Reducing VR Sickness through Peripheral Visual Effects

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ABSTRACT

This paper proposes and evaluates two novel visual effects that can be applied to Virtual Reality (VR) applications to reduce VR sickness with head-mounted displays (HMD). Unlike other techniques that pursue the same goal, our approach allows a user to move continuously through a virtual environment without reducing the perceived field of view (FOV). A within-design study with 18 users compares reported sickness between the two effects and baseline. The results show lower means of sickness in the two novel effects; however, the difference is not statistically significant across all users, replicating large variety in individual reactions found in previous studies. In summary, reducing optical flow in peripheral vision is a promising approach. Future potential lies in adjusting visual effect parameters to maximize impact for large user groups.

Keywords: VR sickness, peripheral vision, locomotion.

Index Terms: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities

1 INTRODUCTION

VR sickness, cyber sickness, or simulator sickness varies a lot from person to person and generally increases with time spent in VR (see [2]). It is typically believed that our visual system detects a motion in VR that is not present in the real world and therefore conflicts with the vestibular system, causing VR sickness. This effect seems to appear prominently with increased peripheral vision present in HMDs. Several techniques try to reduce visual-vestibular conflict thus aiming at improving the VR experience. However, most of them rely on an unnatural locomotion system like teleportation or reduce the perceived FOV. We present two effects that alter the visualization in the peripheral vision with the intention of reducing the conflict with the vestibular system. We also report on the results of a user study where each participant experienced a scenario which typically induces VR sickness. Both effects and no effect as a baseline were shown to each participant and the perceived sickness was tracked. Finally, we evaluate these reported sickness values and test whether any of the effects correlate to perceived sickness.

2 RELATED WORK

Different strategies were developed trying to avoid motion sickness during locomotion in virtual environments like reducing the blur level, changing the speed or the focal point [5]. Kemeny et al. [3] investigated different acceleration thresholds for longitudinal and rotational motions to reduce cyber sickness. Another important aspect is the FOV. Fernandes et al. [2] showed that reducing the FOV can lead to a lower simulator sickness. Chen et al. [1] also showed that an increased FOV can increase the nausea on a screen view as well as on a binocular view. In contrast to these solutions our approach aims at preserving the FOV.

3 EFFECT DESCRIPTION

Both of our proposed effects, the “circle effect” and the “dot effect”, alter the visualization of the application in the peripheral area of the perceived visual image aiming at reducing effective optical flow. Both effects have in common that they are visible only when a user is navigating using a controller, e.g., by pressing a forward button. The effects do not appear when the user moves in a tracked area, because that type of navigation does not induce a conflict of the perceived motion and the vestibular system and therefore should not induce VR sickness.

3.1 Circle Effect

The idea behind the circle effect is that the peripheral vision shows the point of view of a different camera, which stands still while the camera is moving in virtual reality. The border between the outer peripheral vision with the still camera and the inner vision with the image of the regular camera is visible as a circle (see figure 1 left). To limit the negative impact on immersion of this visible artifact, the view of both cameras is blended linearly. As soon as the user stops the movement, the view of the still camera fades into an updated view of the current focal perspective. During depth motion, the peripheral camera blends in updated views periodically every five seconds so that the peripheral image matches color and brightness levels of the focal part of the view.

Figure 1: Circle effect on the left and dot effect on the right.

3.2 Dot Effect

The dot effect adds artificial motion in our peripheral vision that counteracts the virtual motion of the environment when the user is moving. For example, when the user decides to move forward with the controller in virtual reality at velocity **v**, the environment appears to move backwards. The optical flow makes objects in the peripheral area appear moving out away from the center of vision. Such movement potentially leads our brain to assume movement in the desired forward direction (called vection), while the vestibular system contradicts this impression because the user does not actually move in reality, influencing VR sickness. To neutralize this perceived motion or vection, artificial dots are displayed with velocity **2v** in moving direction (see Fig. 1, right). Relative to the user, the dots appear to be moving at velocity **v** and the environment appears to move at velocity **-v**. As a result, motion of the environment and motion of the dots in the peripheral vision cancels

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each other out to zero optical flow in peripheral vision, which then matches the actual motion of the user in real space.

4 METHODOLOGY

To test how both effects impact VR sickness, we created a VR environment, where a VR user solves a navigation task under three conditions: the circle effect, the dot effect, or no effect. The environment is based on the Viking Village Demo, which contains a few buildings and a road with a small slope. We placed 20 blue boxes, each labeled with a number, into this environment, and tasked the participant to collect these boxes in ascending order. We used Unity, VRTK and the HTC Vive as HMD and one of the included controllers for navigation. The controller touchpad changes both backward and forward motion in head-direction. For adjusting orientation, the participants had to rotate their head.

We invited participants via e-mail and awarded 3 random participants with a 20€ shopping voucher. First, a pretest was performed with 7 participants to adjust parameters like motion speed, dot size and radius size of the circle. Then 18 students and employees (12 male, 6 female) at the age of 19-38 participated in the study. Each participant was first instructed about risks of VR sickness, how controls work and what the goal of the game is. While in VR, the instructor asked verbally every minute how the participant was feeling on a scale from 0 to 20: Zero meaning the participant feels the same as when entering the lab and twenty meaning that the participant wants to quit (FMS, Fast Motion Sickness scale [4]). Unless a participant wanted to quit early (which never happened), each one stayed in VR for up to 15 minutes. The participant experienced both the circle and dot effects and no effect for 5 minutes each in counterbalanced order in latin-square design.

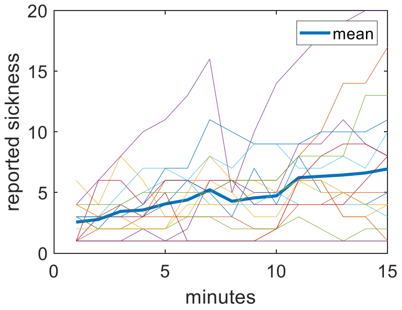

Figure 2: The reported sickness (scale 0-20) every minute for all 18 participants and the mean.

5 RESULTS

Figure 2 shows the reported sickness of each participant over the duration of 15 minutes. The mean shows the expected trend of increased sickness over time. It also shows large variance in the experienced VR sickness. Figure 3 shows the reported sickness during each of the effects and indicates a slight positive effect of the circle effect on VR sickness.

To assess how each effect alters the rate at which VR sickness increases over the duration the effect is experienced, we also compare the finally reported sickness of an effect to the sickness that was last reported before the effect was initially shown (or zero, if it was the first experienced effect). Figure 4 shows the boxplot of these sickness differences and indicates a small positive effect of both the circle and dot effect in comparison to no effect.

To determine whether this positive effect is significant, we performed a Friedman Test. While the resulting Friedman rank indicate, just like the mean and median, that circle and dot effect reduce VR sickness (see Table 1), the resulting p-value does not show statistical significance ($\chi 2(2) = 1.121$, $p = 0.571$, $N = 18$).

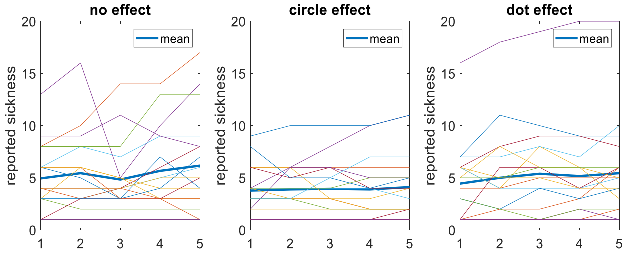

Figure 3: Reported sickness per effect over duration in minutes.

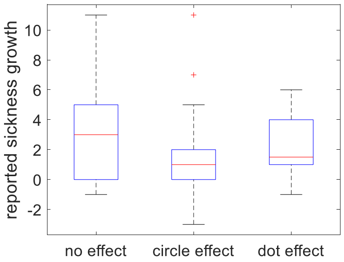

Figure 4: Difference between the reported sickness at the end and the beginning of experiencing each effect (red line is median).

Table 1: Distribution values of the reported sickness growth.

Reported sickness growth	No effect	Circle effect	Dot effect
Mean	3.056	1.556	2.333
Median	3	1	1.5
Standard Deviation	3.208	3.434	2.425
Friedman rank	2.11	1.81	2.08

6 CONCLUSION AND FUTURE WORK

While our study does not show significant effects in reducing VR sickness with our proposed visual effects, they do indicate that reducing optical flow in peripheral vision is promising: less users reported high impact on sickness with the new effects than with no effects. To further evaluate the potential, we will adjust parameters in visual design (dot size, frequency, opacity for dot effect; radius, blending effect and update frequency for circle effect). In comparison to other studies [2] the overall reported sickness in our study seem much lower. Testing with other environments that may generate more VR sickness (e.g., inducing vertical motion, higher speeds) might further help to identify impact from visual effects.

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