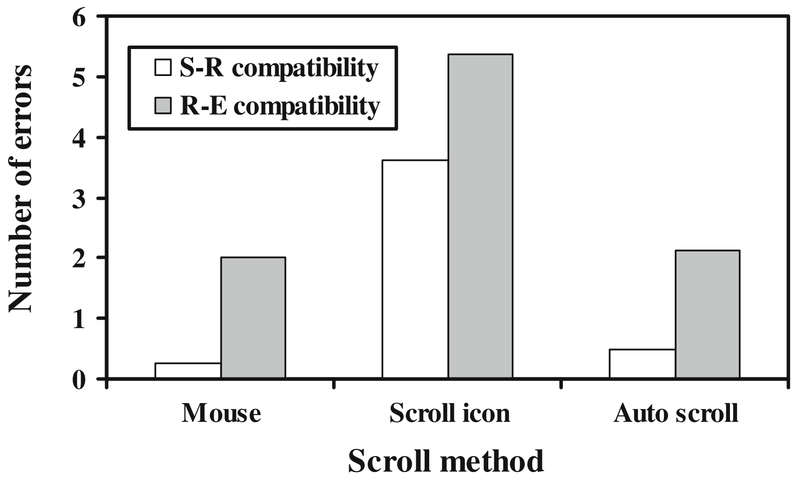

Fig. 5. Number of error per 90 trials as a function of scroll method and compatibility

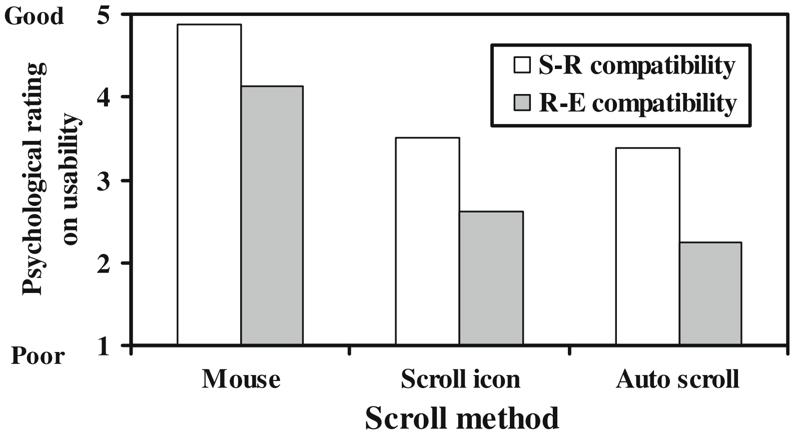

Fig. 6. Psychological rating on usability as a function of scroll method and compatibility

differences were detected between S-R and R-E compatibility conditions. As a result of Man-Whitney nonparametric test conducted on the subjective rating scores on both usability and fatigue for the scroll icon, no significant differences were detected between S-R and R-E compatibility conditions. A similar Man-Whitney nonparametric test conducted on the subjective rating scores on usability revealed a significant difference between S-R and R-E compatibility conditions ($z = -2.836$, $p < 0.01$). As a result of a similar test conducted on the subjective rating scores on usability, no significant main effect of compatibility condition was detected.

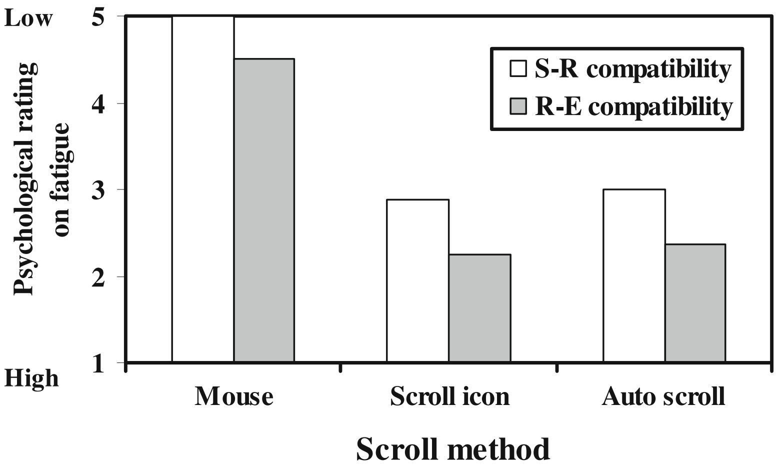

Fig. 7. Psychological rating on fatigue as a function of scroll method and compatibility

4 Discussion

For all scroll methods, the task completion time did not differ between R-E and S-R compatibility conditions (see Fig. 4). In other words, the speed of scroll did not differ between two compatibility conditions for all of three scroll methods.

The number of errors per 90 trials significantly differed among scroll conditions and between R-E and S-R compatibility conditions (see Fig. 5). Judging from the accuracy of scroll, the error was less when the S-R compatibility like non-touch screen Microsoft Windows was applied than when the R-E compatibility like iPod or iPad was applied. In the range of this study, it seems that the S-R compatibility is dominant from the viewpoints of scroll accuracy for all of three scroll methods.

The subjective rating on both usability and fatigue (see Figs. 6 and 7) also supported the superiority of S-R compatibility over the R-E compatibility condition. These results did not agree with the results by Chen and Proctor [10] who showed that R-E compatibility was desirable for the scrolling on PCs. This shows that the desirable scroll method for the traditional interaction using a keyboard and a mouse does not necessarily apply to the scroll method using an eye-gaze input system. In future work, the validity of this study should be verified by collecting more data or observing the learning process to each compatibility and each scroll method.

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