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*Poster*

# Examining the Effects of Reduced Frame Rate in HMDs on Gaze Behavior

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**Abstract**

*By intentionally reducing the frame rate of the HMD when seeing a specific area within the VR space, we investigate whether it is possible to attract the user's attention and direct his/her gaze to that area. To test this method, we asked users to see at all the square panels arranged vertically and horizontally in the VR space, and tested whether there was a change in their gaze behavior by reducing the frame rate of the HMD when they seeing at a particular panel. The results of the experiment suggested that changes in gazing behavior occur in certain individuals.*

**CCS Concepts**

• ***Human-centered computing*** → *Virtual reality;*

## 1. Introduction

In this study, we investigate the effect of intentionally reducing the frame rate of a head-mounted display (HMD) on gaze behavior, building on previous research that showed how reducing screen scrolling relative to touchscreen swiping caused users to experience stickiness and friction [HNN*18]. Inspired by this research, we investigate whether a similar effect such like attention guidance [GM20] can be achieved in a VR environment by manipulating the frame rate. Specifically, we propose a method to subtly guide the user's gaze in an immersive VR space without making the guidance overt. By reducing the frame rate of the entire display when the user's gaze is directed towards a target object, we aim to direct attention to that area.

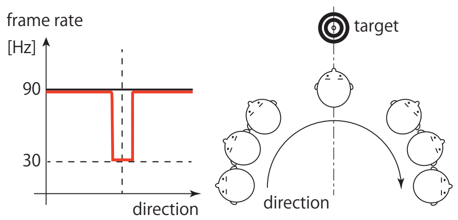


**Figure 1:** *Overview of frame rate reduction*

For example, when the HMD is normally updates at 90 frames per second, the frame rate is intentionally reduced to 30 frames per second at the moment the user's gaze moves to the target area, as shown in Figure 1. This technique uses the change in frame rate to guide the user's focus in a natural way.

## 2. Implementation of frame rate control

The reduction of the HMD frame rate in the VR environment was achieved through the following method. The RenderTexture class implemented in Unity was utilized to achieve this functionality. First, the VR camera captures the 3D scene, and the acquired footage is displayed on a screen inside the VR space. Next, a stationary camera then captures the video from this screen and displays it on the HMD. Figure 2 shows the positional relationship between the camera and the screen. By disabling the VR camera's image capture, the screen retains the last image captured. By adjusting the duration for which the VR camera remains inactive, it is possible to freely reduce the frame rate as needed.

For this study, VIVE Pro Eye was used, which is able detect eye movements. The maximum frame rate is 90 Hz. The frame rate at which we noticed a reduction in frame rate in preliminary experiments was 30 fps.

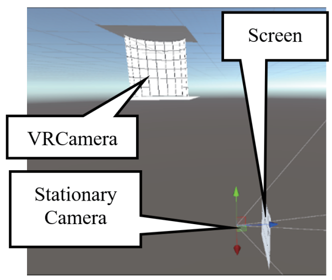


**Figure 2:** *Positioning of each camera and screen in Unity's scene*

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## 3. Relationship between frame rate reducing and gazing behavior

The purpose of this study is to investigate whether a reduction in frame rate affects the duration of gaze behavior. In this experiment, square panels of equal size were placed in a cylindrical shape with the participant in the center. To ensure that each panel is seen, the panel would change color from white to red when participants look at them, as shown in Figure 3. Furthemore, the frame rate of the HMD was intentionally reduced when the participant directed their gaze towards specific panels. If the reduction in frame rate affected gaze behavior, then there should be a bias in the time spent looking at the panels. Throughout the experiment, the duration of the task, gaze trajectory data, and head movement were recorded by the HMD for analysis. At the conclusion of the experiment, participants were invited to provide any comments or feedback freely.

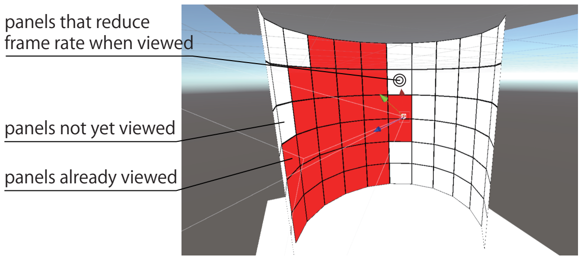


**Figure 3:** *Overhead view of the experimental environment regarding eye movement when the panels are viewed comprehensively (20 degrees horizontal angle of view).*

Participants were instructed to look at the white panel and then look at each panel until all panels were red. All panels, which were aligned at 360 degrees were divided into 20, 24, and 30 degree segments, and the task was performed once in three conditions. For each condition, there was one panel each with frame rates reduced to 30 fps, 15 fps, and 10 fps when viewed. Participants were not informed of the frame rate reduction in advance. In each trials, A total of 10 students participated in each experiment.

## 4. Results and Discussion

There was no significant difference in the proportion of time spent seeing the panels with reduced frame rate compared to the normal panels. The total time spent looking at each panel was divided by the duration of the experiment and then normalized as the percentage of time the panel was looked at during the experiment to produce a heat map. Figure 4, Figure 5, and Figure 6 show the case when the horizontal angle of view of the panels was 20, 30, and 24 degrees, respectively. The center of the diagram represents the position at the start of the experiment, while the edge positions represent departures from the start point. Although the edges do not appear to be connected on the heat map, they are, in fact, adjacent to each other, given that they have a cylindrical origin. Some participants showed a higher proportion of gaze fixations in the reduced frame rate panels.

When the heat maps were checked for each participant in the experiment, it was observed that in some cases the gaze tended to be drawn to the panel with the reduced frame rate, indicating that there were large individual differences among the participants. Figure 4, Figure 5 and Figure 6 illustrate the results at each horizontal angle of view, which were considered to be most affected by the frame rate reduction.

Notably, no participants reported noticing a reduction in frame rate during the experiment. These findings suggest the potential for less user perceived gaze guidance techniques.

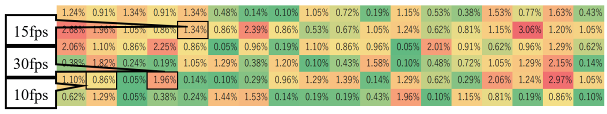


**Figure 4:** *Example of a gaze point heat map in a panel with a 20 degrees horizontal angle of view*

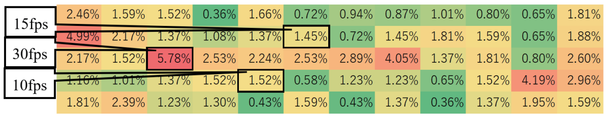


**Figure 5:** *Example of a gaze point heat map in a panel with a 30 degrees horizontal angle of view*

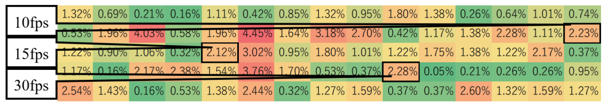


**Figure 6:** *Example of a gaze point heat map in a panel with a 24 degrees horizontal angle of view*

## 5. Conclusion

No significant differences in gaze duration or frequency were observed as a result of the frame rate reduction. However, further analysis is required to determine whether the frame rate reduction affects not only gaze behavior but also head movements. In addition to reducing frame rates, we are currently investigating whether gaze behavior is altered by delays using the HMD's moving average.


## Acknowledgement

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