Eye Strain from Switching Focus in Optical See-Through Displays

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Abstract. The optical see-through (OST) display is one of the key enabling devices for augmented reality. Despite the latest craze such as with the Google Glass, there are still many ergonomic problems associated with the OST displays. One of the already well known such problem is the "refocusing" problem, in which the user has to switch one's focus between the distant real world and see-through display up front. Such refocusing, for one, is bound to cause significant strain and fatigue to the eyes. However, there are not many studies, nor guidelines devoted to this issue. In this preliminary work, we ran experiments to measure the degree for eye strain and its pattern at different refocusing distances and durations (or number of focused targets). The findings should serve as one guideline in designing OST glass based interaction and applications.

Keywords: Optical see-through displays · Eye strain/fatigue · Usability · Augmented reality · Focus

1 Introduction

The continued innovations and advances in computer vision, mobile/cloud computing and portable display devices have brought about a renewed interest in augmented reality (AR) as a prominent information visualization and interaction medium. In particular, since the recent introduction of the Google Glass [1], optical see-through (OST) displays are becoming more compact and fashionably designed, and thereby getting accepted to the mass users. Yet, there are some concerns as well [2, 3], and one such is the eye fatigue and even the potential to hurt the eye as the user has to make conscious effort to focus on the tiny display in the upper right corner of the glass (as in the case of Google Glass). More specifically, the use of OST displays unavoidably entails the frequent switch between looking into the real world and refocusing on the small display up front (or at distance to the virtual image plane).

While this refocusing problem (and fatigue) is unavoidable, its detailed ergonomic effects need to be studied and known to reflect it into the interaction design involving the use of OST displays. However, aside from general literatures on various factors that can cause different types of eye fatigue, not many studies have been made in the context of this AR specific problem. With such motivation, we ran experiments to measure the level of fatigue caused by the frequent refocusing between real and virtual objects, and its relation to the focusing duration.

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2 Related Work

Usability problems with OST displays are not new, e.g. due to its cost, weight, size, image quality and lowered brightness, distorted depth perception, mismatch in the resolution of the augmentation with that of the real world imagery, registration and calibration errors, incomplete masking by the augmentation, etc. [4, 5]. The recent introduction of Google Glass made quite a stir with its sleek and light-weight design, and has much improved the wearability aspect, however, many ergonomic problems still remain. While there have been almost no formal studies on the Google Glass itself, there have been few media reports of the potential eye strain problem [2, 3]. Huckauf et al. compared the visual search and focus switching tasks on between computer screens and OST displays, and confirmed the lowered performance on the OST displays. Furthermore, they also found that users tended to misjudge the target object depth, namely closer than the actual [6].

3 Experiment 1: Fatigue Caused at Different Refocusing Lengths

Obviously, the fatigue from the refocusing task will be closely related and proportional to, among others, the refocusing distance. In this study, we are interested in the changing pattern of the fatigue level, e.g. whether it is approximately linear, exponential, saturating (e.g. log), step-like form and whether it is symmetric with respect to some nominal comfortable focusing distance. Based on the findings, we might limit the objects targeted for augmentation only to be within some nominal range of distance to minimize the eye strain.

Five paid subjects, 3 men and 2 women with a mean age of 23, participated in the experiment. An experiment with one-factor (4 different refocusing distances) within-subject with repeated measures was conducted. The task was to focus at an object in the real world and refocus to information displayed on the Google Glass in which the virtual image plane is formed at about 2.4 m away from the eyes. The objects were placed at 6 m, 3 m, 1 m and 30 cm from the user making the refocusing distances, 3.6 m, 0.6 m, 1.4 m and 2.1 m, respectively. The user had to state whether the object in the real world and the information displayed on the glass matched or not (see Fig. 1).

The fatigue level was measured indirectly by measuring the response time. (i.e. stating whether the information in the display matched or not) and through a survey. The task was repeated over four five-minute blocks after which a fatigue survey was completed. The level of eye fatigue can be measured in many ways, ideally through optometric measurements, physiological signals (e.g. EMG of eye muscles) or using eye tracking devices. However it is generally difficult to use such apparatus because the glass has to be worn. Instead eye strain can be indirectly assessed by other indicators such as degradation in task performance, immediate symptoms such as dryness or over-blinking, and after effects such as headaches and neck [7].

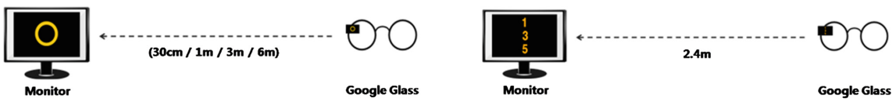

Fig. 1. The refocusing task using the Google Glass and measuring the associated fatigue level: (a) Experiment 1 (left), (b) Experiment 2.

Figures 2 shows the average response time (for total of successive 200 trials) and answers to the survey (about the perceived fatigue and eye strain). As expected, the fatigue level was proportional to the refocusing length, where the least amount of fatigue was felt at the refocusing distance of 0.6 m, and the most at 3.6 m. The fatigue levels actually slightly dropped after 5 ~ 6 min but then rose sharply and steadily increased afterwards. No other clear trend of particular changing patterns, other than direct proportionality, was detected.

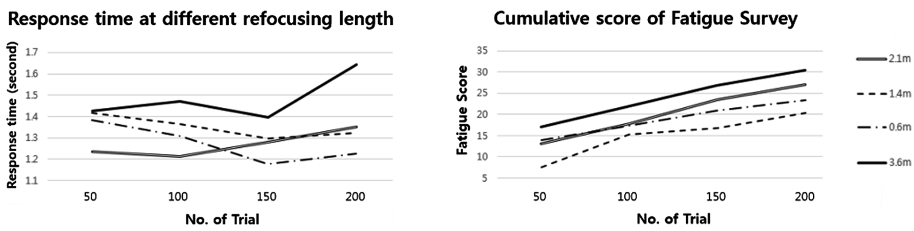

Fig. 2. Average response time (for total of successive 200 trials) and cumulative score of the fatigue survey about the perceived fatigue and eye strain.

4 Experiment 2: Refocusing Frequency vs. Duration

Through the first experiment, we were merely able to confirm an obvious fact that the eye fatigue and eye strain increased according to the extended refocusing distance. In the second experiment, we fixed the refocusing distance and varied the information amount at which to focus, namely one, three and five objects laid out vertically (similarly to the typical Google Glass menu). This way, we can compare the level of fatigue between when displaying little information but having to refocus several times vs. displaying more information at a time and focusing longer on them and having to refocus a less number of times.

Again 5 paid subjects, 3 men and 2 women with a mean age of 23, participated in the experiment. Again the experiment with one-factor (3 different information amounts) within-subject with repeated measures was conducted. In the three treatments (presented in a balanced order), the user had to look at one, three and five real world objects and placed at 2.4 m, refocus to the glass display and report if the objects matched to those in the glass display (see Fig. 1). The user was given 20 min and the user performance was recorded (i.e. how many refocusing tasks could be accomplished and how much pieces of visual information could be processed).

Figure 3 illustrates the results and among the three treatments, the best performance (per effort/fatigue) was achieved by managing the refocusing and focusing duration with a block of three objects (ANOVA, $F(2, 72) = 14.18$, Tukey tests with p-values < 0.03). The results shows the refocusing distance and amount of information displayed need to be carefully modulated to improve general usability of OST displays.

Fig. 3. Number of tasks accomplished (or amount of visual information processed) in unit time. Best performance per effort/fatigue was obtained with the block of three objects.

5 Conclusion and Future Work

In this poster, we have conducted pilot experiments assessing the nature of eye strain and fatigue as related to the refocusing distance and how it might relate to the amount of visual information that need to be focused at one time and processed. The findings are still only preliminary as it requires more subjects and experimental conditions to derive more definite conclusions. The contribution lies in taking the first step toward quantifying ergonomic problems of OST displays in the context of AR, and showing directions for the future full scale experiments.

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