Awareness, Memory, and Object Permanence In Virtual Reality

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As technology continues to surge the usage of technologies such as Virtual Reality begin to grow at an exponential rate. This typically brings in numerous amounts of users who have little to no background experience using this technology. There have been some that say when using this technology you have to re-learn how to see agian. The effects that the virtual world can impose on you compared to the real world is between the virtual world and the real world can be quite in view the world differently than your own. Some studies have shown that vision can be affected via depth perception cues [6]. Due to this phenomenon, this study was designed to test to see other parts of the participants cognitive functions like memory, awareness, and object permanence are also affected depending in which reality they are viewing. This study dives into the results found from conducting an experiment where the participants must accurately count specific type(s) of balloons while keeping an eye out for oddities.

Additional Key Words and Phrases: Virtual Reality, Awareness, Unity, Memory, Object Permanence, Unity

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1 INTRODUCTION

Virtual Spaces are going to become more and more common as time goes along. There has already been a great increase in the number of household virtual reality headsets. This opens the door to being able to embark on a path less traveled in understanding the unique effects that virtual reality can have on perception and cognitive skills. The ability for virtual reality to morph and manipulate your visual and spatial surroundings makes it a unique avenue for experiments testing cognitive functions like awareness, memory, and object permanence. Inspired by previous works that showed the limitations of a human's awareness to things that happen directly in front of them, this experiment aims to explore to see how the human mind fares in a virtual reality setting.

The experiment that is described in this paper examined how most people's vision and memory were affected. The goal of the study was to see how well the participant was able to count balloons quickly and remember the number they counted. As the rounds go on I was testing to see how good their awareness was by throwing the aforementioned Enigma into the scene while they were still in the middle of a test. The Enigma is revealed in the scene quite early so I wanted to see if people noticed the Enigma but later forgot about it due to the over stimulation via numerous balloons. This way I could a deeper understanding of how the virtual reality space could affect someone's cognitive functions. By having these different rounds where the participant was introduced to different situations I was able to notice patterns in most of the participants actions without them telling me what they were doing. From there I was able to develop an understanding of the human brain and how people adapt to certain challenges.

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1.1 Motivation

This study was all about seeing how well people can multitask in a virtual reality setting and still spot the unexpected. Inspired by the very famous awareness test video where the viewer is tasked to keep track of how many times a basketball team passed the ball and classic memory tests. That task doesn't sound too difficult rather an easy one anyone can do right? After both teams are done passing the ball the answer was quite simple to come up with since all you had to do was simply count the number of passes made. But the real test of the video was to see if you could notice something that happened right in front of you. During the time that the teams are passing the ball a man dressed up in a bear costume and moonwalks in the middle of both teams passing the ball. More often than not, people miss that moon walking bear, this goes to show that our perception as humans could be flawed. When creating this experiment I was looking to find out what factors of that video influenced our cognitive and perceptive functions to overlook such a glaring detail. I wanted to create a game in the virtual reality space that would replicate a similar test.

2 RELATED WORKS

Understanding how visual memory, object permanence, and awareness function in virtual reality environments is quite important. One of the more crucial studies on the construct validity of the Continuous Visual Memory Test (CVMT) by Larrabee et al. explored its effectiveness in evaluating visual memory acquisition and retention[3] The study emphasized the importance of using tools like the CVMT to understand how visual stimuli was processed in a virtual reality world. They also noted the challenges of effectively evaluating visual recognition in dynamically changing environments, a challenge often faced in virtual reality settings.

Harris et al. further investigated how virtual reality might impair sensory information, particularly focusing on its effect on vision for action[6]. Their study highlighted how the absence of depth cues and realistic haptic feedback in virtual reality environments could disrupt how accurately participants are able to view the world. This disruption poses significant challenges for conducting cognitive experiments in virtual reality that aim to replicate the real world.

Additionally, Lamers and Lanen's research into the effects of transitioning between the virtual world and the real world demonstrates the impact of context on memory recall accuracy[8]. Their findings suggest that the transition between these two worlds can very much affect a participant's ability to recall information accurately.

Research into the impact of visual immersion components of virtual reality technology on spatial comprehension and memory, conducted by Balakrishnan et al. (2024), reveals significant findings about the effects of stereoscopy, field of view, and photorealism on how well the cognitive functions perform in virtual reality settings[9]. They demonstrate that a wide field of view combined with photorealistic rendering substantially enhances spatial presence and memory recall. However, stereoscopic imaging doesn't always improve memory and spatial comprehension in virtual environments.

These studies highlight the importance of understanding the unique challenges that arise when testing cognitive functions such as memory, awareness, and object permanence in virtual environments. They suggest that while VR offers innovative opportunities for research, it also necessitates careful consideration of the discrepancies between virtual and real-world contexts.

3 METHODOLOGY

Participants. In this study I had a total of twenty four participants (twelve of them using virtual reality headsets and the other twelve I had streamed the experiment to them). These participants are friends and family of me. The virtual reality group are all residents of California with most of them consisting in the middle age demographic with little to no prior

experience using virtual reality technology. Also in this group were two outliers them being either older or younger than the median demographic. While the entire group used the virtual reality headset they were split into four groups of three. They were split based off of the two other independent variables, them being whether the Enigma walks across the top or bottom part of the screen and whether or not there was light or not in the scene. The second group consisted of my friends that are about college age. They followed the same procedure as the virtual reality group except they conducted the experiment over a discord stream where I showed them the game tab of the Unity project. This group was also split into 4 groups of three people each. A major thing to note is that this group has a major background in video games and FPS (First Person Shooters). This background gave me reason to believe that they may perform better due to the stationary room and improved reaction times.

Equipment. As stated in the aforementioned paragraphs the virtual reality group used a Oculus Quest 2. To be able to conduct the experiment remotely I used teamviewer to remotely patch into my father's computer back home that was running a i7-7700k, NVIDIA RTX2060 graphics card along with 32 GB ram and a water cooling system. For my system in Colorado I ran the experiments over discord with an i12-12700k, NVIDIA RTX4060, 32GB ram and a water cooling system. On both systems we used Unity Hub to open and operate the experiment, we used editor version 2022.3.10f1.

Procedure. I used between subjects in my experiment and made sure that nobody knew if their answers were right or wrong. I also ensured that no participant would tell any future participant what the experiment was about that way every participant had the same knowledge going into the experiment to ensure good data. I made sure to inform each participant that this was for a college class CS 464 and informed them that the experiment was designed to test their awareness, memory, and object permanence. I made to sure to let them know if they started to feel unwell due to motion sickness or any other reason they had every right to stop and quit on the spot even if they had already agreed prior. Once that was all out of the way I went ahead and started with the experiment which in the first round I had them only count RED balloons. After the round was over and they gave me the number of balloons they counted we moved onto round two. In round two the participants goal was to only count BLUE balloons, in addition this round we added a potential distraction of YELLOW balloons floating at the same time as the other ones. Lastly, we move on to round three where the participants goal is to count every balloon on screen regardless of its color. In this round I introduced a third color, YELLOW, and along with the new color this is where the Enigma comes into play. Depending on the group the Enigma either walks across the top or bottom half of the screen. After the round is over if the participant makes a comment about the Enigma the experiment ends. On the other hand if the participant doesn't mention the Enigma during the round I ask them "Did you notice anything odd throughout the exam". In which case they will answer with yes or no and if they respond with yes I would ask vague questions to truly see if they noticed the Enigma.

4 RESULTS

After conducting all of the experiments for both the virtual reality group and the non-virtual reality group I looked at the data and found some interesting results. Regardless of every single independent variable, if the Enigma's placement was on the bottom part of the screen every single participant noticed the Enigma. On the other hand for the virtual reality group when the Enigma's placement was on the top only a single participant noticed its presence. I found this interesting when comparing it to the non-virtual reality group because more often than not the Enigma was noticed even when traversing the top side of the screen. There are a couple of reasons I believe for this to be the case. First, the non-virtual reality people are using a screen that is static and not moving around when they are looking and counting the balloons so any slight movement may reveal the Enigma's location. Secondly, I picked up that most people when doing this experiment would keep their eyes solely on the bottom half of the screen and count the balloons as soon as

Participant #	Lighting Type	Equipment Used	Location of Alien		Conclusion
1	Light On	Virtual Reality	Bottom		Noticed the Enigma
2	Light On	Virtual Reality	Bottom		Noticed the Enigma
11	Light On	Virtual Reality	Bottom		Noticed the Enigma
8	Light Off	Virtual Reality	Bottom		Noticed the Enigma
9	Light Off	Virtual Reality	Bottom		Noticed the Enigma
10	Light Off	Virtual Reality	Bottom		Noticed the Enigma
5	Light On	Virtual Reality	Top		Did Not Notice
6	Light On	Virtual Reality	Top		Did Not Notice
7	Light On	Virtual Reality	Top		Did Not Notice
3	Light Off	Virtual Reality	Top		Did Not Notice
4	Light Off	Virtual Reality	Top		Did Not Notice
16	Light Off	Virtual Reality	Top		Noticed the Enigma
12	Light Off	Stream	Bottom		Noticed the Enigma
19	Light Off	Stream	Bottom		Noticed the Enigma
23	Light Off	Stream	Bottom		Noticed the Enigma
13	Light Off	Stream	Top		Did Not Notice
20	Light Off	Stream	Top		Noticed the Enigma
22	Light Off	Stream	Top		Noticed the Enigma
14	Light On	Stream	Bottom		Noticed the Enigma
18	Light On	Stream	Bottom		Noticed the Enigma
21	Light On	Stream	Bottom		Noticed the Enigma
15	Light On	Stream	Top		Noticed the Enigma
17	Light On	Stream	Top		Did Not Notice
24	Light On	Stream	Top		Noticed the Enigma

Fig. 1. Results With Each Independent Variable

they spawned in and wouldn't follow them up. I believe that this goes ahead and proves the research conducted by Harris et al. that having a virtual environment that lacks depth cues could have an effect on the participants memory and awareness. Lastly, in figure one is a spreadsheet of all the data that I collected from the participants.

5 DISCUSSION

Overall the experiment went really well, I liked being able to see that there was a pattern in how the participants conducted their experiments without even talking to each other. This shows that there may be a way to manipulate their strategy in a future development of this study. Some limitations of this assignment was that I struggled getting participants for the virtual reality group. Every one of my friends in Colorado was caught up with finals and finishing their own projects. So I reached out back home to remotely set up a virtual reality experiment with family and friends back home in California. Some things that I would like to improve on this study would be to eliminate the need of a second person by making the experiment fully functional on its own by having OnClick() methods, using counters for the participants to submit answers, and output the results via a .CSV file.

6 CONCLUSION AND FUTURE WORK

I believe that there is a connection between virtual reality and the effected cognitive functions along with the participants visuals. With this information parts of the study could be tweaked in a way to further develop the connection or

find a better way to test these conditions. I would like to develop this further to try and replicate the magic of the aforementioned Awareness Test video.

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