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**Visual interfaces effect on player performance in virtual reality**

A dissertation submitted in partial fulfilment of   
the requirements for the degree of   
MASTER OF ENGINEERING in Computer games development

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1. Nomenclature

**Abbreviations:**

VR Virtual Reality.

Non-VR No Virtual Reality.

IPD Interpupillary distance [14]

GOMS Goals, Operators, Methods, and Selection rules [11]

HMD Head mounted display

Oculus Oculus Rift

1. Acknowledgements

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I’d also like to thank Darryl Stewart my supervisor for his guidance over the course of this project helping me refine my ideas

1. Abstract

Fully immersive experiences into virtual reality (VR) will become common place in the next decade, with that comes the need for research to make sure that these experiences are the best they possibly can be, Visual interfaces used in games are key to tracking a players progress, providing feedback to the player and helping them navigate the environment, Using a fabricated scenario created in Unreal Engine4 [1] in conjunction with the Oculus rift [2], we will track metrics and then ask the participant to fill in a questionnaire to discover what categories of Visual interfaces work best in the oculus rift compared to a traditional gaming setup, The experiment conducted has been performed with fifteen human subjects each playing the game with an Oculus rift and without, The results presented statistically show that the different types of interfaces perform equally as well in virtual reality as they do in non-virtual reality, discussed is the uniqueness of the research and areas for future work, existing games have made changes specifically for VR however most have been done as side projects to main development and such are not their most optimum, this paper will be a useful resource for any developer tackling VR development specifically with any design and implementation choice they need to make on Visual interfaces.

1. Introduction

VR has been in existence since the 1950’s primarily used by the military for training or hobbyists to escape into a virtual world, it has been growing steadily over the past few years with technology becoming cheaper and more accessible, and this has accumulated with VR Company Oculus being bought by Facebook for two billion dollars [12], funded by Facebook Oculus will release the first consumer affordable VR device the Oculus rift. Many large companies are now picking up VR development even going as far as developing with VR as their primary platform for playing the game such as EVE Valkyrie [13], this paper in particular focuses on the importance of the use of visual interfaces to provide feedback to players on their performance, the results of this paper will guide developers into the best interfaces to use to make sure the player while enjoying the immersive nature of VR is still able to play the game to the best of their ability.

1. Background

5.1 Visual Interfaces.

Games have always required ways of giving feedback to a player, Visual interfaces play a key role in performing this task, While other interfaces such as audio and haptic exist most games still use visual interfaces for the majority of their feedback. They can be broken down into four categories [3].

5.1.1 Interfaces part of the game narrative.

Diegetic interfaces are a part of the characters story, they tend to be presented with an animation of a character raising a map or opening a hologram menu as not to interrupt their immersion in the game world. An example of this is Ark survival Evolved which uses a diegetic interface for the players map and compass.

Figure 1. Ark Survival Evolved

Figure 2. Call of duty

Meta interfaces are still a part of the avatars narrative, they take the form of temporary information such cornering suggestions in a rally game. An example of this is call of duty that uses Meta interfaces to show where the player is being attacked from as can be seen in Fg2, this draws the player further into the game world by showing a blood splatter and reducing visibility.

5.1.2 Interfaces not part of the game narrative.

**Non Diegetic interfaces are not apart of the avatars narritive but are visible to the player they provide information such as health, ammo count or in the form of a minimap for the player. A good example of this is world of warcraft that shows the player health, mana, spells, map and much more as shown in Fg 3.

Figure 3. World of Warcraft

Spatial interfaces are used when there’s a need to break the narrative in order to provide more information to the player than the avatar would be aware of, they take the form of glowing trails on the ground or instructions on walls. An example of this splinter cell conviction that uses spatial interfaces to display the current task to the player as seen in Fg 4.

Figure 4. Splinter Cell Conviction

5.2 Examples of visual interfaces in virtual reality games.

Many early adopters and indie dev’s are already creating and changing existing games and experiences for virtual reality this section outlines some of these and the adjustments they have made for virtual reality[4].

5.2.1 Euro Truck Simulator 2.

Euro truck simulator 2 places the player in the position of a truck driver in Europe requiring them to deliver cargo, the game helps the player perform this task using several interfaces, the normal game uses extensively non diegetic interfaces for the sat nav of the vehicle, delivery details, email, money etc. It also uses spatial elements such as road signs and indicators on other cars, In the oculus version of the game the developers stripped out the non-diegetic sat nav and turned it into a diegetic interface by placing it constantly on the dashboard of the vehicle allowing the player to naturally look at it any time, they also turn the general interfaces into a floating diegetic interface that hovers above the steering wheel, all other spatial elements remain the same in the game.

Figure 5. Euro Truck Simulator 2

5.2.2 Half-life 2.

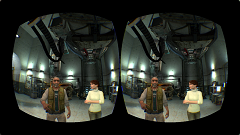
Half-life 2 is a first person shooter, it extensively uses non-diegetic interfaces to help the player keep track of their ammo health and armour, it also uses meta interfaces to help the player identify where an enemy is shooting them from, Half-life is set up two ways depending on the controller used in conjunction with the oculus rift, Using just the oculus rift on its own the developers left everything as is, however if the user is using a controller such as the razer hydra [5], they remove all the non-diegetic interfaces for ammo, health and Armor and replace them with diegetic ones on the players wrist and gun, the meta interfaces are unchanged.

Figure 6. Half Life 2

5.2.3 War Thunder

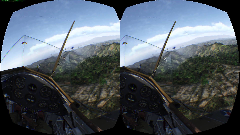
War Thunder places the player at the controls of a fighter plane participating in multiplayer dogfights, it primarily has a cut back interface but has some key non diegetic elements, and the planes speed, altitude and throttle are all displayed, a reticule for where the gun of the plane is aiming is displayed, scores of each of the teams are also displayed in a similar manner along with a mini-map of the battlefield, Spatial indicators appear to help identify targets and their relative distance, In the oculus rift they strip away all these interfaces, It uses the diegetic interfaces of the cockpits dials to display speed, altitude, and throttle, The game also gets rid of score board and places it in a meta interface that has to be brought up by button press, The spatial elements are also replaced with meta interface arrows that point at the enemies in your vicinity.

Figure 7. Warthunder

5.2.4 Surgeon Simulator

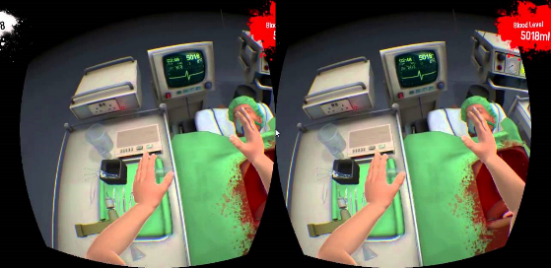
Surgeon Simulator puts the player in charge of various surgical procedures, the player has to perform the surgery as quickly as possible while keeping the patient healthy this is represented by blood loss, the time and amount blood the patient have are shown twice with 2 interfaces there is a spatial interface of a heart monitor in the game world that shows both the blood level and time, there is also a non-diegetic interface that displays the blood level and time constantly on in the top right and left respectively.

Figure 8. Surgeon Simulator

5.3 Dead space interface post mortem

The Dead space game series was famously the first to use a fully diegetic interface Fg 9, the following section is from a talk given by Lead UI Designer Dino Ignacio at GDC 2013 [6].  
The designers wanted the game to be as immersive as possible due to it falling into the horror genre, This meant their choice was to implement a fully diegetic interface to the user for game feedback, They also made the decision of the players character being view at all times, even if it is just his arm, in Fg 9, you can clearly see the players health represented by the light blue tube on the avatars back. However in the third instalment of the game the designers wanted to expand the crafting system in the game to include further mechanics to allow the player to change their weapons.

Figure 9. Dead Space 1 Screenshot

The first iteration of the design is shown in Fg 10, it was a diegetic interface conveying all the various parts of putting together a gun or upgrade, Although this fitted their mission statement of always using diegetic interfaces and having the avatar in view, It soon became apparent that the interface crippled the usability of the game, developers opted for using the in game debugging console commands instead of the interface because it was so unusable.

Figure 10. Initial bench design DS3

Eventually the final design came together as shown in Fg11, it is non diegetic and vastly improved the ability for the user to interact and be able to use the interface in order to complete the task of building a weapon, this is a good example of previous issues that games have faced long before the advent of virtual reality, it also helps to reinforce the importance of this research through a solid example where design and implementation compromises had to be made to enable the player to be able to accomplish a goal.

Figure 11. Final bench design DS3

5.4 Previous Studies.

The oculus rift offers interaction from a first person perspective from previous case studies into the First person shooter genre [7] we know the following.

Figure 12. Distribution of information amongst the visual, auditory and haptic channels

From Fg12. We can clearly see that a vast majority of feedback to the player in a first person game is done through visual interfaces, this is very important for virtual reality were it is primarily a first person experience, this shows the importance of this research into user interface (UI) design for games.

5.4.1 Evaluating Interfaces.

The following section outlines empirical papers that have done experiments into interfaces and user performance it discusses their findings and any pitfalls they fell into.

5.5 Evaluating two interfaces for searching a database [9].

The paper outlines two alternative user interface designs that are exposed to user testing to measure user performance in a database query task.

They create two interfaces for a database one comprising of a drop down box and another a dialogue box, they are interested in the time taken by each user to look up a randomised phone number using the interfaces. Firstly experts with nine or more years of experience were consulted to make estimates on how much time would need to be taken for each interface, in addition the experts were split into three groups, hot, warm and cold, below is outlined what affect this had on their exposure to the system.

* Hot – Access to the system for longest time period.
* Warm – Access to the system for a mean of the hot and cold time period.
* Cold – Very little access to the system for a time period.

The study also uses GOMS (Goals, Operators, Methods, and Selection rules) [11], GOMS is analysis tool for creating estimates of user performance, with the estimates from the expert group and the GOMS user testing was performed, this involved getting twenty students to use the software, the users had no experience but were shown how to use the interfaces and allowed practice.   
At this point a cost benefit analysis was performed it was noted that expert analysis would have a higher cost to it than a student’s group as would the cost of having to perform GOMS analysis.

**Conclusions.**

The paper concludes showing that user testing performed very closely to the “Hot” expert estimate, this shows that user testing is an accurate measure of user performance, however the testing is not always a perfect predictor of real world performance. It was also noted that hot estimates were as accurate as user testing but cost substantially more.

**Use to this research.**

The paper helps identify the need for an experiment to evaluate user performance it shows that user testing is the best means to attain meaningful data, although it does warn of the variability of testing and that a large sample should be attained to get a good average, it also shows time as a heuristic to track when evaluating two interfaces which will be beneficial to my experiment.

5.6 Driving an armoured vehicle using a head-mounted display [10].

This paper outlines an experiment for testing the effectiveness of head-mounted display (HMD) and a head tracker for driving an armoured vehicle compared to traditional direct view and periscope view.

The main focus was to compare the HMD system to the periscope view, direct view was used as a control for the experiment, the participants were then tasked with driving the vehicle over rough and paved terrain, on the paved terrain the vehicle had to pass through a funnel of cones and slalom, the number of pylons knocked over were counted.

**Conclusions.**

The experiment showed that the user performance with the HMD was better than that of the periscope system on both paved and rough terrain, HMD users also performed faster in some sections of the off road, although it is mentioned that even better results could be attained for the HMD if the drivers were more experienced with the technology.

**Use to this research.**

This research highlights the importance of investigating HMD technology such as the Oculus to compare to the existing standard, In the case of this paper it may be beneficial to run the experiment both on the Oculus and a standard computer setup and compare the results to see if they are comparable or vastly different.

5.7 Evaluating three different interfaces for a mobile game [8].

The paper implements three user interfaces for a scroll shooter video game on an iPod Touch and test their effectiveness and how enjoyable they are to the user.

The game is structured to have three interfaces, simulated button, touch gesture and accelerometer, seven levels of difficulty are defined for the player to play, and over the course of the game the following metrics are tracked.

* Total time played.
* Number of projectiles fired.
* Number of player projectiles that connected with enemy ships.
* Number of enemy ships destroyed.
* Time the ship spends moving in each of the eight directions.

The game screen was segmented into nine distinct zones, the amount of time the player spends in each zone is also tracked.

During the test sessions the tester is given a questionnaire prior to participating in the experiment the first questionnaire is there to ask some general information on the user, the users are also asked about their experience of with the videos games on mobile platforms, the participates are then allowed to practice the game for a maximum of three minutes, they then plays the full game with a specific interface. A questionnaire is then filled in with questions specifically on the interface. The process is repeated until all three interfaces have been used. After the experiment concludes the user fills in a questionnaire about their preferred user interface.

**Conclusions.**

The findings of the paper showed that the users preferred the accelerometer interface and this was backed up with the heuristics of their performance, however the research admits that the specific implementation they did of the interfaces may have affected the opinion of the user as the touch gesture was not like industry standard they had come accustom to, the researcher also notes that caution should be taken as the design heuristics are based on a single experiment involving one type of game.

**Use to this research.**

This papers highlights that through questionnaire and game performance heuristics it is possible to gather data on the effectiveness of an interface, however caution is to be taken in the implementation of the interfaces with not breaking all ready pre-established patterns for implementing them.

1. Investigation Method

Based on the previous research investigated it was decided that an experiment revolving around a game where the user is tasked with objects to complete both using VR and Non VR, we will monitor their performance and draw conclusions, the design of this builds on the existing experiment design presented by Browne and Anand [8], Fg13. Shows the outline flow of the experiment, each stages rationale and content will be explained in the following section.



Figure 13. Procedure for the experiment.

6.1 Pre Experiment Questionnaire

The main purpose of this questionnaire is to gauge the experience of the user with not only games in general but also their experience with the Oculus, this information will be used to draw comparisons against the user performance metrics gathered, it would be expected someone with less experience in the respective areas would perform worse than an experienced user, this questionnaire will help identify such users. The following questions will be included in the questionnaire, a copy of the full questionnaire is included in Appendix A.

|  |  |
| --- | --- |
| **Question** | **Rationale** |
| What is your gender? | Used to categorize gender groups, may be a difference between the sexes. |
| What is your age? | Used to categorize age groups we would expect poorer performance from older subjects, in a traditional non VR [18], VR is untested however. |
| In the past 7 days roughly how many hours have you spent playing video games? | Used to help categorize people in to groups of familiarity of games we would expect people who play games more to perform better. |
| What genres of games do you play? | Used to gauge if the user is familiar with genres similar to that of our experiment. |
| In the past 7 days how many hours have you spent playing first person games? | Specifically asked to gauge how experienced a user is with the genre of the experiment more recent playtime would likely link to better performance. |
| What is your experience with the Oculus rift? | Here we want to gauge whether the user has extensive experience with the oculus or not, the question is twofold absolutely non exposed users will get a pre amble about the Oculus and will be highly encouraged to partake in the demo of the game. |
| How many hours have you spent using an Oculus rift? | Again this is to split the groups that have some experience of the Oculus into one off users or frequent users. |

Table . Pre experiment questions.

6.2 Instructions

After completing the survey the subject is shown an instruction screen with the task to be performed, it shows them the waypoints they have to move to while avoiding the projectiles being fired at theme, also there is an image displaying each of the interfaces that they will be using during the experiment and a legend to show what each entity is represented by, Fg14, shows the instruction screen.



Figure 14. Instructions Screen.

6.3 Calibrate Oculus

During this stage of the procedure the user will be sat at the desk and run through the configuration of the Oculus headset, this is done to make sure the head tracking and user position is correct, it is also good for new commoners to VR to get experience in a controlled environment, during the configuration it is made sure the user can freely look directly behind them without cables tangling as to not disrupt the experiment and allow them the full range of motion in the game.

The height of the user is collected and the headset is comfortably fitted to the users head, advance settings such as IPD [14] is not required due to the experiment not investigating emersion and thus the picture quality will suffice with the default configuration.

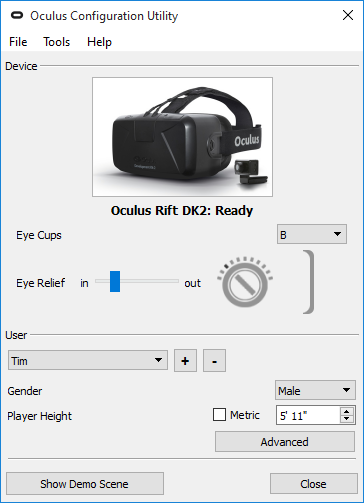
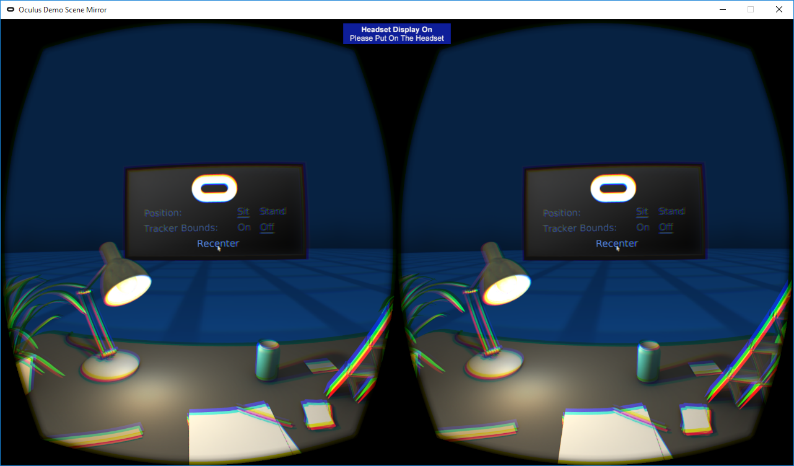
Fg15, 16 show the configuration tool and scene displayed to the user.

Figure 16. Configuration scene.

Figure 15. Configuration tool.

6.4 Game Demo

The user is now given the choice to play a demo of the game, this is a much simplified version of the real experiment without metric tracking, far less projectiles to avoid and the interfaces appear in a set order, the purpose of the demo is to allow users to get used to how the experiment operates such as how the player moves around the arena and how the interfaces convey information.

The demo runs for a much shorter period than the real experiment to reduce over exposure to the system.

6.5 Game Scenario

The experiment itself puts the user in arena which they have to manoeuvre about collecting flags (waypoints) while avoiding being hit by asteroids (projectiles), the user is given five different interfaces to help them perform the task they are as follows.

Diegetic

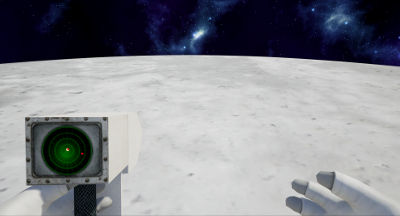
The users holds in their hand a radar device that highlights to them where the waypoints and are located and incoming projectiles this interface can be looked away from and therefore can appear in and out of view Fg17 shows the interface.

Figure 17. Diegetic interface.

Non Diegetic

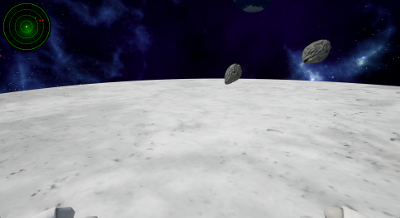
The user is given a radar that appears permanently in the top right of their view, the waypoints and projectiles are displayed on the interface, the interface orientates to the players rotation and displays them in the middle of the interface, Fg18 shows the interface.

Figure 18. Non diegetic interface.

Spatial

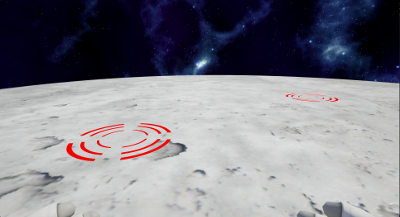
The user is presented with targets that appear on the ground showing where the projectiles are targeting, also the waypoints have a target placed beneath them, Fg19 shows the interface.

Figure 19. Spatial interface.

Meta

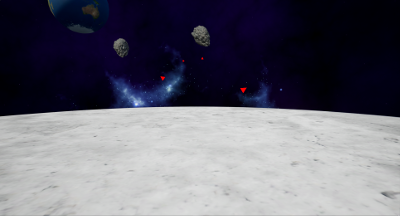
The user is presented with a temporary interface that appears when either the projectile or the waypoint is in range, the arrows that represent these entity’s increase in size depending on their distance from the user. Fg20 shows the interface.

Figure 20. Meta interface.

No Interface

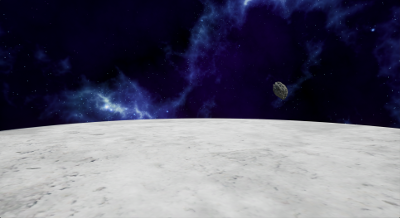
The user is left in the game arena with no interface to help them perform the task, this is used as a control for the experiment. Fg21 shows the game world without any interface.

Figure 21. No interface.

To make sure the experiment focuses on how the Oculus impacts the user performing the task, the user performs the experiment once with the Oculus and once without the Oculus for each of the interfaces, this allows us to collect data and draw correlations as to whether the Oculus remains the same for user performance or whether a specific interface has lower/higher performance than a standard setup.

The player moves around the game world using an Xbox360 controller, this helps to keep the movement consistent across both mediums and reduces the complexity.

To make sure the game is challenging enough to gather good metrics multiple projectiles approach the player at the same time, the projectiles also have varied behaviour some seek out the player while others target a random area in the arena, the waypoints appear in various predefined locations in the game world this is so that we can tell where a player is moving from, for example player has just collected waypoint three which we know the location of and will now be looking to move towards waypoint four, this helps with the metrics we will be observing that is explained in section 5.6, for most instances of the waypoints the next place for the player to move to will not be in their direct view on collecting the antecedent waypoint, thus forcing them to rely on their interface for looking around the game arena.

The interfaces are randomised for each run of the experiment, each interface appears for ninety seconds to aid the user bringing the total run time of the experiment to fifteen minutes, these times were chosen to make sure a user did not become lethargic or bored thus reducing the risk of these outside factors affecting the preceding results.

6.6 Metrics to be collected

Similar to the other experiments stated in section 5.4, we track the following metrics for data synthesis.

* The total number of asteroids the player has dodged, this is split between the different types of asteroids mentioned previously the has an algorithm for working out whether the player was ever in danger and being hit and made an effort to dodge the given projectile.
* The number of asteroids that hit the player are tracked.
* The time it takes for the player to move between to waypoint locations is tracked, this lets us see how quickly the player identified the next waypoint and how long it took them to move there.
* The total number of waypoints the player visits during each interface is tracked.
* The player’s movement is tracked over the experiment to see whether they are moving or standing still, movement shows progress towards the objective while no motion shows the player accessing their current situation.

6.7 Post experiment questionnaire.

Now that we have gathered quantitative data the final questionnaire will be used to collect qualitative data from the users as shown in the background section the research by Kevin and Christopher [8] a questionnaire was filled in at the end of each interface test, this would add to much time to this experiment and therefore has been cut down and merged to form the post experiment questionnaire , the following questions will be included in the questionnaire, a copy of the full questionnaire is included in Appendix B.

|  |  |
| --- | --- |
| **Question** | **Rationale** |
| Rank the interfaces in order with 5 being the worst and 1 being the best which helped you perform at your best using the Oculus rift. | This question is used to gauge how the subjects felt they performed we will then compare with their actual result, If a user of an interface feels it helped them it’s likely it was the one that they performed best at. |
| Why was the interface you chose as number 1 your most preferred? | Here we present them with a list of options, to get a qualitative analysis of why the users felt this interface was preferred, this is to verify the supplied interfaces were well designed and aren’t just fundamentally flawed. |
| How often did you use your most preferred interface to make decisions? | Used as verification as it is possible the users could just ignore the interfaces entirely, this was not technologically possible to verify without expensive eye tracking. |
| Why was the interface you chose as number 5 your least preferred? | Here we present them with a list of options, to get a qualitative analysis of why the users felt this interface was not preferred, this is to verify the supplied interfaces were well designed and aren’t just fundamentally flawed. |
| How often did you use your least preferred interface to make decisions? | Used as verification as it is possible the users could just ignore the interfaces entirely, this was not technologically possible to verify without expensive eye tracking. |

Table . Post experiment questionnaire.

The previous questions are repeated for the non-oculus version of the experiment.

Further post experiment questions

The user is now presented with a set of statements which they answer Oculus rift, Non Oculus rift or Not sure, again these questions are primarily designed in order to back up the metrics gathered and also to verify the validity of the study.

|  |
| --- |
| **Question** |
| I felt I performed at my best when using. |
| I felt I had to concentrate more when using. |
| I felt I stood still more using. |
| I enjoyed the experiment more when using. |
| I felt the interfaces worked better when using. |
| I felt the experiment was more intuitive using. |
| I found the experiment more difficult using. |
| I felt more confident using. |

Table . Oculus vs non Oculus questions.

The final section of the post experiment questionnaire is general questions about the experiment and how the user agrees on a scale from strongly disagree to strongly agree.

|  |  |
| --- | --- |
| **Question** | **Rationale** |
| The game felt responsive. | We want to verify that the game was designed in an acceptable manner so users could perform at their best, used to refine the experiment design. |
| The game was fun. | In the pursuit to make sure users perform at their best Agarwal and Karahanna [19] suggest that if a user is having fun there are more cognitively absorbed in what they are doing. |
| I understood my objective at all times. | Verification that the user was never standing still out of confusion and was always attempting to make progress towards their goal. |
| The interfaces were well made. | Verification once again that the interfaces supplied where of a good quality and representative of the results found. |
| The interfaces were easy to understand. | Verification once again that the interfaces supplied where of a good quality and representative of the results found. |
| The experiment took too long. | It’s likely that the experiment lasting to long could lead to lethargy, meaning that their second test would be negatively impacted by an outside factor. |
| I enjoyed my experience using the Oculus rift. | Similar to “The game was fun” users who enjoyed the Oculus are more likely to perform at their best. |
| The Xbox controller was easy to use. | Verification that the input scheme used was intuitive and useable by all participants, this is good to check the decision to use this control scheme in both scenarios was a sensible one. |
| The game felt challenging but not impossible. | To verify that the metrics tracked on the user’s performance were representative, we wouldn’t want users to be struggling and getting lower scores due to the game being exceptionally unfair. |
| I felt I performed at my best. | We get a direct response as to whether the user felt they did indeed put their best into their performance. |
| Any additional comments? | General question for feedback on the experiment mostly any areas that need improved that have not already been questioned. |

Table . General experiment questions.

From these questions we can then begin to compare the qualitative and quantitative data and begin to draw conclusions as to the best interfaces to use on the Oculus.

1. Results and Analysis

The experiment was run with fifteen different testers and their results gathered the following section shows the results.

7.1 User demographic

Before each experiment the user answered a series of demographic questions, the results of which are shown Fg22.

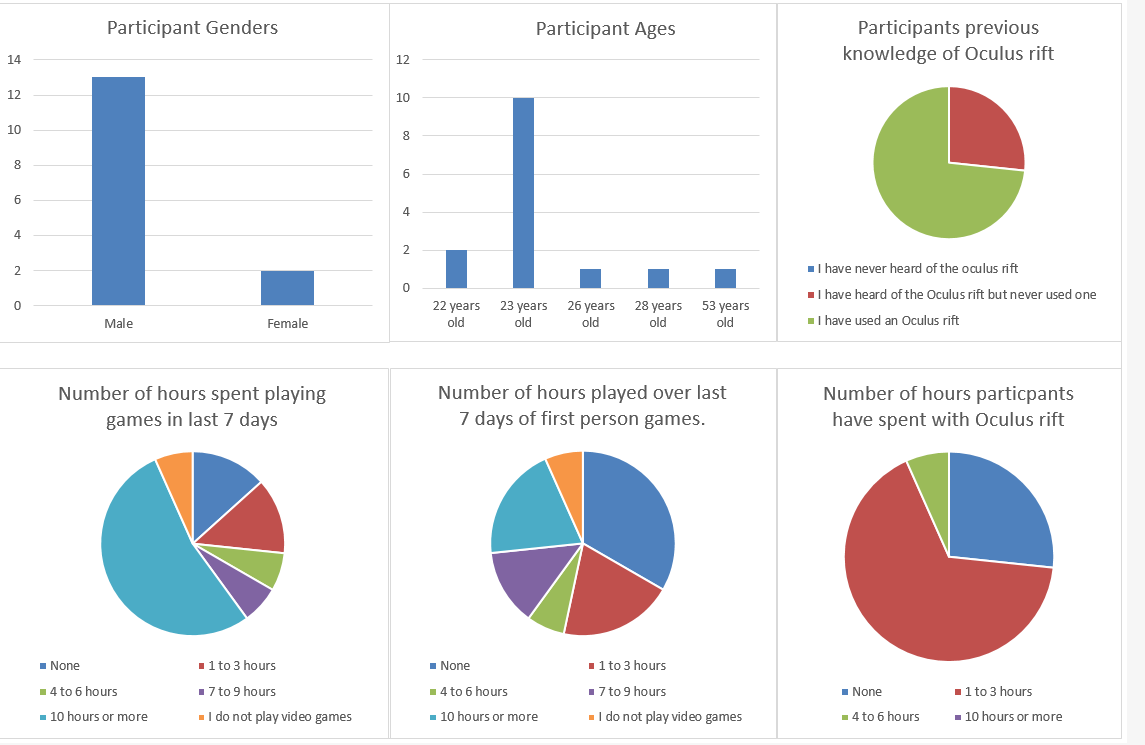


Figure 22. User demographic.

As shown in the graphs a large amount of the participants were regular players of games, playing on average more than ten hours a day, however most users had very little hand on experience with an Oculus rift, most commented during the experiment saying they had only tried short demo’s, this distribution and number of demographics is perfect for the experiment as outlined in the research proposal [15].

7.2 Results and Discussion

The metrics outlined in section 5.6, have been collected and are displayed in the following graphs.

At the end of the experiment users were asked to rank the interfaces in the order they felt that helped them perform at their best during the experiment Fg23, 24 show these graphs.

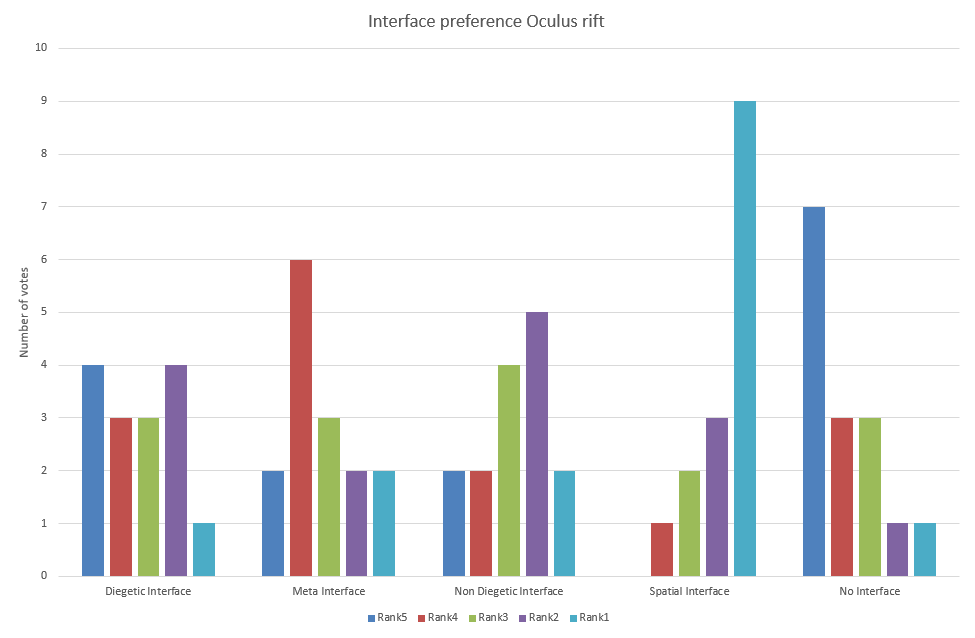


Figure 23. Oculus rift interface preference, each user ordered the interface by preference, each column represents the number of votes for that rank, in this case spatial was the most preferred and no interface the least preferred.

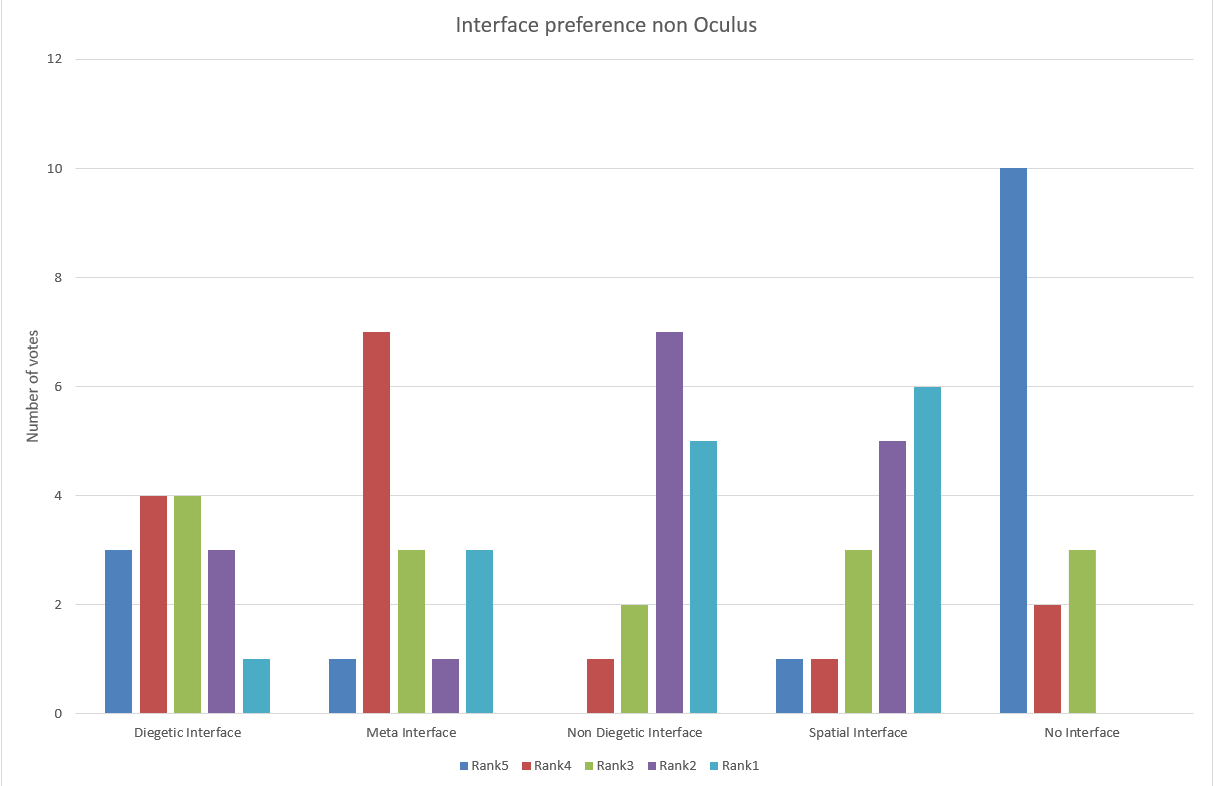


Figure 24. Non Oculus rift interface preference, each user ordered the interface by preference, each column represents the number of votes for that rank, in this case spatial was the most preferred and no interface the least preferred.

We can see that in VR spatial was the clear preferred interface and no interface at all was the least preferred, in contrast however it was much closer for non-VR where spatial only narrowly passed non-diegetic Interface, Fg25, shows the reasoning behind users choices for these interfaces.

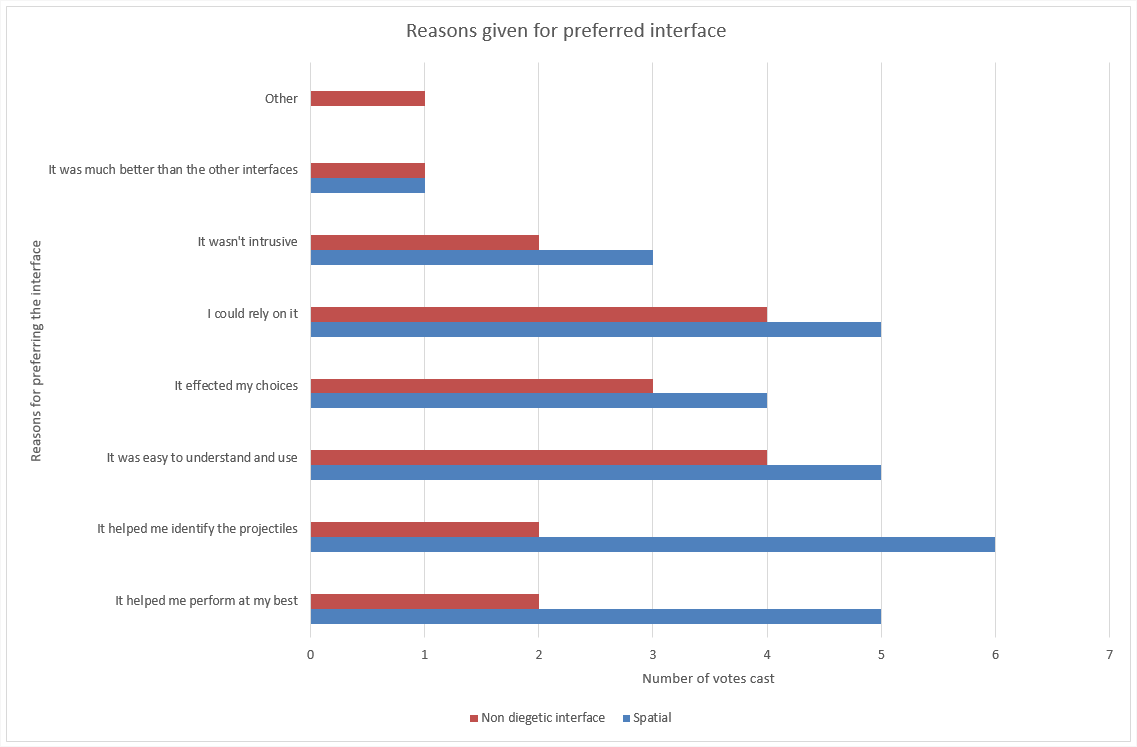


Figure 25. User’s rationale for voting for spatial and non diegetic.

As we can see users had similar opinions about the spatial interface as they did non-diegetic, most felt in both cases the interface wasn’t intrusive, could be relied on and effect their choices, one subject went as far to say when they were using the non-diegetic interface they never took their eyes off it.

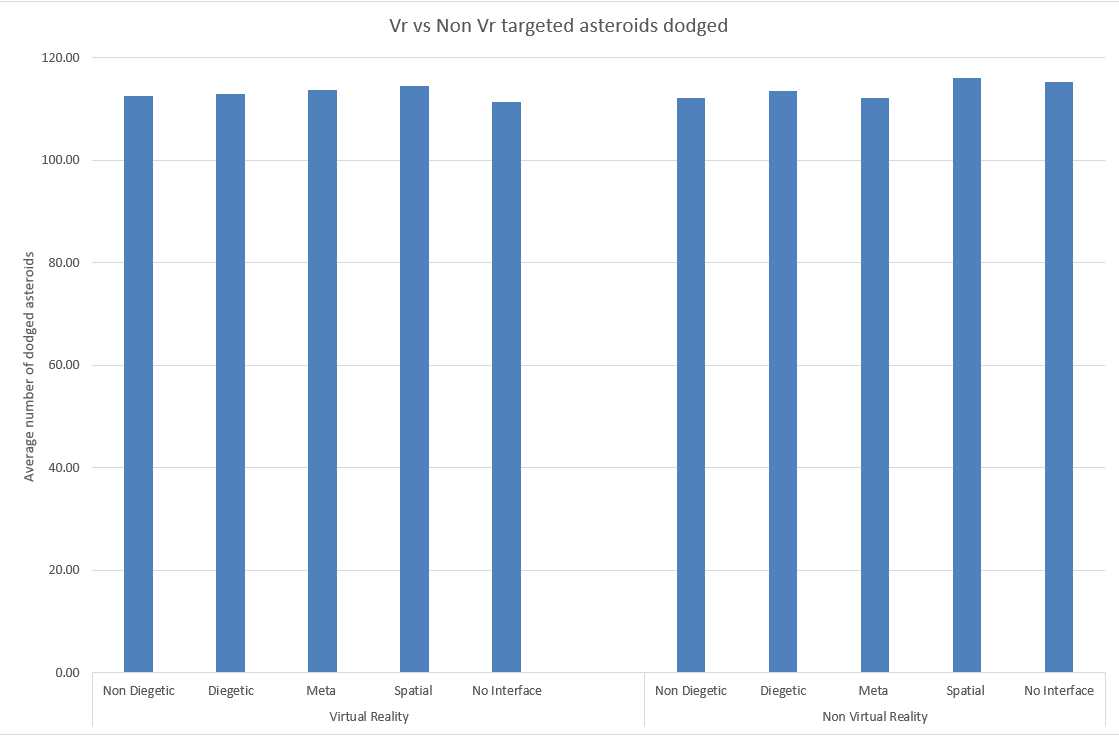


Figure 26. Average number of targeted asteroids users were hit by during the experiment, targeted asteroids were ones that directly sought out the player.

When it comes to targeted asteroids there is very little difference between the various interfaces, for each interface ~120 targeted asteroids would be launched at the player on average players dodge 113 resulting in a successful dodge rate of ~94%.

Players must remain moving in order to avoid these types of asteroids Fg27 shows the movement metrics of the players.

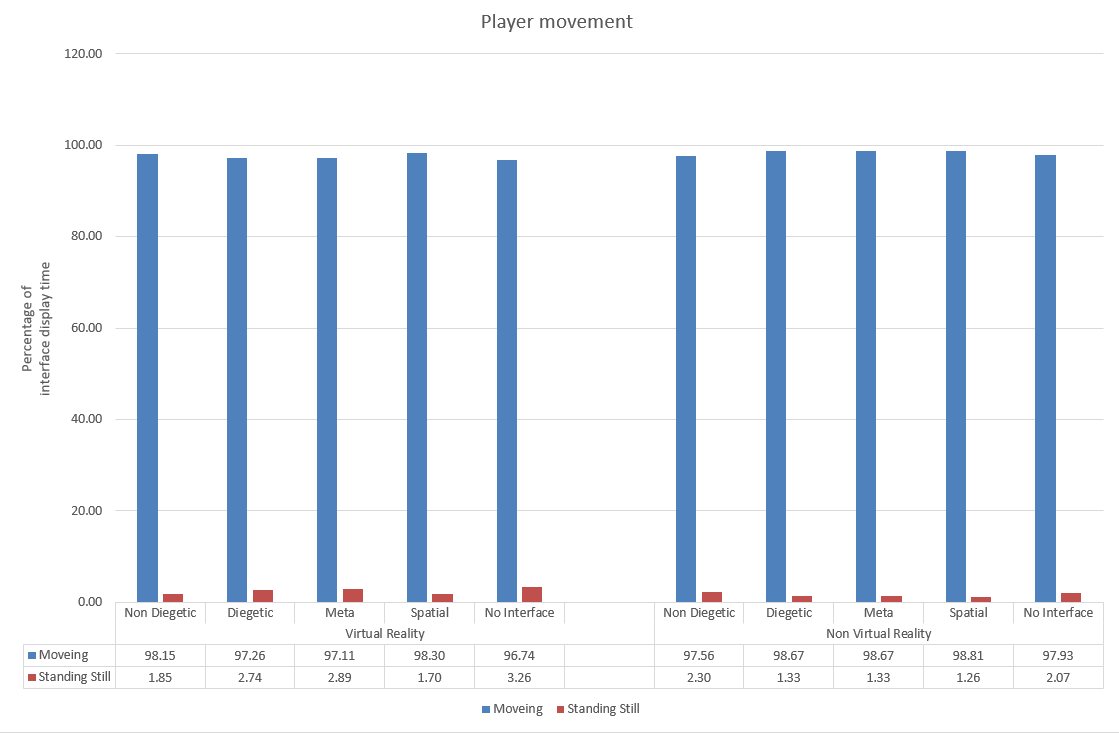


Figure 27. Percentage of 90 seconds a player spent moving for each interface.

As we can see on average most users were constantly moving ~98% of the time, therefore we can say that the targeted asteroids were probably while valid did not offer enough difficulty to really challenge a user to perform table 5 shows several subjects with above average times for standing still.

|  |  |  |
| --- | --- | --- |
| **Subject 3 Non Vr results.** | | |
| **Interface** | **Time spent standing still (s)** | **Targeted asteroids dodged** |
| Non Diegetic | 23 | 87.5% |
| Diegetic | 14 | 83.0% |
| Meta | 9 | 95.8% |
| Spatial | 7 | 95% |
| No Interface | 23 | 90% |
| **Subject 6 Vr results** | | |
| **Interface** | **Time spent standing still (s)** | **Targeted asteroids dodged** |
| Non Diegetic | 6 | 94.1% |
| Diegetic | 4 | 90.0% |
| Meta | 17 | 94.1% |
| Spatial | 12 | 94.1% |
| No Interface | 14 | 91.0% |

Table . Table of players that stood still for more time than the average.

Subject 3 shows correlation between standing still and getting hit by a targeted asteroid as we would expect however Subject 6 has instances where he spent nearly all his time moving but still was being hit, this could be caused by a user moving backwards or circling on the spot meaning they are still in danger of a collision.

Targeted asteroids show some insight into user performance but does not on its own provide a strong conclusion.

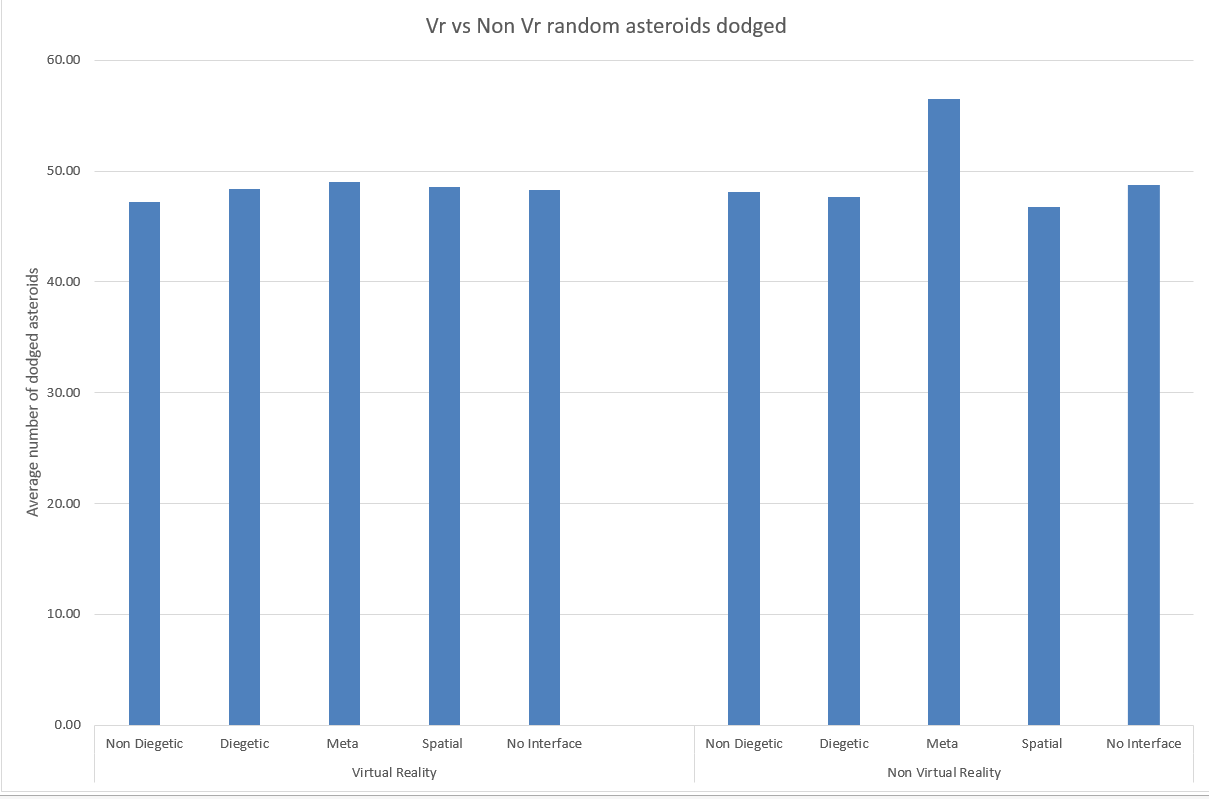


Figure 28. Average number of random asteroids users were hit by during the experiment, random asteroids landed randomly around the game arena.

Similarly to targeted asteroids there is a trend between both mediums, however in non-VR we can clearly see the Meta interface out performs the others, this is in contrast to what the users felt was the best interface for performance, in fact out of the 11 participants that said they ranked non diegetic or spatial as their number one interface, 63% actually performed better when it came to dodging random asteroids when using the meta interface, more interestingly meta was ranked as the 2nd least preferred for non-VR.

Having looked at the asteroids the participants have avoided in detail, we move onto the number of asteroids they actually collided with, remember that this is the total number of asteroids the user collided with combined see Fg29.

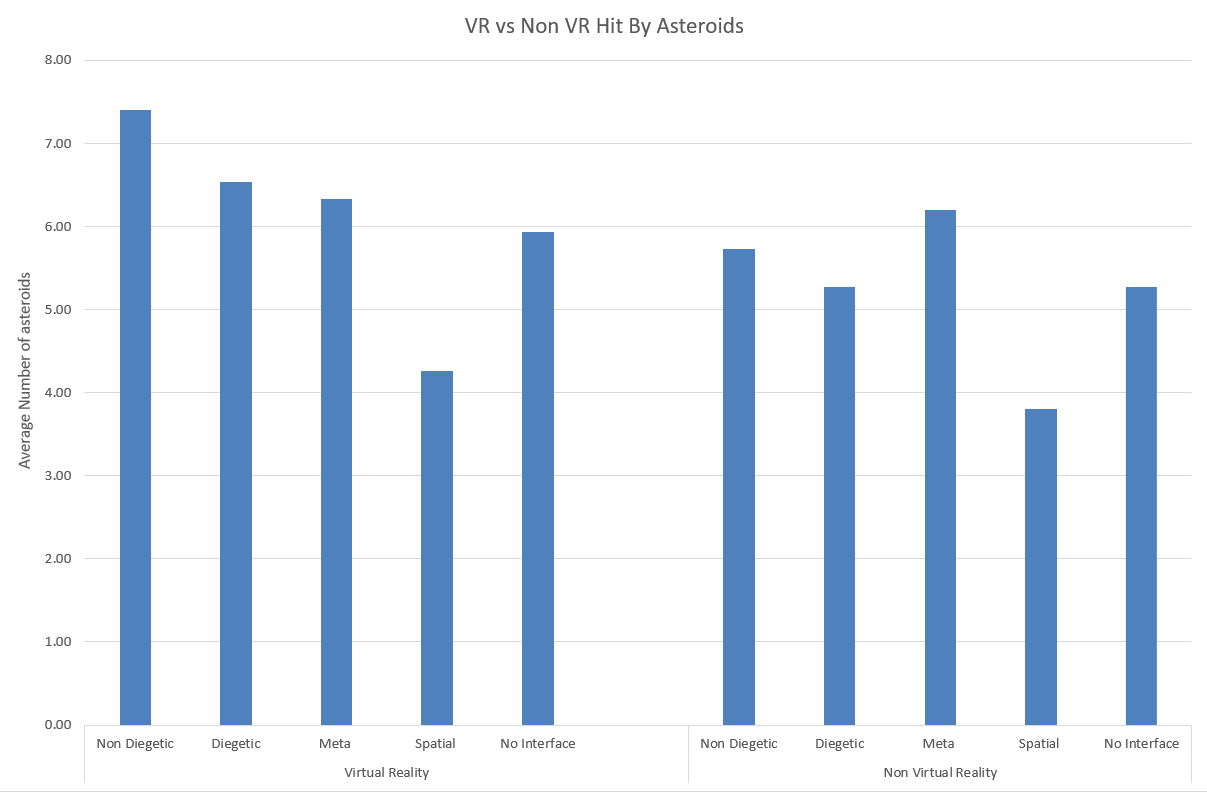


Figure 29. Average number of asteroids the participants were hit by during the experiment, contains both targeted and random asteroids.

Spatial interfaces in both mediums show positive results as being the best interface, we can see a drop in all interfaces between VR and non-VR, if we look at the users responses shown in Fg30.

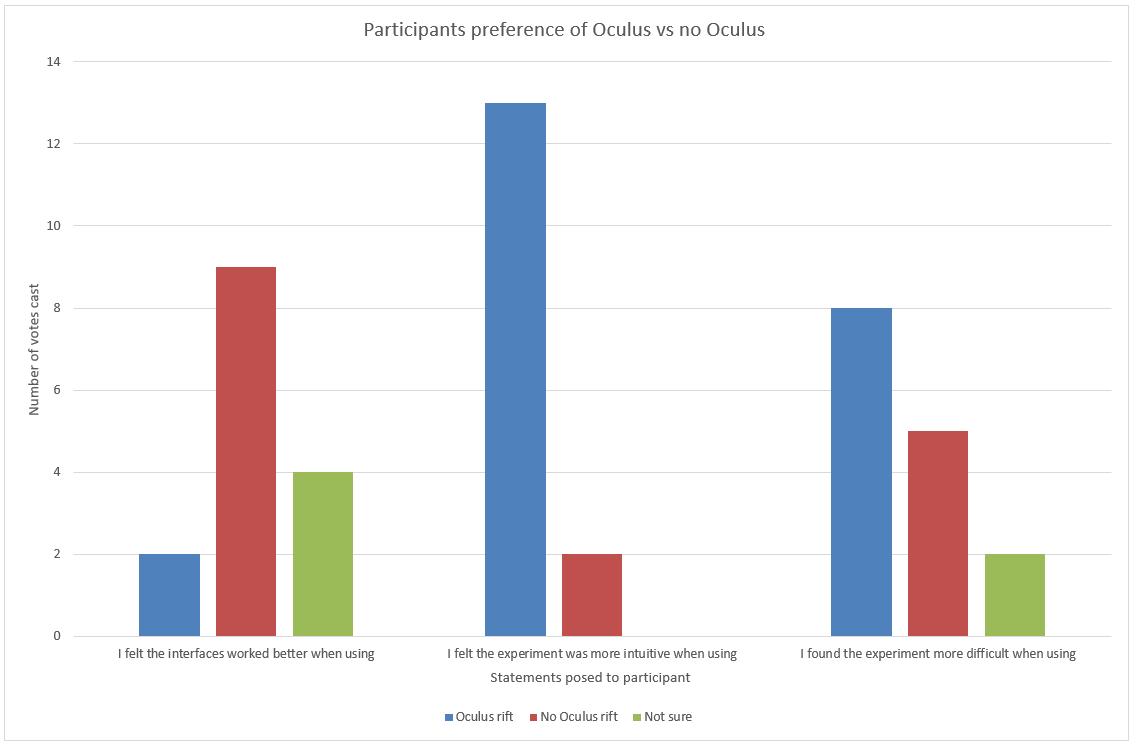


Figure 30. Choice of medium, Users were posed with a series of statements and asked to choose either the Oculus or no Oculus or not sure.

From the participants responses we can see that they felt the interfaces worked better in non-VR this is not saying that the interfaces were useless in VR Fg31.

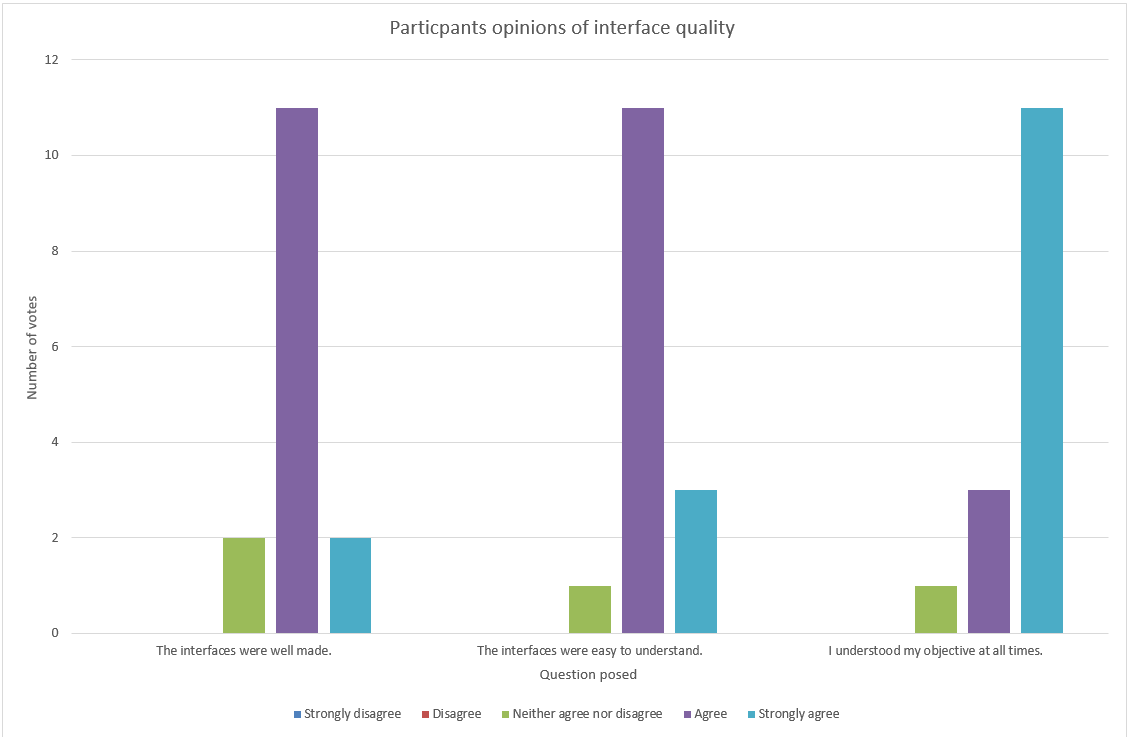


Figure 31. Interface quality opinions, users were asked a series of questions and allowed to respond within the range of strongly disagree to strongly agree.

Users felt the unanimously felt the interfaces were well made and easy to understand, the other two statements of Fg30 may shed light on users lower performance with VR as we can see they felt the game was more intuitive and difficult when using the Oculus, this could lead to them relying less on the interfaces and more on visually identifying asteroids themselves this on top of perceiving it as more difficult could lead to the performance discrepancy we see in Fg29.

Next we move on to the other objective the user had of traversing between waypoints Fg32.

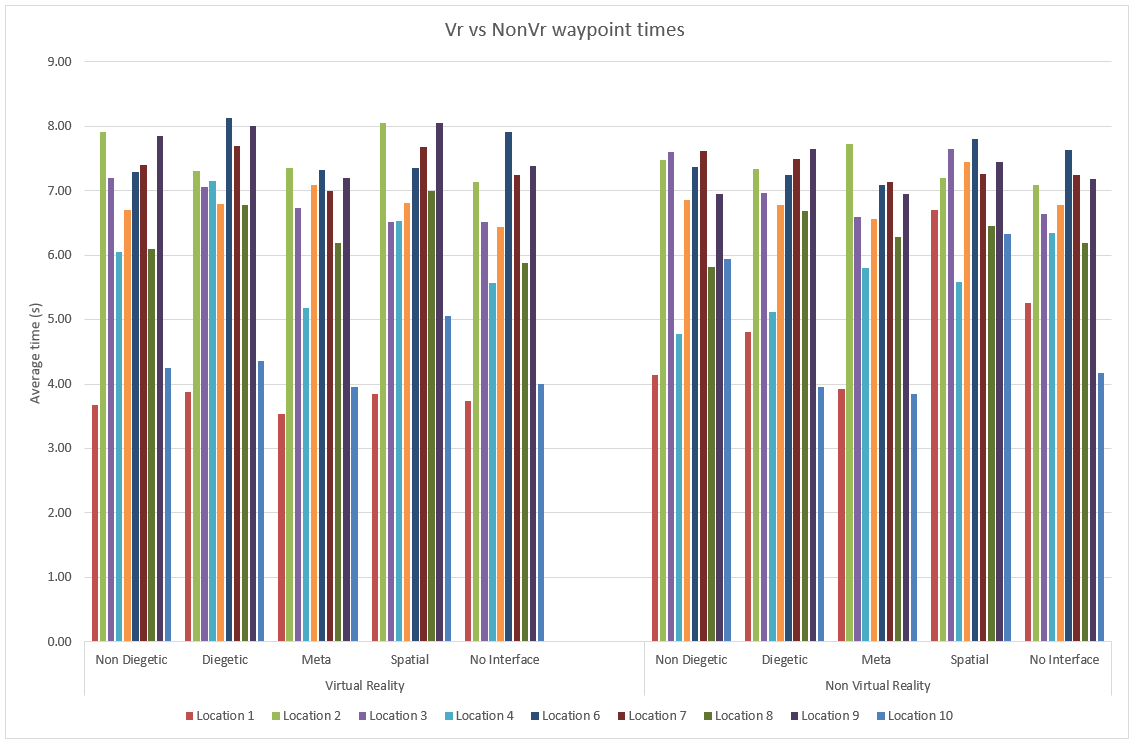


Figure 32. Time taken to navigate to a given waypoint by each interface, each column represents a waypoint from 1 to 10.

Due to the positions of the waypoints being fixed we know the distance a user had to travel between points Table 6 shows this.

|  |  |
| --- | --- |
| **Distance between waypoints** | |
| **Waypoints** | **Distance** |
| **Waypoint10->Waypoint1=Location1** | 1650 |
| **Waypoint1->Waypoint2=Location2** | 3146.82 |
| **Waypoint2->Waypoint3=Location3** | 3100.40 |
| **Waypoint3->Waypoint4=Location4** | 1978.00 |
| **Waypoint4->Waypoint5=Location5** | 3100.40 |
| **Waypoint5->Waypoint6=Location6** | 3231.20 |
| **Waypoint6->Waypoint7=Location7** | 3301.90 |
| **Waypoint7->Waypoint8=Location8** | 2800 |
| **Waypoint8->Waypoint9=Location9** | 3301.90 |
| **Waypoint9->Waypoint10=Location10** | 1650.95 |

Table . Distance between waypoints.

Firstly we see that location 1 and location 10 have the shortest distances to travel this accounts for their time being below average, however location4 has a lower distance for users to travel but when using the Diegetic interface in VR it was much slower than some of the other much further away locations, comparing VR to non-VR we see a stark difference between the spatial category, Using VR spatial out performed on location 1,3,5,6,7,10 compared to its non-VR counterpart, while one instance of the spatial interface performed much better in VR we can’t say the same for the Diegetic interface which performed on average worse in VR.

Table 9 shows the total number of waypoints visited on average by players.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Non Diegetic** | **Diegetic** | **Meta** | **Spatial** | **No Interface** |
| **Virtual Reality** | 13.93 | 13.6 | 14.67 | 13.13 | 14.00 |
| **Non Virtual Reality** | 13.67 | 14.07 | 14.47 | 12.87 | 14.00 |

Table . Average number of waypoints visited by a participant during an interface.

As discussed before spatial interface took slightly longer on average using non-VR this is reflected in the total number of waypoints visited, however it is consistent across the board, therefore there is no discernible difference between the two mediums.

7.3 Experienced user vs New User

From the user demographics we know that 11 out of 15 participants said they had previous experience with an Oculus rift and 4 had no experience at all, in this section we shall look into whether there is any differences between these two user groups, Fg33 shows the Amount of random asteroids dodged by new users and experienced users.

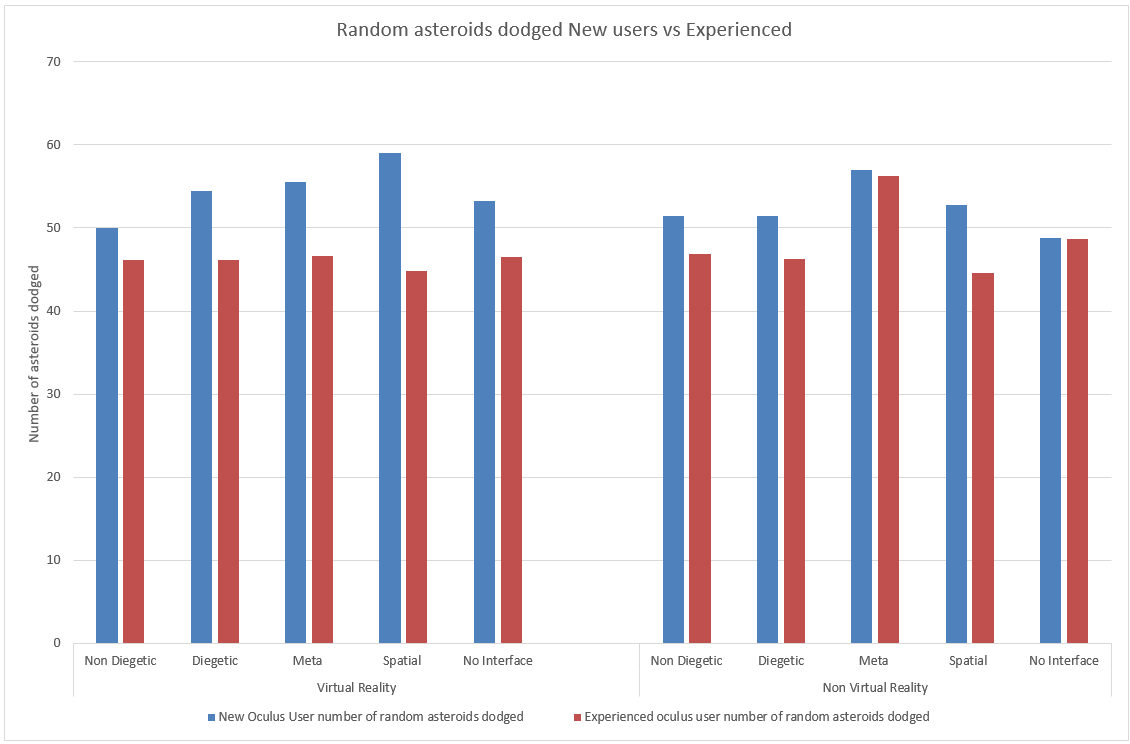


Figure 33. Random asteroids dodged by new users compared to experienced users, each column represents the average dodged by each user group.

Interestingly participants with no experience of the Oculus outperformed the more experienced users in all cases when using VR, spatial interfaces in particular show the largest difference this may be caused by new users relying on the interfaces more and experienced users being confident and charging in relying more on their previous knowledge and ability to get by.

Fg34 shows the difference between the two groups when it comes to being hit by asteroids overall.

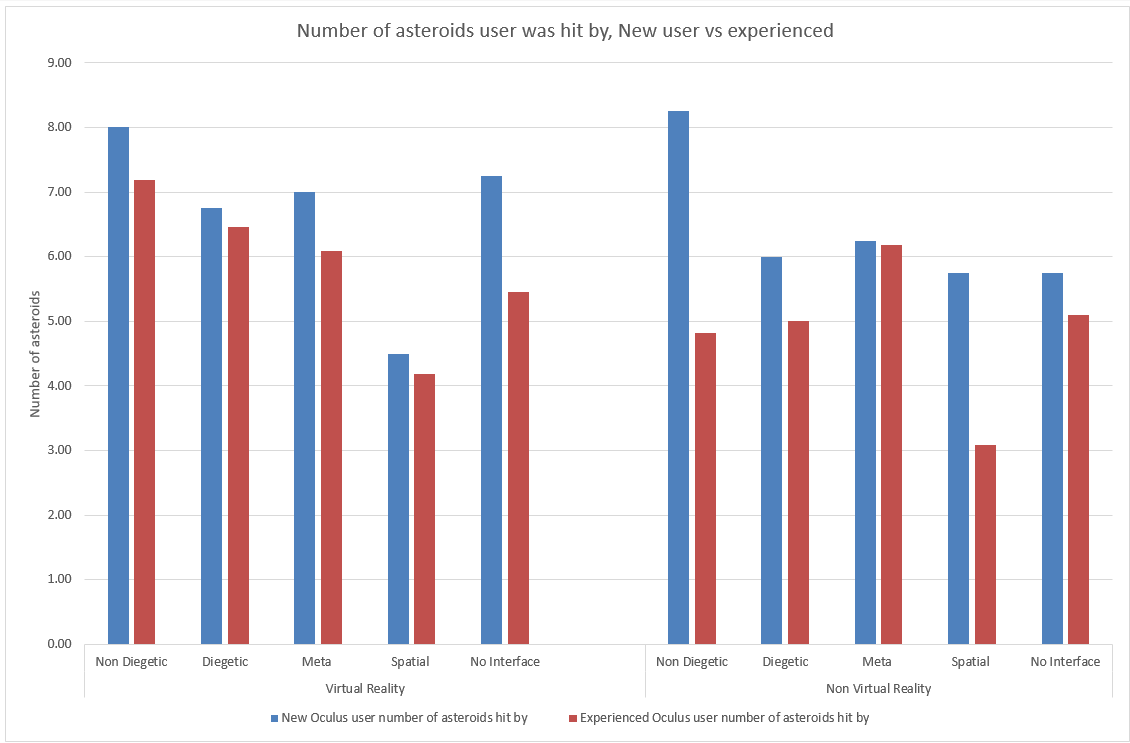


Figure 34. Number of asteroids new and experienced users were hit by, each column represents the average number of asteroids each user group was hit by.

In contrast to the previous example new users overall were hit by more asteroids, we display both sets of results for VR and non-VR to see how each group performed without VR we would expect there to be commonality however inexperienced users performed substantially worse with non-diegetic interfaces when not using VR for no discernible reason.

Finally we look at how new Oculus users and experienced users compared when traversing the game arena between waypoints Fg35.

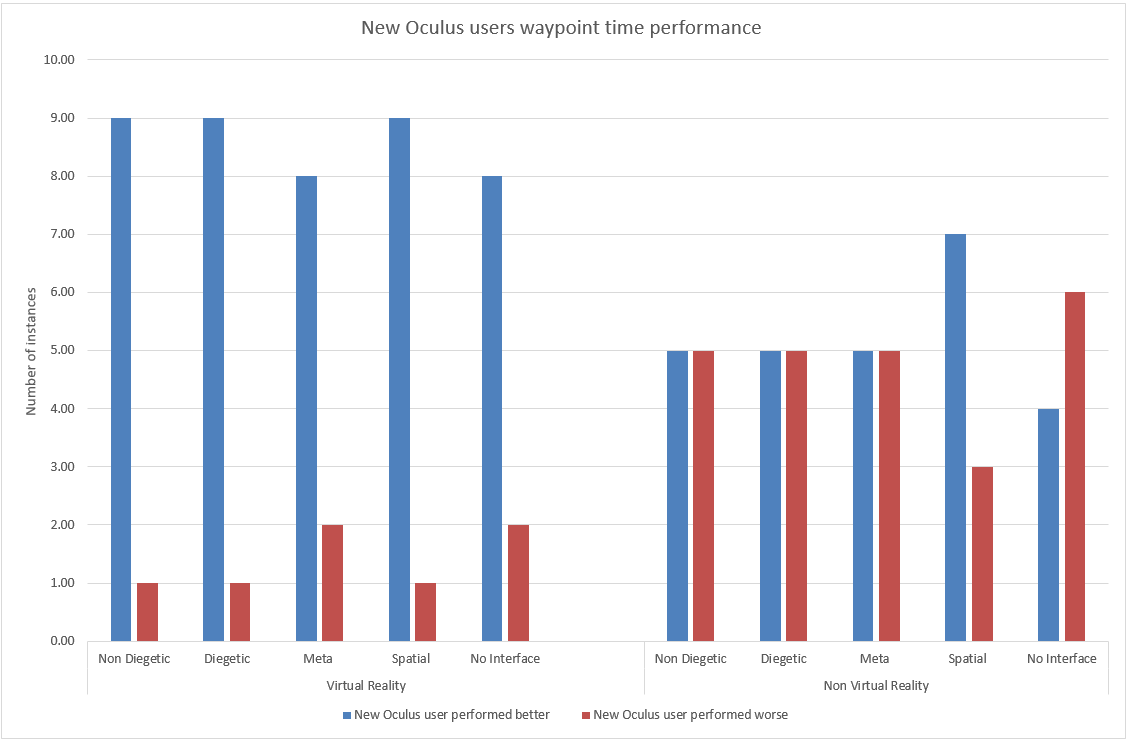


Figure 35. The graph shows a comparison across the 10 locations as to whether the new user performed better or worse than an experienced user, each column represents how many out of the 10 locations a player performed better or worse.

While no one interface stands out as being a forerunner with new users, interestingly new users across the board out performed experienced users when using Oculus in terms of traversing between waypoints faster, however in the non-Oculus setup where there was common ground, the new users performed as well, the reason behind this may be explained by users response to which medium they felt was more intuitive Table 8.

|  |  |  |
| --- | --- | --- |
| **I felt the experiment was more intuitive when using** | | |
| **Oculus Rift** | **Non Oculus Rift** | **Not sure** |
| 13 | 2 | 0 |

Table . User response to how intuitive the system was to them.

As we can see users unanimously felt that the Oculus was more intuitive, this may mean for new users they found it easy to pick up and therefore perform using the Oculus, while no specific interface was a clear fore runner it does allow for future work to take into consideration the effects of new users vs experienced when developing similar experiments.

1. Conclusions

The main purpose of this work was to investigate the effect of visual interface choice against user performance when using VR, it must be noted however that the results presented are based on a single experiment involving on genre of game, with a sample not large enough to be representative of the entire human population. With that said most VR experiences are first person based, however publishing the game to gather more statistical results would be difficult due to the infancy of VR and the cost barrier it presents.

For each of the interfaces they were tested both with VR and without, while we saw differences in performance between the interfaces, they were consistent across mediums, small improvements were noticed when using the spatial interface in the Oculus rift however this is probably related to the scenario created and not representative of VR in general. From this simple scenario we can see that interfaces designed previously for non-VR will allow a user to perform at their best while using VR, therefore it is my recommendation that anyone designing for VR not to throw the existing rules out the window as they will be equally applicable in VR.  
In order to determine how novel this idea was existing papers were investigated and shown in section 5, I believe the idea presented is novel while the testing procedure and the metrics tracked are similar to the existing research presented the state of the art nature of the Oculus and modern VR in general make this research original. Looking at the industry recommendations for VR Guidelines on design we can see recommendations on interfaces with relevance to user interaction [17], and general developer guidelines [16] there is no recommendations similar to those presented here.

For future work I propose investigation into more first person scenarios with more varied tasks for the user to do, such as driving around a race track or navigation of a maze, in addition getting more participants for these experiments more specifically users that have less experience with an Oculus and games in general would lead to a more diverse population and therefore better results. While this experiment displays consistency between VR and non-VR only through further experimentation will this conclusion become stronger.

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Appendices

Appendix A

23/04/2016 Pre Experiment Questionnaire

Pre Experiment Questionnaire  
Thank you for participating in this experiment, please attempt to answer all questions as accurately as possible.  
\* Required  
  
Questions  
Background Information on previous experience of the participant.

1. What is your gender? \* Mark only one oval.

Female

Male

1. What is your age? \*
2. In the past 7 days, roughly how many hours have you spent playing video games (e.g. gaming consoles, mobile phones, computers, etc.)? \* Mark only one oval.

None

1 to 3 hours

4 to 6 hours

7 to 9 hours

10 hours or more

* 1. do not play video games

1. What genres of games do you play? \* Check all that apply.

Massively multi player online

Shooter

Adventure

Role­Playing

Simulation

Strategy

Survival horror

* 1. do not play video games

1. In the past 7 days how many hours have you spent playing first person games? \* Mark only one oval.

None

1 to 3 hours

4 to 6 hours

7 to 9 hours

10 hours or more

* 1. do not play video gams

1. What is your experience with the Oculus rift? \* Mark only one oval.
   1. have never heard of the Oculus rift

I have heard of the Oculus rift but never used one

I have used an Oculus rift

1. How many hours have you spent using an Oculus rift? Mark only one oval.

None

1 to 3 hours

4 to 6 hours

10 hours or more

* 1. have not used an Oculus rift

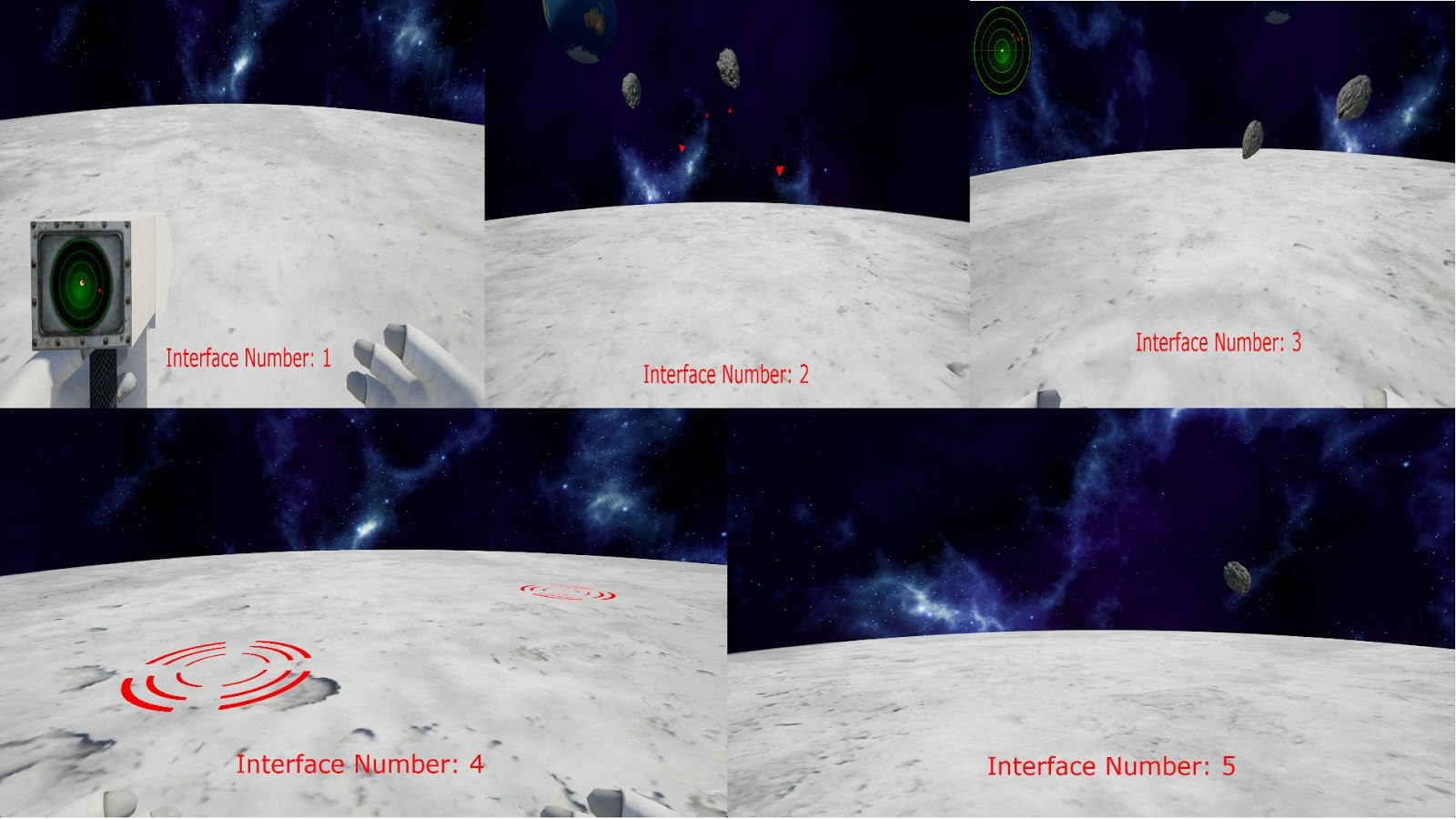
Appendix B

Post experiment questionnaire

Questions to be answered after the completion of the experiment on the users experience when using the Oculus rift.

\* Required

Interfaces



1. Rank the interfaces in order with 5 being the worst and 1 being the best, which helped you perform at your best when using the Oculus rift. \* Mark only one oval per row.

5

4

3

2

1

Interface Number 1

Interface Number 2

Interface Number 3

Interface Number 4

Interface Number 5

1. Why was the interface you chose as number 1 your most preferred? \* Check all that apply.

It helped me to perform at my best.

It helped me identify the projectiles.

It was easy to use and understand.

It effected my choices.

* 1. could rely on it.

It wasn't intrusive.

It was much better than the other interfaces.

Other:

1. How often did you use your most preferred interface to make decisions? \* Mark only one oval per row.

Never Rarely Sometimes Often Very Often

Interface 1 Usage

1. Why was the interface you chose as number 5 your least preferred? \* Check all that apply.

It did not help me perform at my best.

It did not help me identify the projectiles.

It was not easy to use and understand.

It did not effect my choices.

I could not rely on it.

It was intrusive.

It was much worse than the other interfaces.

Other:

1. How often did you use the interface to make decisions? \* Mark only one oval per row.

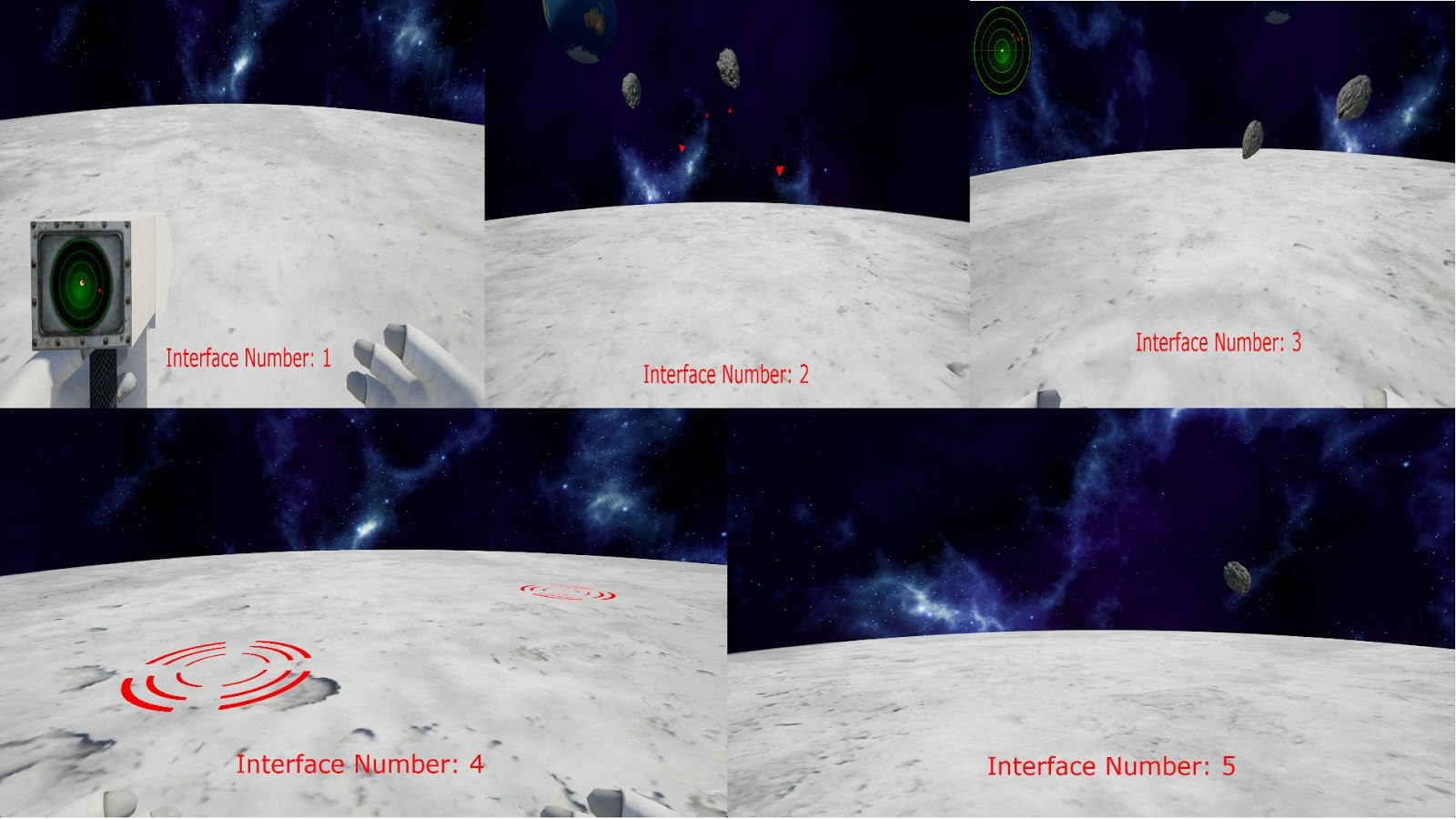
Never Rarely Sometimes Often Very Often

Interface 5 Usage

Post experiment questionnaire

Questions to be answered after the completion of the experiment on the users experience when not using the Oculus rift.

Interfaces



1. Rank the interfaces in order with 5 being the worst and 1 being the best, which helped you perform at your best when not using the Oculus rift. \* Mark only one oval per row.

5

4

3

2

1

Interface Number 1

Interface Number 2

Interface Number 3

Interface Number 4

Interface Number 5

1. Why was the interface you chose as number 1 your most preferred? \* Check all that apply.

It helped me to perform at my best.

Interface 1 Usage

It helped me identify the projectiles.

It was easy to use and understand.

It effected my choices.

* 1. could rely on it.

It wasn't intrusive.

It was much better than the other interfaces.

Other:

1. How often did you use the interface to make decisions? \* Mark only one oval per row.

Never Rarely Sometimes Often Very Often

1. Why was the interface you chose as number 5 your least preferred? \* Check all that apply.

It did not help me perform at my best.

It did not help me identify the projectiles.

It was not easy to use and understand.

It did not effect my choices.

* 1. could not rely on it.

It was intrusive.

It was much worse than the other interfaces.

Other:

1. How often did you use the interface to make decisions? \* Mark only one oval per row.

Never Rarely Sometimes Often Very Often

Interface 5 Usage

Comparison of performance.

Questions on which median the user preferred for a series of statements.

1. Please pick the median which completes the statement. \* Mark only one oval per row.

Oculus Rift

No Oculus Rift

Notsure

I felt I performed at my best when

using...

I felt I had to concentrate more

when using...

I felt I stood still more using...

I enjoyed the experiment more

when using...

I felt the interfaces worked better

when using...

I felt the experiment was more

intuitive when using...

I found the experiment more

difficult when using...

I felt more confident using...

General questions.

General questions about the users experience with the experiment.

1. Please answer the following on your experience of the experiment. \* Mark only one oval per row.

Strongly

disagree

Disagree

Neither agree

nor disagree

Agree

Strongly

agree

The game felt

responsive.

The game was fun.

I understood my

objective at all times.

The interfaces were

well made.

The interfaces were

easy to understand.

The experiment took

too long.

I enjoyed my

experience using the

Oculus rift.

The Xbox controller

was easy to use.

The game felt

challenging but not

impossible.

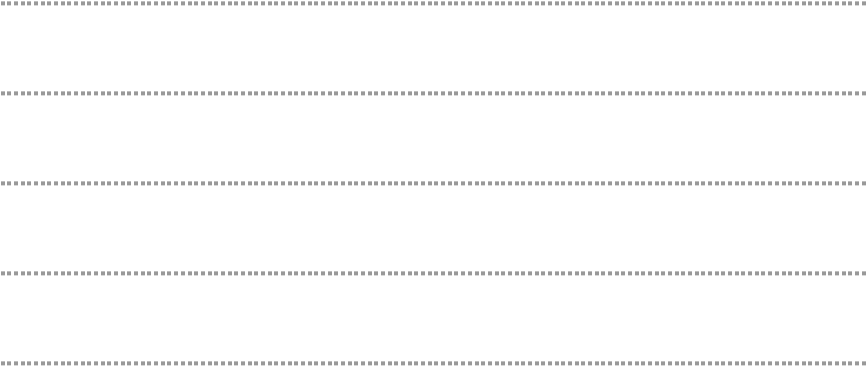
I felt I performed at my

best.

13

.

Any additional comments.



Appendix C

**(Minutes Sheets will go here)**