Gaze-based Cursor Control Impairs Performance in Divided Attention

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Abstract: In this work we investigate the effects of switching from mouse cursor control to gaze-based control in a computerized divided attention task. We conducted experiments with 9 participants performing a task that requires continuous focused attention and frequent shifts of attention between the parallel tasks. Although the mouse control version was well-practiced, we hypothesized that gaze-based control would impair performance considerably because of the increased cognitive load. Our assumptions were confirmed by statistical analysis methods. The results of this study provide evidence that care should be taken in the design of interfaces controlled by human eye-gaze, which require divided attention.

Keywords: gaze-based control, eye tracking, divided attention, human performance, cognitive load

Introduction

Eye movements reveal emotions and cognitive processes, and indicate the search target during visual exploration [1]. Due to the technological advancements in eye tracking research, non-intrusive and accurate hardware solutions are readily available (see, e.g., [2]). Moreover, explosion in computer vision in recent years lead to the development of state-of-the-art appearance-based gaze estimation methods that use only images and videos from off-the-shelf monocular RGB cameras, and have an acceptable range of errors in prediction (see [3] and the references therein).

Gaze estimation has important applications in the field of human-computer interaction [4]. The traditional method for controlling the computer cursor is the PC mouse. Switching to gaze-based control has a number of advantages. Especially the performance of children with disabilities can be enhanced considerably through gaze controlled computers [5]. In the case of older adults, it may be able to compensate for the declined motor functions [6]. Gaze can also represent a superior input modality in simple computer games in terms of achievements or user experience [7].

On the other hand, when the task is cognitively demanding and requires the divided attention of users, gaze-based control might impair performance. In this study we provide evidence for this latter assumption by comparing the performance of subjects in a divided attention task between the practiced conventional mouse control and gaze-based control versions.

We designed and implemented a simplified version of the popular Train of Thought game from the Lumosity (http://www.lumosity.com/) online platform. Lumosity is comprised of a set of computerized games designed by scientists, each aiming to train one of five core cognitive abilities: attention, processing speed, memory, flexibility and problem solving [8]. We will refer to our version of the Train of Thought game simply as the *Train Game*. We do not detail the design and implementation process due to space limitations, but only describe briefly the purpose of the task.

The Train Game tests players divided attention and working memory by requiring them to continuously focus on multiple simultaneous targets, to switch frequently between them keeping track of each one. The task of the user is to direct continuously oncoming trains to their color-matching destination through flipping switches at forks with mouse clicks and changing this way the direction of the tracks and the path of the moving trains.

The paper is organized as follows. In Section we describe the experiments with the Train Game and differentiate two types of user errors. Section presents the results of the statistical analysis. This is followed by a discussion in Section . Finally, Section concludes the paper and mentions future directions.

Methods

Participants and experiments

We have performed a series of experiments with 10 participants, who were asked to play with the mouse control and the gaze-based control of the Train Game. The volunteers were aged between 25 and

30 (mean age was 27 years, SD=1.76), had normal or corrected-to-normal vision and reported no attention disorders nor color vision deficiency. Also they were naive in the sense that they were not familiar with the Train Game as well as did not have prior experience in Lumosity games. The participants were instructed that data about their gameplays will be logged for further analysis and they were asked to sign a consent form before the experiments.

The experiments with the mouse control version of the Train Game lasted several days, with multiple trials played each day. We manipulated the difficulty of the game according to the score of the players from the previous trial. Based on this, the experiments were separated into three phases: beginner, intermediate and advanced.

For the experiments with the gaze control version of the Train Game, 9 out of the 10 participants were invited back for ten additional trials. For gaze tracking the Tobii EyeX Controller (`https://tobiigaming.com/product/tobii-eyex/`) device was used, which is attached to the bottom of the monitor, has a sampling rate of 60 Hz and requires personal calibration before each data collecting session. The traditional mouse cursor was replaced by a yellow dot displayed at the screen coordinates of the gaze direction. To reduce the noise of the gaze tracker device, we applied a moving average window on each of 5 consecutive samples. If the distance of consecutive gaze points and the center of a switch node was below a threshold for longer than 500 ms, a mouse click was simulated that results in flipping the switch.

User error types

The details of the experiments with the mouse control version of the Train Game are presented in our previous work [9]. For the purposes of this study we selected 10 consecutive trials from the intermediate phase to compare them with the 10 gaze control trials.

The performance of the participants is determined by the user errors, which can be separated into two categories. (i) Errors of omission are the cases when the player misses an action, are the more common ones and can have several causes: the place of the action is outside the visual field, too little time to perform multiple parallel tasks. (ii) Errors of commission occur when the player performs a prohibited action, and do not correct it. These latter actions are the more rare ones in the Train Game and happen when the player confuses two colors, performs an action too early or acts recklessly because of pressure.

In our analysis we computed the number of each type of user errors and compared the means between the mouse control and the gaze-based control versions using the repeated measures analysis of variance (ANOVA) statistical model.

Results

We calculated the total number of user errors for each trial in both conditions (mouse control and gaze control). There was a statistically significant difference in means of user errors between the two control types, as determined by the repeated measures ANOVA, $F(1, 8) = 61.19$, $p < 0.001$. Figure 1 shows the mean of the user error numbers across trials in each of the two control versions of the Train Game, separately for every subject.

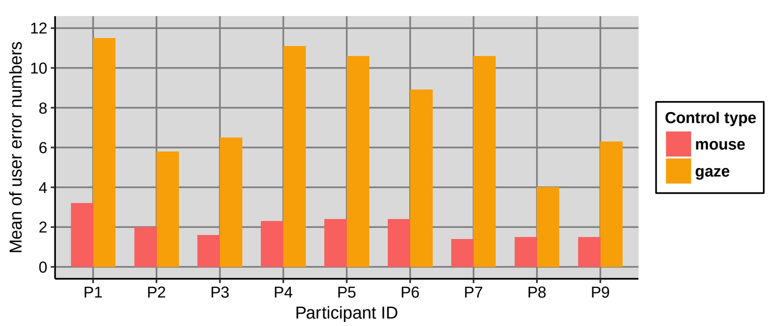

Figure 1: Comparison of mean of overall user error numbers separately for participants.

The proportion of the commission type of errors to the total number of errors was also calculated. Figure 2 compares these percentages computed over all 10 trials for each participant. We can see that generally the proportion of commission errors is considerably higher in the gaze version. Also, the repeated measures ANOVA for proportion of commission errors (computed for each trial separately) showed significant main effects of control type (mouse vs. gaze), $F(1, 8) = 20.28$, $p = 0.002$.

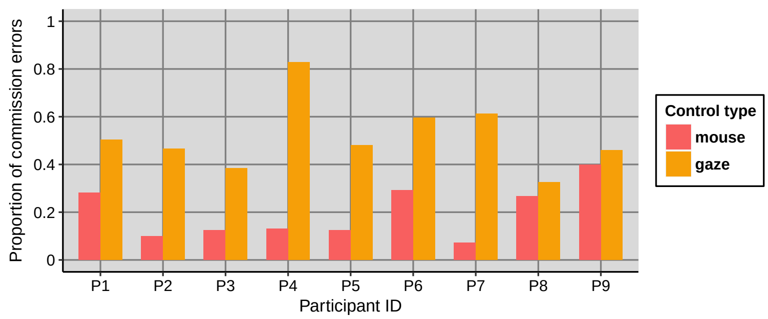

Figure 2: Comparison of proportion of commission type user errors separately for participants.

Discussion

We tested the effect of switching from mouse control to gaze-based control in a complex divided attention task. The number of user errors was increased in the latter version as seen on Figure 1, and this change was also statistically significant, as determined by the repeated measures ANOVA. One might argue that our results are biased because of the latency for mouse click simulation or the selection of the trials for comparison. The latency contributes indeed to cognitive load because it limits the exploration time. However, the intermediate phase was the part where subjects were familiar with the Train Game and could play comfortably after the beginner phase. In the advanced phase difficulty was high in order to test the effects of time pressure. More importantly, we also compared the proportion of errors of commission, shown on Figure 2, and have seen that this also increased significantly in the gaze control version. Consequently, performance decrements can be attributed to reckless actions from the increased cognitive load and not time constraints.

The sample size in this study is small, which limits the generalizability of the results. Also,the performance differences are partially due to the lack of practice with gaze-based control. However, not only was the overall number of errors larger, but the proportion of errors of commission increased consistently for all of the subjects in our experiments. This is a result of increased cognitive load. Furthermore, our conclusions are in line with studies investigating gaze-based control in demanding tasks. For example, Smith and Graham [10] found that mouse control was easier in a first-person shooter game. This may be related to the "Midas Touch" problem, which could be expanded in our case too.

Conclusion and future work

Eye movements are an important cue for inferring human behaviour. Gaze can indicate emotions, intentions, objects of interest and focus of attention. Gaze estimation has relevant applications in the design of interfaces that facilitate human-computer interaction. Gaze control had a negative impact on the performance of users in our experiments. These results provide evidence that in the case of complex tasks requiring the divided attention of users, switching from the traditional mouse control to gaze-based control may not be the best choice. Our efforts suggest that at least considerable amount of testing and/or training is necessary before using such interfaces in real-life scenarios.

The combination of mouse and gaze-based input may represent a suitable solution in such cases. Future studies should also investigate the effects of gaze control on the strategies of subjects, which influence performance in multitasking to a great extent.

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