International Conference on Artificial Reality and Telexistence
Eurographics Symposium on Virtual Environments (2024)
T. Tanabe and V. Yem (Editors)

Poster

Analyzing the Impact of Movement Speed on CyberSickness in Virtual Reality Using Eye-Tracking Data

Tenchi Ozaki[1], Akemi Tera [1] and Tsutomu Fujinami [1]

Japan Advanced Institute of Science and Technology[1]

Abstract

Cybersickness poses a major obstacle to using virtual reality, especially when visual stimuli and physical motion are misaligned. This study examines how speed variations in a virtual roller coaster simulation affect cybersickness. Participants experienced the simulation at five speeds (67km/h-202km/h) while their eye movement data (pupil size, blink count, gaze direction, pupil position) and Virtual Reality Sickness Questionnaire (VRSQ) were recorded. The findings showed that the lowest (67km/h) and highest (202km/h) speeds increased sickness, while moderate speed (135km/h) resulted in the least. Correlations between pupil size, blink count, gaze direction, pupil position, and VRSQ suggest these indicators may help predict VR-induced cybersickness. This study seeks to deepen understanding of the relationship between speed, eye movements, and cybersickness to improve methods for predicting and mitigating cyberSickness in VR environments.

CCS Concepts

• ***Human-centered computing*** → ***Virtual reality;*** • ***General and reference*** → ***Evaluation;***

1. Introduction

Cybersickness is characterized by symptoms such as headaches, eye strain, nausea, and vomiting that occur while using VR. Depending on the experimental setup, 60% of users reported some symptoms of cybersickness [APJ*20]. This issue poses a significant barrier to the rapidly growing VR market. One of the main causes of cybersickness is the phenomenon known as "vection," which occurs when the body's movements and visual information are inconsistent. Vection is the sensation of self-motion induced by visual stimuli, and it is believed to trigger cybersickness. Research by Behrang Keshavarz has shown a positive correlation between vection and cybersickness. [KUP23].

In this study, we use a roller coaster simulation because it is known to strongly elicit cybersickness due to sudden changes in visual stimuli, making it suitable for recreating motion environments. The roller coaster simulation includes diverse movements such as rapid acceleration, rotation, and abrupt stops, making it ideal for experiments that involve varying speed and rotation in visual stimuli.

The variation in speed is important because it has a significant impact on vection, which in turn affects the overall experience. We systematically adjusted the speed to study how speed changes affect vection and cybersickness. Our goal is to closely examine the relationship between cybersickness and vection, and how speed influences this relationship.

2. Related Work

Studies on the relationship between vection and cybersickness have been conducted. Behrang Keshavarz's research investigates the relationship between vection and cybersickness, confirming the effects of visual stimulus density, speed, and rotation on vection. His research shows a positive correlation between vection and cybersickness, but it also reports that an increase in vection does not necessarily lead to a worsening of cybersickness [KPMH*19]. In this study, we believe that using a dynamic roller coaster will highlight the relationship between vection and cybersickness.

Research on eye movements and cybersickness, such as Alper Ozkan's study, indicates that VR navigation speed, blink count, saccades, and pupil size changes are linked to cybersickness [OC23]. Although a correlation between pupil size changes and subjective assessments was found, it relied on basic features like mean values.

In previous studies that use machine learning to estimate cybersickness, the time-series data of eye movements has been directly used as input for predictions [SPI*23]. This study aims to examine the link between eye movements and cybersickness by using a variety of features, potentially uncovering new indicators for predicting cybersickness.

3. Method

The participant group included 10 individuals, consisting of 7 males and 3 females. We showed the participants videos of roller coasters at different speeds and then assessed their cybersickness

DOI: 10.2312/egve.20241385

Figure 1: *The view seen by the subject.*

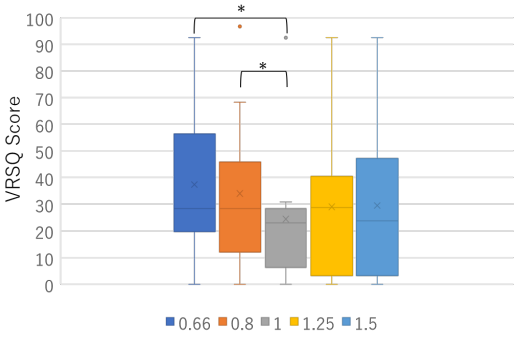

Figure 2: *Box plot of speed and VRSQ.*

(Figure 1). The experiment was divided into two sets, with each set including five speed conditions (1.00(135km/h), 1.25(169km/h), 1.50(202km/h), 0.80(108km/h), and 0.66(67km/h)). We used the Virtual Reality Sickness Questionnaire (VRSQ) to evaluate cybersickness.

The VR system used was HTC's Vive Pro Eye, which enabled us to collect eye-tracking data. The sampling frequency of the eye-tracking data was set at 60Hz. We gathered data on eye movements, including blink count, pupil position, gaze direction, and pupil diameter. The analysis involved extracting 10 features from the data. To analyze blink count, we normalized the time axis to align the data and filled any missing values with zeros. Then, we counted the number of blinks within specific ranges and extracted features. Finally, we calculated correlation coefficients between gaze direction, pupil position, pupil diameter, and the VRSQ results.

4. Result

The relationship between speed and cybersickness is shown in Figure 2. The "×" mark represents the mean, and the horizontal line indicates the median. Results from the t-tests revealed significant differences in the levels of cybersickness between speeds 0.66 and 1.0, as well as between 0.8 and 1.0 ($p < 0.05$). This suggests that speed 1.0 has the least impact on cybersickness compared to the other speeds. This trend can also be visually confirmed in Figure 2.

Fig 3 shows the correlation coefficients between blink count and the VRSQ. The data were collected from the start of the roller coaster's descent until it reached the goal, and all correlations were statistically significant ($p < 0.05$). The highest correlations were observed for blink count (0.57), the standard deviation (Std) of gaze direction (0.57), the median absolute deviation (Mad) of pupil position (0.54), and the maximum pupil size (0.32), indicating moderate correlation. These results may be attributed to the vertical movements of the gaze during the ride, which likely contributed to vection.

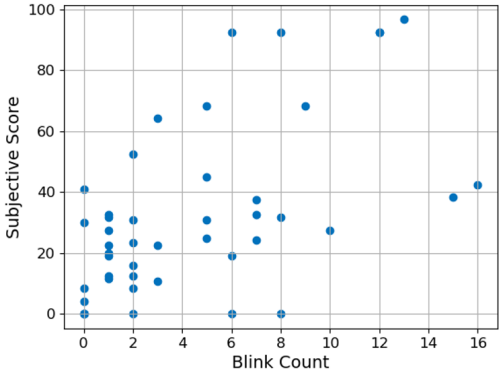

Figure 3: *Correlation Coefficients for Blinks with VRSQ*

5. Conclusion

This study examined the impact of speed on cybersickness in virtual roller coaster simulations, focusing on eye movements. Both low and high speeds increased cybersickness, while intermediate speeds reduced it. Eye movement data, such as gaze direction, showed moderate correlations with cybersickness levels. Future work will aim to reduce cybersickness by optimizing speed and utilizing eye movement data for evaluation.

References

[APJ*20] AHN M.-H., PARK J. H., JEON H., LEE H.-J., KIM H.-J., HONG S. K.: Temporal dynamics of visually induced motion perception and neural evidence of alterations in the motion perception process in an immersive virtual reality environment. *Frontiers in Neuroscience 14* (November 2020). doi:10.3389/fnins.2020.600839. 1

[KPMH*19] KESHAVARZ B., PHILIPP-MULLER A. E., HEMMERICH W., RIECKE B. E., CAMPOS J. L.: The effect of visual motion stimulus characteristics on vection and visually induced motion sickness. *Displays 58* (July 2019), 71–81. doi:10.1016/j.displa.2018.07.005. 1

[KUP23] KESHAVARZ B., UMATHEVA N., PECK K.: Investigating the role of vection, presence, and stress on visually induced motion sickness. In *Virtual, Augmented and Mixed Reality: 15th International Conference, VAMR 2023, Held as Part of the 25th HCI International Conference, HCII 2023* (Copenhagen, Denmark, July 2023), Shumaker R., Lackey S., (Eds.), Springer, pp. 619–633. 1

[OC23] OZKAN A., CELIKCAN U.: The relationship between cybersickness and eye-activity in response to varying speed, scene complexity and stereoscopic vr parameters. *International Journal of Human-Computer Studies 176* (Aug. 2023), 1–13. doi:10.1016/j.ijhcs.2023.103039. 1

[SPI*23] SHIMADA S., PANNATTEE P., IKEI Y., NISHIUCHI N., YEM V.: High-frequency cybersickness prediction using deep learning techniques with eye-related indices. 2169–3536. doi:10.1109/ACCESS.2023.3312216. 1