Oculus rift: Does it improve depth perception?

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Summary

The Oculus Rift is a head mounted display (HMD) that allows users to experience a virtual environment. The main differences between a monitor and an HMD are the immersion effects and stereopsis. The aim of our research was to study whether an HMD improves depth perception (operationalized as object-alignment performance) in comparison with a monitor. Two virtual environments were used: a street environment (target distance at 15 m) and an office environment (target distance at 0.7 m), which were developed with the Unity game engine. To determine the effects of stereopsis and immersion separately, three hardware setups were used: 1) a traditional computer monitor, 2) HMD with binocular-vision settings (HMD Stereo), and 3) HMD with monocular-vision settings (HMD Mono). Twenty males (mean age = 21.2 years, SD age = 1.64 years) participated, and each participant completed 60 trials in total. The results showed no statistically significant differences in object-alignment performance between the three hardware setups. However, a self-report questionnaire showed that participants were more involved in the virtual environment and experienced more oculomotor discomfort with the HMD in comparison with the monitor.

1. Introduction

The Oculus Rift is a Head Mounted Display (HMD) that allows the user to experience a virtual environment [1]. HMDs are becoming popular, for example, in driving and flight simulators or for presenting virtual architectural designs. Former studies have shown several effects of an HMD. The most important effects are: distance perception (a real life environment was observed through an HMD, however, the distance was underestimated) [2] and immersion (participants experienced the environment to be more intense in comparison with a monitor) [3]. However, these improved effects with an HMD have not been compared with a monitor within the ability of depth perception.

Distance perception and immersion (the feeling of being inside a virtual environment) are effects, which are dependent on depth perception [2] [3]. Two types of cues mainly influence depth perception: monocular and binocular ones [4]. Both cues depend on the viewing distance. Monocular cues are depth cues that can be seen by one eye. Binocular cues are created by stereopsis. Stereopsis results from the combination of the two images received by the brain from each eye.

The main differences between a monitor and an HMD are stereopsis and immersion experienced by the user. Both stereopsis and increased immersion could increase the depth perception in a virtual environment. This is why we decided to focus our research on the difference in depth perception between a monitor and an HMD in a virtual environment.

Former studies have measured depth perception by blind walking [5] or absolute distance estimation techniques [6]. These studies revealed that virtual environments are associated with a significant distance underestimation of about 20% [2] [5] [6]. These tests relied on either memorizing distances [5] or the skill of estimating absolute distances [6]. Measuring the ability of object alignment excludes those confounding influences on the results but still depends of the ability of visual depth interpretation. Thus, it was decided to focus this research on relative distance perception.

We hypothesized that an HMD yields better object-alignment performance than a monitor. This hypothesis was formulated by the expectations that the stereopsis and the increased immersion with an HMD improve depth perception [4].

2. Experimental procedures

The influence of stereopsis depends on the viewing distance [4]. Therefore, it was decided to use two virtual environments: a street environment and an office environment (Figure 1). Virtual environments are widely used for driving simulators. Therefore a street environment was designed. To design a small-scale environment, the office environment was chosen.

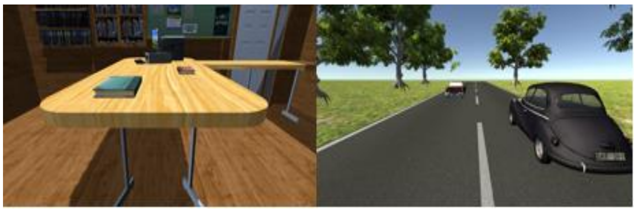

Figure 1: the two designed virtual environments

To separately determine the effects of stereopsis and immersion, three hardware setups were used: 1) computer monitor, 2) Oculus Rift with binocular-vision settings with an inter-pupillary distance of 64.7 mm (HMD Stereo) and 3) Oculus Rift with monocular-vision settings (HMD Mono). The computer monitor used was the monitor of an HP EliteBook laptop with a resolution of 1920 x 1080. The HMD was an Oculus Rift Developer Kit 2 with a resolution of 960 x 1080 per eye. Both environments, developed with Unity v5.0.1, combined with the three hardware setups resulted in six different conditions.

The experiment started with a consent form. This form instructed the participants and explained the object of the experiment, which was to align the controlled object as accurately as possible with the fixed object. Subsequently, the participants were requested to complete a questionnaire to gain background information about the participants, specifically: gender, age, vision defects and the amount of experience with videogames. Afterwards, the participants performed the alignment assignment in the first condition. The order of conditions has been chosen randomly to exclude the effect of a learning curve. In the street environment, a car was fixed at 15 m from the viewing position. The viewing position of the car was in the middle of the road at a height of 1.80 m. Pressing the upper and lower arrow keys of a keyboard could control the other car in the virtual environment. Camera motion was disabled. Pressing the spacebar automatically loaded the next trial.

At the beginning of each of the six assignments, we held one practice trial. The trial was repeated ten times for each condition. With each assignment, the distance of both the fixed and controllable car varied equally within a range ± 5% of the starting distance. The reason for this was that participants could otherwise align the cars with other features of the virtual environment. Additionally, the fixed car was randomly placed on either the left or right lane.

In the office environment, two books had to be aligned. The viewing position was in the middle of the table at a height of 0.65 m. The distance from the viewing position to the fixed book was 0.7 m with a variation of ± 5%.

After each condition, a questionnaire was completed, in which participants were asked to estimate their distance to the fixed car or book in meters. Participants were also asked to describe the strategy they used to fulfil the alignment assignment. This was followed by eight questions about self-rated performance, effort, immersion, sensory perception, and discomfort that were rated on a 21-point scale ranging from -10 (very low / not at all / failure) to 10 (very high / very much / perfect).

The participants continued this process until the completion of all six conditions. In the background the computer determined the error through:

$$error\ [\%] = \frac{distance\ between\ controlled\ and\ fixed\ car\ [m]}{distance\ between\ camera\ position\ and\ fixed\ car\ [m]} * 100\%$$

We statistically tested the following performance measurements for the alignment assignment: standard deviation of the error, mean error, and mean of the absolute error with a paired-samples t-test. Furthermore, the absolute distance estimation was statistically tested with a paired-samples t-test (*df* = 19). The remaining data from the questionnaires were statistically tested with the Wilcoxon signed rank test.

3. Results

Twenty males (average age = 21.2 years, SD age = 1.64 years, no vision defects) participated in the experiment, each participant completing 10 trials per condition. We calculated the standard deviation error, mean error and mean absolute error of the ten trails per participant. The processed data from the alignment assignment and questionnaires are shown in Table 1. From the question regarding the absolute distance, we found a mean error of μ = 114% with σ = 84% of the participants at the street environment, and a mean error of μ = -15% with σ = 36% of the participants at the office environment.

p-value < 0.05 is highlighted as ***'number'***			Monitor Office vs. Mono Office	Monitor Office vs. Stereo Office	Mono Office vs. Stereo Office	Monitor Street vs. Mono Street	Monitor Street vs. Stereo Street	Mono Street vs. Stereo Street
Median			Monitor Office	Mono Office	Stereo Office	Monitor Street	Mono Street	Stereo street
Alignment assignment	***Standard deviation error***	*p-value* [-]	0.679	0.692	0.309	0.441	0.357	0.649
		Median [%]	1.58	1.44	1.41	2.26	2.79	2.15
	Mean error	*p-value* [-]	0.528	0.720	0.487	0.253	0.667	0.193
		Median [%]	0.07	0.07	-0.09	0.95	0.33	0.78
	Mean absolute error	*p-value* [-]	0.734	0.696	0.330	0.969	0.289	0.189
		Median [%]	1.48	1.20	1.26	2.14	2.30	2.52
Questionnaires	***Absolute distance***	*p-value* [-]	0.059	0.275	0.186	0.781	0.373	0.399
		Median [%]	114.27	114.27	114.27	-33.33	-20.00	-10.00
	Performance	*p-value* [-]	1.00	0.94	0.091	0.195	**0.048**	0.295
		Median [%]	-4.50	-5.00	-3.50	-6.00	-6.00	-7.00
	Effort	*p-value* [-]	0.213	0.107	0.638	0.191	0.445	0.835
		Median [%]	-5.00	-1.00	0.00	-5.50	-3.00	-4.00
	Immersion	*p-value* [-]	**0.021**	**0.005**	0.141	**0.010**	**0.016**	0.208
		Median [%]	-6.00	-2.00	-1.00	-5.00	-0.50	0.00
	Distraction	*p-value* [-]	**0.003**	**0.002**	0.979	**0.013**	0.117	0.296
		Median [%]	-5.00	1.50	0.00	-5.50	1.00	-3.50
	Perception	*p-value* [-]	0.775	0.417	0.687	0.670	0.282	0.544
		Median [%]	3.50	4.00	4.00	4.50	5.00	5.00
	3D impression	*p-value* [-]	**0.005**	**0.002**	0.792	**0.007**	**0.004**	0.297
		Median [%]	0.50	5.00	5.00	2.00	5.00	6.00
	Discomfort	*p-value* [-]	**0.002**	**0.001**	0.917	**0.001**	**0.001**	0.762
		Median [%]	-8.00	-5.00	-5.00	-8.50	-5.00	-6.00
	Oculomotor Discomfort	*p-value* [-]	**0.003**	**0.002**	0.945	**0.001**	**0.002**	0.792
		Median [%]	-9.50	-4.50	-4.50	-9.50	-5.50	-5.00

Table 1: Results from both alignment assignment and questionnaires

4. Discussion and conclusions

The results showed no statistically significant differences in object-alignment performance between a monitor and an HMD for both environments. Therefore, the hypothesis is not accepted and it suggests that immersion and stereopsis, which are added values of the Oculus Rift, have no substantial effects on the object-alignment performance in this particular setting. It seems the Oculus Rift does not improve the depth perception between objects.

The answers from the question regarding the absolute distance resulted in an overestimation at close distances and underestimation at further distances. However, no significant difference between each hardware setup regarding the absolute distance estimation was detected.

Nevertheless, participants with an HMD were more involved by the visual aspects of the environment, experienced a more three-dimensional impression of the virtual environment, but suffered more (oculomotor) discomfort. We found no statistically significant differences between HMD Mono and HMD Stereo regarding the following topics: expected performance, effort, immersion, distraction, perception, 3D impression and (oculomotor) discomfort.

The results regarding absolute distance estimation are similar to former studies. Nevertheless, it seems the alignment assignment is more precise than the blind walking method and the absolute distance estimation method [5].

The relative distance perception of objects in the environment seems well, however, the conversion to an absolute distance seems to cause the error. Further research could strive to explain the difficulties of this conversion.

References

1. Desai, R. et al. (2014). *Review: on Oculus Rift*, IJETT Journal
2. Messing, R. et al. (2005). *Distance perception HMD*,ACM
3. Reiners, T. et al. (2014). *Learning in simulation*,TL Forum
4. Pfautz, J. (2000). *Depth Perception Computer Graphics,* UoC
5. Willemsen, P. et al. (2009). *The Effects of HMD properties in distance judgements,* University of Utah
6. Young, M. et al. (2014). *Comparison VR-systems*, Vanderbilt