Continuous Gaze Cursor Feedback in Various Tasks: Influence on Eye Movement Behavior, Task Performance and Subjective Distraction

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Abstract. Using gaze as input modality has often been promoted as a method for advanced computer interaction. One important detail in gaze controlled interfaces is the design of optimal feedback. Highlighting the current point of gaze by a gaze contingent cursor represents a simple form of feedback. In an experimental study, we investigated the influence of gaze cursor feedback on eye movement behavior, task performance and subjective distraction. Participants of the study completed three different tasks (gaze typing, reading and image exploration) with five different feedback conditions. No-feedback was implemented as baseline condition and compared with gaze cursor feedback of various spatial precision and temporal delays. A blue, semitransparent small dot served as gaze cursor. The observed findings are discussed in the context of user friendly feedback for gaze based computer interaction.

Keywords: eye tracking, gaze interaction, cursor feedback, eye movements, distraction, gaze typing, reading, image exploration.

1 Introduction

Using gaze as input modality has often been promoted as a method for advanced computer interaction [1]. Although various concepts for gaze interaction have been proposed, the most often used and intuitive concept is that of gaze pointing in conjunction with dwell time based selection [2]. In order to interact with the on-screen interface elements (e.g. buttons), the user has to look at the respective element for a predefined (dwell) time; typically 500-1000 ms. Previous research has focused on various aspects of gaze interaction, such as the optimal dwell time for text entry or the design of appropriate user feedback [2].

A simple form of feedback in gaze based interfaces is a cursor that follows the user's eye position [1]. The gaze cursor provides a direct continuous feedback and might be beneficial to adjust gaze behavior in case of poor eye tracking accuracy. However, there might also be disadvantageous effects due to the continuous movement of the cursor that could distract from the task at hand [1]. Moreover, a gaze cursor might alter gaze behavior itself and influence basic processes of perception and

C. Stephanidis (Ed.): HCII 2014 Posters, Part I, CCIS 434, pp. 323–329, 2014.

cognition. Previous research has examined influences of cursor shape on usability [3] or the temporal delay of the shown gaze cursor on performance in gaze typing [4]. However, the relationship between gaze cursor feedback and its influences on perception and performance are still unknown.

This issue becomes more relevant as cheap and mobile eye tracking devices become available. These systems often come with limitations regarding their spatial precision and temporal resolution, resulting in imprecise and inaccurate gaze position signals. Such noisy signals can be improved by data filtering [5] providing a more stable and exact signal. Applying such forms of filtering, automatically introduces a temporal delay between the point of gaze in real time and the gaze cursor position, which presumably affects performance in gaze based interfaces [2].

Here we investigated influences of gaze cursor feedback on user behavior in three different tasks: dwell time based gaze typing, text reading and exploration of images. We manipulated spatial and temporal characteristics of the gaze cursor behavior in order to simulate eye tracking systems of various precision or effects of data filtering. We analyzed the influences on the control of eye movements, on the task performance, and on the subjective evaluation of distraction caused by the gaze cursor.

2 Method

2.1 Participants

Fourteen subjects, (8 females) participated (age: M=25 years) in the study. All had normal or corrected to normal vision and received a reward of 10€ for their efforts. Informed consent was obtained prior to the test session.

2.2 Apparatus, Stimuli and Procedure

An EyeLink CL (SR Research Ltd.) system served as an eye tracking device. Recording was done monocular (right eye) with a temporal resolution of 250 Hz. A chinrest was used to stabilize the head. A 24” wide screen monitor (BENQ Model XL2420-B, refresh rate: 120 Hz, screen resolution: 1920x1080 pixel) was used to display the experimental tasks and placed at a distance of 68 cm from subjects head.

In the experiment subjects performed three different tasks: gaze typing, reading and image exploration. Each task was run in a separate block, consisting of multiple trials. The order of the tasks was balanced across the participants.

For gaze typing, subjects had to enter a sequence of five numbers on a numeric screen keypad by using gaze. A trial started with a random sequence of five numbers, shown on the left side of the screen for 3 s. Then, a numeric keypad (ten-key type with numbers 0-9) was presented, centrally aligned to the screen. Each number (font size 16) represented the center of a gaze sensitive button (size: 150x150 pixel, clearance: 50 pixel) with a dwell time of 500 ms. In the gaze-over state, the button changed its color to blue, the font size increased to 20 and the font style changed to bold. If the gaze remained on the button for the set dwell time, color changed to light blue for 300 ms and font size increased further to 28; it was registered as a button press and the respective number was entered. Subsequently, the button resumed to its gaze-over status. If the gaze left the button it returned to its original appearance. Once the typing of the five numbers was completed, subjects had to activate a dwell button in the lower left corner of the screen to proceed with the evaluation query. A question appeared, asking to rate the intensity of distraction during the task completion due to the cursor feedback (six-item Likert scale). Subsequently, subjects were able to continue with the next trial. Altogether the gaze typing task contained 50 trials.

In the reading task subjects had to read paragraphs of text for comprehension. A trial started with a central fixation cross (2 s). Then, the paragraph (~160 words, font size: 24) was presented, aligned centrally to screen. After reading the paragraph once, subjects had to activate a dwell button at the lower left corner in order to proceed with the evaluation query. Two questions appeared; one question asked for a certain word in the paragraph and the second question was the same rating as in the gaze typing task. After answering both questions, subjects summed with the next trial.

In the image exploration task subjects' had to explore images of paintings in order to memorize its content. The images (1152x864 pixel) were shown in colors and were centrally aligned to the screen. Each trial started with a fixation cross (2 s), followed by the image presentation for 15 s and was completed by the evaluation query. One question required to judge if a presented image cutout (80x80 pixels) belonged to the previously seen image. The second question was again the distraction rating.

Within the experiment five variations of gaze cursor behavior were implemented and quasi randomly assigned to the trials of each task. A small semitransparent blue dot (size: 20 pixel) served as cursor. A condition without cursor (*no feedback*) served as a baseline. In the *direct* feedback condition the cursor was displayed at the current gaze position on screen with a slight jitter. In the *direct-noisy* condition an error (Gaussian distribution with $M = 0$, $SD = 15$) was added to gaze position signal, creating a noticeably erratic cursor. In the *smoothed* condition the mean value of the last ten samples was used, generating a highly precise cursor with a small temporal delay (40 ms). In the *smoothed-delayed* condition the smoothed signal was further delayed by ~280 ms, creating the impression of dragging the cursor behind. Only the cursor feedback was manipulated, not the gaze input that was used to control the typing task.

2.3 Data Analysis

Subjective ratings of distraction for each task and cursor condition were pooled for each subject. Eye movements and behavioral data were analyzed for the time span while the task was performed. Median of fixation duration, saccadic amplitude and number of short saccades (<2°) for each task, cursor condition and subject were aggregated. Task performance for each task was analyzed individually. For gaze typing, we analyzed the time for task completion, total number of errors (missing and erroneous activations) and the number of repeated button activations. For the reading task, we calculated reading time per word, number of regressive saccades (saccades opposite to the reading direction) and percent of correct answers in the word query. For the image exploration task, the percent of correct answers for the cutout recognition was analyzed. All measures were analyzed with repeated measure ANOVAs.

3 Results

The analysis for rating of distraction showed main effects for task, $F(2,26) = 5.68$, $p < 0.05$, and cursor condition, $F(4,52) = 78.7$, $p < 0.001$, and a significant interaction between task and cursor, $F(8,104) = 10.1$, $p < 0.001$. Subjects rated cursor feedback most distracting in the reading task and least distracting during gaze typing (see Figure 1A). The noisy cursor was evaluated most distracting. As reflected by post-hoc pair wise comparisons, all other cursor conditions were significantly different from the noisy as well as from the no feedback condition, ($p < 0.05$). The significant interaction was related to a reversed evaluation in the no feedback condition.

Analysis of fixation duration revealed a main effect for task, $F(2,26) = 8.89$, $p < 0.01$, cursor condition, $F(4,52) = 9.27$, $p < 0.01$, as well as a significant interaction, $F(8,104) = 7.44$, $p < 0.01$. Fixation durations were shortest for reading and longest for gaze typing (see Figure 1B). Cursor feedback generally increased fixation duration (about 10 ms in the reading and 20 ms in the image exploration/gaze typing task). In gaze typing there was an additional increase for the smoothed and delayed condition, which was not observable during reading and image exploration.

No effect of cursor condition was found in the analysis of saccadic amplitudes. Only a main effect of task was observed, $F(2,26) = 91.2$, $p < 0.001$. Saccadic amplitudes were largest in the gaze typing and smallest in the reading task. A more detailed picture was obtained in the analysis of frequency of small saccades, which revealed significant effects for task, $F(2,26) = 92.7$, $p < 0.001$, cursor condition, $F(4,52) = 11.7$, $p < 0.001$, and a significant interaction, $F(8,104) = 3.5$, $p < 0.05$. The frequency of small saccades was higher in the reading task compared to image exploration and gaze typing. Generally, more small saccades occurred in the no feedback compared to the cursor conditions, apart from the smoothed cursor condition (see Figure 1C).

Task performance measures for gaze typing revealed poorest results for the smoothed/delayed cursor condition. Subjects were significantly slower (task completion time) and made more errors (total number of errors, number of repeated activations and number of erroneous entries) with the delayed cursor, all $F > 15$, $p < 0.001$. There were no differences between all other cursor conditions, including no feedback.

For reading we found a main effect for reading time per word, $F(4,52) = 3.7$, $p < 0.05$. Subjects were slower in the no feedback condition (280 ms) and fastest with the smoothed cursor (257 ms). Pairwise testing revealed a significant difference between these two conditions only. A similar finding was observed for frequency of regressive saccades. Again we found a main effect for cursor condition, $F(4,52) = 4.5$, $p < 0.01$. Fewest regressive saccades were made in the smoothed cursor condition, which differed significantly from no feedback and delayed feedback condition

($p < 0.05$, pairwise testing). No significant effect was found concerning the recognition performance of target words, but a similar trend was observed with poorest performance for no feedback and delayed cursor condition.

The analysis of recognition performance for cutouts in the image exploration task revealed no main effect of cursor condition, $F(4,52) = 2.01$, $p = 0.09$. However, the trend was similar as in the reading task, with poorest recognition performance in the no feedback and best performance in direct and noisy feedback condition.

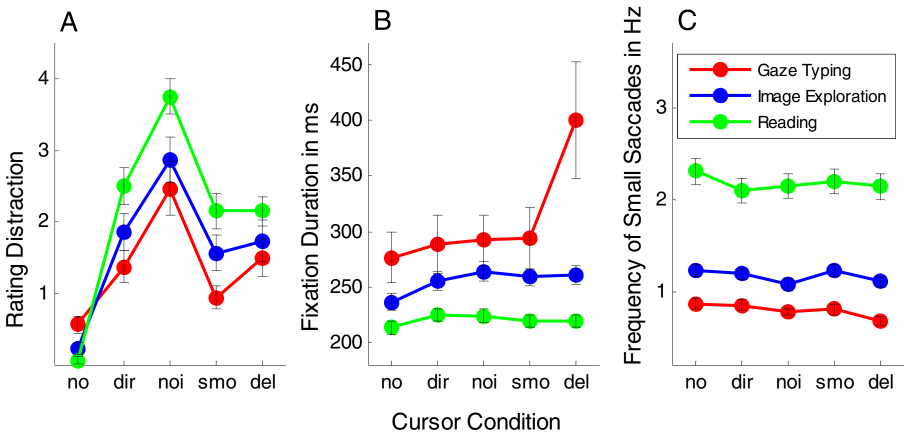

Fig. 1. Effect of cursor feedback on subjective ratings of distraction (A), fixation duration (B) and the frequency of small sized saccades (C) for three different tasks. Larger values in (A) indicate higher level of subjective distraction during the task. Abbreviations cursor condition: no = no feedback, dir = direct, noi = direct and noisy, smo = smoothed, del = smoothed and delayed.

4 Discussion

Our results show that perceived distraction by a gaze cursor is strongest in the reading task; especially the noisy cursor was rated as disturbing. Accordingly, cursor feedback seems not appropriate if an interface contains text or images. For gaze typing, however, a cursor seems less detrimental; it might be even experienced as useful. This raises the question of what to do if mixed contents, i.e. text, images and buttons, are present? No cursor presentation might be one option. Another one is a configuration, with the cursor visible only in the spatial extent of buttons. Consequently, this cursor would switch on and off abruptly when the user moves the gaze across the interface. This might lead to new and probably unwanted effects of distraction [6]. A possible solution would be to replace the rapid on- and offsets by more gradual fading.

The gaze cursor also induces direct effects on the control of eye movements by increasing fixation durations and influencing the frequency of small saccades. Contrary to the rating of distraction this effect was smaller for reading than for image exploration and gaze typing. The feeling of subjective distraction is thus not related to objective effects on behavioral control. Particularly, the highly disturbing effect of a noisy cursor is not reflected in data of fixation duration. Unexpectedly, the frequency of small saccades decreased when a cursor was shown. This might reflect efforts of the visual system to cope with the distracting event by stabilizing the gaze, which, in turn, could increase fixation durations. Yet, this explanation is not backed up by data. Fixation duration was longest in the delayed cursor condition of the gaze typing task, but neither a decrease in the frequency of small saccades nor an increased rating of distraction was observed.

Regarding task performance in gaze typing, subjects' were slowest and made most typing errors in the delayed cursor condition. There were no differences between other cursor conditions (incl. no feedback). Despite the fact that the interface control was the same as in the other conditions the highly delayed cursor seems to be very obstructive for gaze typing performance. Apparently, subjects' seemed to wait for the cursor to arrive at the current gaze position, slowing down performance and leading to more errors (repeated and erroneous activations). A higher dwell time (>500 ms) might help to circumvent this problem. For interface design this needs to be acknowledged by adjusting dwell times according to the cursor delay or include adjustable dwell times [4].

Surprisingly, we did not observe a negative influence of a gaze cursor on performance in the reading task. In contrary, findings point in the opposite direction. According to our results, performance in both tasks, i.e. word and cutout recognition, was poorer for the no feedback compared to the cursor conditions (apart from delayed cursor). Despite the increase in fixation duration, reading time per word and the frequency of regressive saccades decreased, both indicating enhanced reading performance. We are not aware of any theoretical or empirical background that could explain or support these findings. Therefore, further empirical testing is needed for clarification of this surprising effect.

Acknowledgements. This research was supported by grants from the German ministry of education and research (BMBF 16SV5843) to the project FAIR.

References

1. Jacob, R.J.K.: Eye movement-based human-computer interaction techniques: Toward noncommand interfaces. In: Hartson, H.R., Hix, D. (eds.) Advances in Human-Computer Interaction, vol. 4, pp. 151–190. Ablex Publishing Co. (1993)
2. Majaranta, P.: Text Entry by Eye Gaze. Dissertation. In: Interactive Technology, vol. 11. University of Tampere, Tampere (2009)
3. Murata, A., Uetsugi, R., Hayami, T.: Study on Cursor Shape Suitable for Eye-gaze Input System. In: Kurosu, M. (ed.) HCII/HCI 2013, Part IV. LNCS, vol. 8007, pp. 312–319. Springer, Heidelberg (2013)

4. Helmert, J.R., Pannasch, S., Velichkovsky, B.M.: Influences of dwell time and cursor control on the performance in gaze driven typing. Journal of Eye Movement Research 2, 1–8 (2008)
5. Spakov, O.: Comparison of eye movement filters used in HCI. In: Proceedings of the Symposium on Eye Tracking Research and Applications, pp. 281–284. ACM, Santa Barbara (2012)
6. Yantis, S., Jonides, J.: Abrupt visual onsets and selective attention: evidence from visual search. Journal of Experimental Psychology: Human Perception and Performance 10, 601–621 (1984)