Immersion and Engagement in a VR Game

Subramanian Pradeep*
DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING
Virginia Tech

Antonio Alexander†
DEPARTMENT OF COMPUTER SCIENCE
Virginia Tech

Siddharth Narayanan‡
DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING
Virginia Tech

Nicholas Polys§
DEPARTMENT OF COMPUTER SCIENCE
Virginia Tech

ABSTRACT

In this paper we present our experimental results from a virtual reality game and user study where we compared the levels of user engagement, task performance and distance travelled across a desktop and a Head Mounted Display platform. We built an interactive search game using the Unity game engine for both a regular desktop version and the Oculus Rift HMD. We wanted to restrict the number of independent variables to specifically study the aforementioned values and have therefore used the same resolution, field of view and input controls for both versions of the game. Apart from our primary focus on the comparison of desktops vs the HMDs, we have also tried to explore exocentric vs endocentric approaches, the level of confusion factor, and the effect of the virtual avatar representations. We also studied the situational awareness of the user when they play the game. Our game was evaluated using a total of 18 subjects in accordance with the IRB protocol and the results were analysed to bring forth statistically significant conclusions. We present our findings in this paper along with the appropriate categorization of the results

Index Terms: J.1.1 [Human computer interaction (HCI)]: HCI design and evaluation methods—User studies; J.1.2 [Human computer interaction (HCI)]: Interaction paradigms—Virtual reality;

1 INTRODUCTION

Virtual Reality (VR) has become a medium that helps unify and incorporate a lot of technologies that came before it. Production methods, interactive thinking and game development engines all see a growing use of VR for new artistic endeavours. There is also a fundamental shift that requires users to suspend their reality to engage in different shapes and sizes, allowing them to inhabit a multitude of places and times. However, even as interpretations for new technologies that push boundaries change, they still share a common goal which is makes the user experience something. Even in the most rudimentary and crude form, this requires a balance in the creativity and production between story and technology in ways not seen before [2]. In other words, this is about facilitating experience and engagement. i.e. making something feel real.

Virtual reality has created many new markets and opportunities and in the gaming industry, it is being explored to create new experiences and autonomous narratives to engage the user. The word Immersion gets used a lot in this context particularly when discussing graphics and games. In virtual environment design, immersion refers to a feeling of being present within a virtual world. It is also the first thing that has to be achieved in a Virtual Reality experience [18]. This may actually even occur while watching a video or even reading a book, but immersive environments capitalize on this by employing the users field of view and give them a sense of presence inside a Virtual Reality experience. Virtual environments (VE) can influence a users state of mind much in the same way that a real environment does. In addition, different users experience VE the differently just as they experience real situations differently. Moreover, they can be expertly tweaked to change and manipulate the way users think. Truly immersive environments help a user feel like they are actually in another location.

The Unity game engine is a versatile development platform that simplifies the process of building immersive virtual environments. There are three key features that make the platform especially helpful. Physically Based Shading allows properties like the albedo colour, shininess, and surface normals to be applied along with a physically correct appearance. The dynamic Substance Designer allows textures to be built for objects that go into the physically based shading pipeline. Finally, the Global Illumination uses physics to calculate lighting and create realistic lighting for the environment with minimal amount of setup. Users can now use the Oculus Rift to create some truly unique experiences like playing with real human scale figures of dinosaurs and even sending viewers into outer space [9]. While the quality of environments created is currently limited by the processing power in head mounted display devices, with the fast pace of evolving devices and Virtual Reality environments will become more compelling and immersive.

Our game involves navigating and finding objects in a virtual environment under time constraints. The virtual environment we use is a model of the Moss Arts Centre at Virginia Tech. The game was designed with an "alien invasion" storyline to keep the user interested. Initially, the aliens drop bombs at different times and at different places in the building and player has to run around the building, quickly collecting the bombs or else he would fail. We made twelve levels of difficulty and as the game progresses, the game levels start varying in their difficulty. The user has to play the twelve rounds once on the desktop. The user would then be allowed to view this data from an aerial view to get an idea of what the environment looks like and then would use the Oculus to navigate with virtual world and try and locate the object. We measure the level of awareness and success in the form of a 'hot n cold' format and the number of turns the user needs to finally locate the object. We also collect data based on questionnaires from the user study by performing the experiment on eighteen candidates. Eight of these candidates worked at the Moss Arts center building and were aware of the insides of the building and out of those users, 4 were also highly familiar with the virtual model of the building. The remaining ten candidates did not work at the Moss Arts Center and were neither aware of the virtual model nor were they aware of the insides of the building. It was seen that all of the users were more comfortable playing the game using the desktop than the Oculus. However, they enjoyed the Oculus more. We measured the task performance of the users based on two primary factors: How long it took to find all of the objects and the amount of times they used the in-game map. We also study about the situational awareness of the user when they play the game.

Section 1 of this paper discusses virtual and mixed reality in conventional terms and explores ways to quantify them in the context of this paper. Section 2 looks into body of contemporary work done in this area and several competing definitions from various applica-

*e-mail: manian93@vt.edu
†e-mail:antonio8@vt.edu
‡e-mail:nsiddh3@vt.edu
§e-mail:npolys@vt.edu

tions are reasoned. Section 3 discusses the design of the study and metrics used of evaluating the performance of a user. Section 4 explains the game design and development process and finally section 5 present our findings for the study. The paper culminates with a conclusion of the concepts discussed.

2 RELATED WORK

Our study leverages the Mirrorworlds [1] project, which was designed to provide a way of interacting between real and virtual participants in a physical space and its virtual rendition. [17] explores abstract Mirror worlds and their composition using multiple sources and their support for a wide variety of applications. [12] was also important in explaining a prototype Mirror Worlds framework. We also referred to navigation methods and travel in immersive virtual environments [3]. Their results indicate that virtual travel techniques, in which users do not physically translate their bodies, can allow the maintenance of a user's spatial orientation as measured by a pointing task. These papers were also significant from the context of different virtual travel techniques in immersive virtual environments and the spatial orientation of users. [4] gave us an insight on first person motion control and travel through immersive virtual environments. This was useful in deciding between the various pointing techniques vs the gaze-directed steering mechanism and also that teleporation could lead to more user disorientation. We also used [13] for a better understanding of how immersive virtual environments provide a higher level of spatial understanding for complex 3D structures.

We also referred to works on different immersive interfaces and media. Alison Mcmahan [19] explores the shift in computer game design involving a move away from 2-D level design (Prince of Persia) or from isometric design (Warcraft), to 3D design and a first-person point of view. She discusses how this increases the sense of immersion by replicating the aesthetic approaches of first-person shooter games in other types of games, such as adventure games, role-playing games, and even strategy games, which previously used 2-D levels or isometric views. This trend is also indicative of an overall trend to make desktop video games feel more like virtual reality. She examines the users concept of immersion in video games and suggests how it is necessary to break down the concept of immersion into its more specific meanings and develop a more specific terminology. Jane Stones research [15] sets out the purported generational and technological issues that might influence engagement with education in virtual reality. The study employs ethnography, as involvement in virtual reality research requires participation, observation and immersion in the scenarios to fully comprehend the potential educational advantages and shortcomings of the environment. Chris Dede [7] explains that immersion is the subjective impression that one is participating in a comprehensive, realistic experience. The more a virtual immersive experience is based on design strategies that combine actional, symbolic, and sensory factors, the greater the participants suspension of disbelief that she is inside a digitally enhanced setting. He also refers to studies that show immersion in a digital environment can enhance education through multiple perspectives, situated learning, and transfer. Charlene Jennett [10] notes that despite the words common usage by gamers and reviewers alike, it is still not clear what immersion means. Their paper explores immersion further by investigating whether immersion can be defined quantitatively, describing three experiments in total. The first experiment investigated participants abilities to switch from an immersive to a non-immersive task. The second experiment investigated whether there were changes in participants eye movements during an immersive task. The third experiment investigated the effect of an externally imposed pace of interaction on immersion and affective measures (state-anxiety, positive affect, negative affect). Their findings suggest that immersion can be measured subjectively (through questionnaires) as well as objectively (task completion time, eye movements). Furthermore, immersion is not only viewed as a positive experience: negative emotions and uneasiness (i.e. anxiety) also run high. Emily Brown [5] also corroborates this by explaining that the term immersion is widely used to describe games but it is not clear what immersion is or indeed if people are using the same word consistently. Their paper describes work done to define immersion based on the experiences of gamers. They use Grounded Theory to construct a robust division of immersion into the three levels: engagement, engrossment and total immersion. Further, they discuss that this division alone suggests new lines for investigating immersion and transferring it into software domains other than games. Steven Dow [8] presents the results of a qualitative, empirical study exploring the impact of immersive technologies on presence and engagement. Through interviews and observations of players, they find that immersive AR can create an increased sense of presence, confirming generally held expectations. They also demonstrate that increased presence does not necessarily lead to more engagement. T Tan et al. [16] use an Oculus Rift DK1 and a traditional computer with monitor setup to play a first-person shooter game (Half-Life 2). The study shows that most participants experienced cybersickness 8 on a scale from 1 to 10 and that cybersickness only occurs on the Oculus Rift. They say that: cybersickness was a strong factor in modulating peoples gaming experiences using the Rift. A noteworthy finding was that immersive CAVE like environments are best used to evoke happy emotions while HMD devices were advantageous for negative emotions. The comparative study showed that their desktop system produced the least change in overall and moderate task performance of the users. Settgast [14] conducted a similar study by three different scenarios in the fully immersive room-based virtual environment DAVE (Definitely Affordable Virtual Environment) and a head-mounted display, the Oculus Rift. McMahan [11] also designed a similar setup through a First person shooter game and found that both display and interaction fidelity significantly affect strategy and performance, as well as subjective judgments of presence, engagement, and usability. The results of their study indicate that both display and interaction fidelity significantly affects strategy and performance, as well as subjective judgments of presence, engagement, and usability. Given, the diversity of terms and variables, our paper focuses on a few of these variables (discussed in the following section) in order to improve the quality of the game and data analysis.

Cybersickness also came up are a significant obstacle in previous user research studies involving VR devices. The symptoms of cybersickness include disorientation, discomfort, dizziness. Also, since most studies gather self reported data, the results are highly dependent on the participant and also vary in how the results of the study develop. Davis, Nesbitt, and Nalivaiko [6] conducted a study with 30 participants and found that the coaster with more complex realism causes a higher level of nausea offset compared to the other and is therefore suggested for further studies regarding objective measurement of cybersickness. This was helpful is making decisions for our game and design.

3 GAME DESIGN

The first person motion is controlled by a set of scripts in unity engine that allow movements in the environment using the keyboard and mouse interface. The automatic built interface for camera views between Oculus and Unity was employed for this study. Our study focuses on the following three research questions:

1. What is the level of engagement that the user experiences ?

2. What is the task performance and time elapsed for the task for each user within the designed game ?

3. What path does the user take to complete the task ?

When making the study, we explored a number of design decisions. The resolution and field of view were also significant difference between the two versions of the game and the users definitely would have experienced distinct visual feedback due to these factors on the two version of the game. We also dealt with presence questions to evaluate how the users experienced co-presence and social presence within the game.

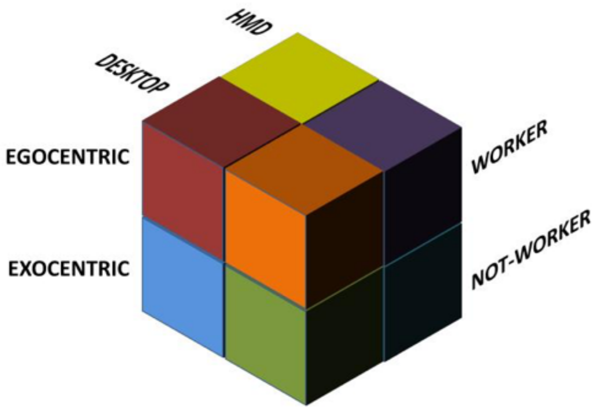

Figure 1: Matrix showing the major decision variables of the study

Some of the game decisions that we encountered were:

1. Type of vision: Mono on desktop vs Stereo on the Oculus Rift
2. Type of hiding scenarios
3. A confusion factor with the growing difficulty and the number of aliens and hidden objects
4. Egocentrics vs Exocentric view: Allowing an initial aerial view and then letting the player find objects in first person

Input controls are also be a major factor in the experience of the game and we wanted to keep the input experience uniform across both platforms and therefore chose to use the keyboard for navigation. The aspects of the situational awareness of the user are calculated as the time he takes to complete the game, confusion- based on the distance travelled; and a panic mode-based on the time.

The aliens in the game move around the Moss Arts Centre and drop the bombs at any possible location at different times. The game has 12 playable levels and one practice level that the player is first introduced to when the game starts. The first four levels are easy: The first level has one alien with one bomb, the second one has two with two bombs, the third one has 4 aliens with 4 bombs and the fourth level has 8 aliens with 8 bombs. The difficulty of the subsequent levels is increased by varying the number of bombs from 1 to 7 and with a maximum of 8 aliens. The user was given the option of a help map that offered a glance at the alien locations with a birds eye view of the model. In this view, the user can see where the aliens are moving, however, but cannot see where they are hiding the bombs. We also take a note of how many times the player uses the map for help.

An interactive graphic user interface was built to show the instructions along with the option of skipping to a specific level. During the game play, the total number of bombs in the area, total bombs collected the time elapsed are displayed for the user. If the user is able to collect all of them, the time count stops and a success message is displayed. If the user fails to collect the bombs within the given time, a failure message pops up and he is not allowed to collect the bombs even if he finds them after the elapsed time.

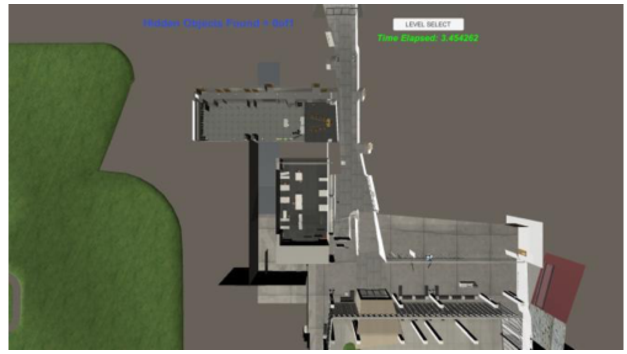

Figure 2: Aerial bird's eye view of the building

We also introduced animated models of dinosaurs and snowmen within the scene to make it more enjoyable and at the same time, serving the purpose of distractions to the user. The antagonists of the game, the aliens, are clearly distinguishable dome shaped creatures of different colors and appearances. The bombs are created in multiple colors in the easy levels, while in the difficult scenes, the bombs are colored in a way that they might even be camouflaged within the environment so that the user does not notice them easily. Further, we also track the path made by the aliens and the users. When the user completes the game, the trail can be seen on the top view. However, we let it remain visible in the first person view as well just to create more clutter in the environment. This trail can be indicative of the situational awareness of the user and shows how well he is able to strategize and complete the task. So, a more clumsy and cluttered trail is indicative of confusion, poor strategy and panic. However, a less cluttered trail corresponds to being able to play a good game. The trails made by the aliens are just a tail that follows them and disappears after certain number of frames. However, the trail made by the user is created and visible throughout the game-play.

Figure 3: The aliens, dinosaurs and doughnuts are aimed to make the game interesting and increase the level of participation

We form the trails for the aliens and the first person using the trail renderer. It renders a point as a group of pixels and the trajectory of the first person is thus generated. The colour and thickness of the rendered line can be adjusted programmatically or using property fixes in the trail renderer.

The alien movements are performed using dedicated scripts that control their motion and restrict them to the surface. The bombs are a child object of the alien and it is programmed to be separated out after sometime. Then it is programmed to be collected by the first person by detecting collisions. The text objects are attached to the first person and controlled by the UI library in Unity. To create

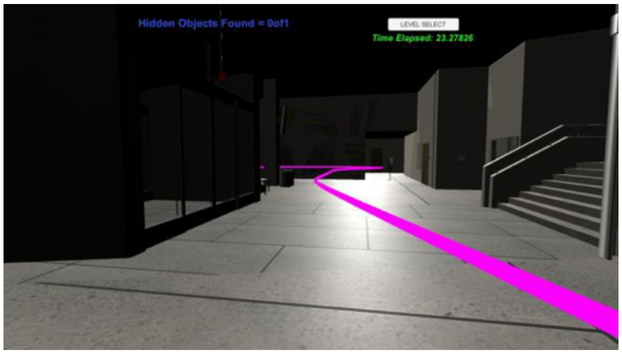

Figure 4: The path traced shows the user how they went on to complete the given task. This helps them increase performance in the next levels

the GUI, we make twelve different scenes which are connected to a common script. This script generates a functionality that connects the scenes to events. These events are triggered by push buttons in our case. When the event is triggered (i.e. button is pushed) the required action happens (i.e. the level opens up). Some changes in the camera properties and including a 3D space mouse pointer, made the text objects visible in the Oculus as well.

4 STUDY

The game levels are divided into three stages of difficulty: 4 easy, 4 medium 4 hard based on time and number of aliens. Hard levels also have imposter aliens where the user loses time by misidentifying the aliens dropping the bombs.

4.1 Participants

There were a total of 18 subjects for the user study 4 Females and 14 Males. 8 users were workers/students at the Moss Arts Center and were familiar with the building architecture. Of those, four users were well versed with the virtual model of the building as well while the other 4 were not. The other 10 subjects were not workers at the building, they had never visited the Moss Arts Center and neither did they know about the virtual model. Participants completed an pre-survey with general information (e.g. age, gender, profession), experience with games and virtual realities. The participants also rated their computer fluency and their general experience in video games and Virtual Reality devices. Only 2 reported to playing video games and only 4 had experienced an HMD device. Users with reported cyber sickness or any health issues such as epilepsy or seizures were not taken as subjects in this study.

4.2 Questionnaire

We asked the participant to rate immersion, fun, and if they have liked the experience on a Likert scale between 1 (not at all) and 10 (very) to receive immediate feedback after each level on a setup. Following this, the user would then try the other device and we requested feedback through our questionnaire. We also used a subjective individual rating of the participants perception of disorientation while playing the game to evaluate cybersickness. The participants were asked after each task to rate their disorientation level between 0 - no discomfort to 10 completely disoriented.

4.3 User Reviews

All of the users were comfortable playing the game using the keyboard/mouse interface. There were comments from 2 male candidates about the game play being slightly dizzy using the keyboard/mouse. Most of the users were successfully able to complete the game within the given time. However, 30 percent of the users failed to complete at least one of the hard levels within the given time. We also took a note of the number of times the users take the help of the birds-eye map of the area. The users who knew about Moss Arts model or were really good gamers did not use the hint map more than twice. They also completed the game faster comparatively. However, the remaining subjects used the hint map more than twice to locate the aliens and also to judge their position within the scene. Candidates with similar gaming experience also took similar efforts and time to complete the game. It was observed that prior experience in gaming and knowledge of the building positively affected the performance. Despite the varying performances and different completion times by the users playing the game on both setups, all of the users found it easy and enjoyable to play the game. However, all of them agreed that the keyboard/mouse interface was detrimental to the immersive experience. Only 5 out the 14 users who played the game using the Oculus rift played all the levels. Some played only the hard levels and some played only the last part of each category of the levels. We had mixed opinions about the Oculus after the experiment was done. All of the users thought that the Oculus rift was a cool device because of it gives a more immersive experience than the desktop. 11 users complained of dizziness and discomfort upon using the Oculus after reaching level 4 of the game. However, the users had fun playing the first level. Users enjoyed the Oculus rift, but they preferred using it only for a short period of time and preferred the desktop setup for long duration game-plays. We were not able to collect data for all the levels using Oculus in some cases as result of the users did not finish the required tasks. Out of the people who played the hard levels, 2 of them failed few of the hard levels. But all of them were able to complete the easy and medium levels. This is perhaps because of immersion and increased detailing of the environment using the Oculus. However, it took significantly more time to complete the game using the Oculus as compared to the desktop.

4.4 Analysis

We perform statistical analysis based on t-tests on time, distance user rating based data for significance testing. We also analyzed aspects of the user such as situational awareness, comfort level and engagement based on factors such as time taken to complete the levels, extent of clutter created by the trail (i.e. the distance travelled) and awareness about the Moss Arts model and building.

5 RESULTS

We use the data gathered as part of our experiments for significance testing. We first employ the t-test for a check on the null hypothesis and p values. We then proceed to interpret t-test results.

5.1 Objective Metrics

The level of immersion is tested through task performance based on time of completion and distance travelled. Our first t-test is conducted between each of the users total time to completion on the head mounted display and the desktop experience.

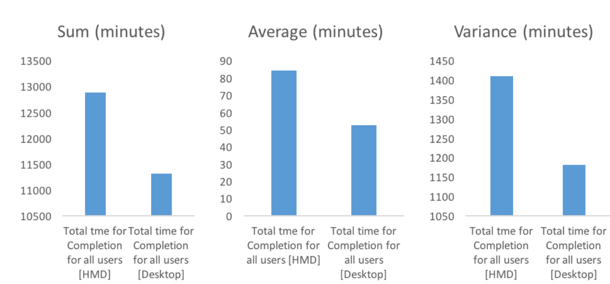

Figure 5: Total time for completion on HMD vs Desktop

The p-value for user time completion of the task between HMD times for all users vs Desktop times for all users was found to be 7.5217E-16 which was deemed to be statistically significant. That is to say that all users will complete the current game faster on the desktop than on the HMD. A similar t-test was also conducted on the users total distance travelled during the task.

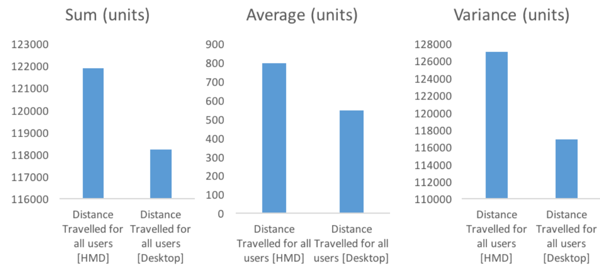

Figure 6: Total distance travelled on HMD vs Desktop

The p-value for the distance travelled by the users was also found to be statistically significant at 4.86324E-11. The next test was conducted between the levels of difficulty on the HMD vs desktop platforms. The game had 12 levels in total that can be grouped into 3 groups of 4 based on their difficulty. We use the medium difficulty level group an example to explain the results. The sample path taken be the user in the desktop version of the game on medium difficulty is shown here.

Figure 7: Sample path by user on medium difficulty - Desktop

An example data-set for medium difficulty level is given here. We used the time for completion on these groups on both platforms as the dataset for the t test. These results demonstrate that all users would complete the desktop version of the game faster than the HMD on the medium difficulty levels.

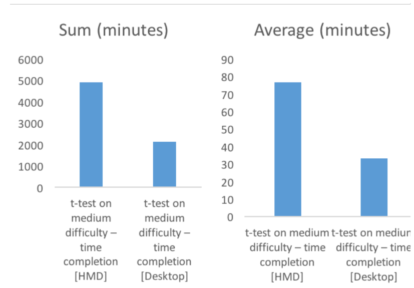

Figure 8: Time for completion on medium difficulty on HMD vs Desktop

The table below shows the results for all levels of difficulty and the p-value for medium difficult is 6.41E-10.

	Easy (No. of aliens = No. of bombs)	Medium (1 bomb with many aliens)	Hard (No. of aliens > No. of bombs)
p value	0.5295	6.41E-10	0.36908725

Table 1: Task completion time p value for all users at different groups of difficulty

Similarly, the data set for distance travelled by users on medium difficulty is provided in Figure 8.

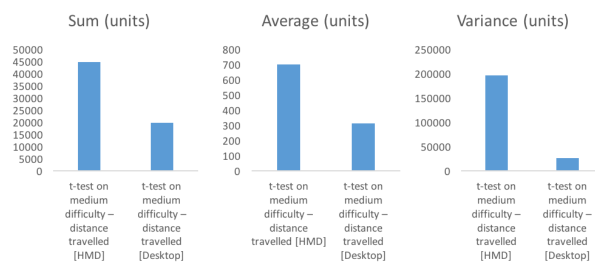

Figure 9: Distance travelled p value for all users at different groups of difficulty

We can see that the distance travelled by all users on medium difficulty was found to have a p-value of 1.23E-09 (Table 2). This demonstrates that all users will travel fewer units to complete a task at the medium difficulty on the desktop version.

	Easy (No. of aliens = No. of bombs)	Medium (1 bomb with many aliens)	Hard (No. of aliens > No. of bombs)
p value	0.3614646	1.23E-09	0.220997533

Table 2: Distance travelled p value for users at all level of difficulty

5.2 Subjective Metrics

The overall experience of the setup was also tested with the level of engagement studied through the mapping of physical actions, the ease of finding objects and realism that the users experienced. The mapped actions and realism factors were found to be statistically significant using their respective interfaces.

Figure 10: User level of Engagement - Physical action mapping and Realism Ratings

The Analysis of Variances (ANOVA) for statistically significant data had a p-value less than 0.05. This led us to the conclusion about trends that can equally be true to a larger number of users. We can see that F-values are also greater than the F-critical. This again leads to the rejection of the null hypothesis, leading to a conclusion that the HMD and Desktop interfaces are statistically different. In addition, we also use the user path trajectory to determine the level of confusion experienced by the user.

There was an interesting trend observed in the reference frames used by the user while playing the game. While the game play is designed with an ego-centric reference frame, all users (even the workers who were familiar with the building and model) used the exo-centric view of the map to achieve a better level of situational awareness. Another significant trend in the data was that the workers performed much better in all levels and had lower completion times on both the desktop and the HMD. For distance travelled taken, workers on the desktop significantly outperformed the others. This can be attributed to better situational awareness and user strategy within the game. Based on our observations and comments from participants, we attribute this increased performance within the game to familiarity of the virtual environment and gaming setup. Conceptually, the desktop setup was very similar to a standard, desktop FPS game with the participants using a mouse and keyboard to interact with a game. Several participants also commented that this condition reminded them of playing a desktop FPS. The HMD setup was aimed to be similar to an interaction in the real world with a much wider FOV. Several participants also commented on how realistic the HMD setup was for them, however other reported that the mouse and keyboard setup was a hindrance to the realism of the virtual world.

6 Conclusion

We were successfully able to conduct a user study and were able to obtain statistically significant results to differentiate between the Oculus Rift HMD and the Desktop interface. It is seen that in the medium difficulty levels the Desktop interface took less time to complete the game as compared to the Oculus. However, it need not necessarily be the case in easy and hard levels. We found that the users took less time and also travelled less distance using the Desktop setup despite the fact that the usage of Oculus rift increased the detailing of the scene. Overall, the game was easier to play in the Desktop interface as compared to the Oculus Rift. This shows that an increased level of scene realism and higher FOV do not directly correspond to increased user experience and task performance. Thus, while the subjective metrics point toward a greater level of engagement on the HMD setup, the objective metrics lean show superior level of immersion and engagement on the desktop. We also found that familiarity with the setup and virtual world can often have positive effects on the task performance of a user. This is also supported by the hint map usage counts and the user path trajectory maps and can be interpreted as a form of better situational awareness and user strategy within the game.

For future work, we plan to conduct additional systematic evaluations of display and interaction setups. In particular, we plan to study aiming and locomotion independently, since those aspects were reported to have the most significant effects on the results of this evaluation. Additionally, considering our discovery that familiarity influences user strategy, we plan to conduct some experiments using first person subtasks based on differing strategies, in order to learn more about the effects of familiarity of the virtual world on user performance. We also exploring gesture control and physics within the virtual world to create new forms of interaction and confusion to study how this affects the user strategy.

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