Graeme Barclay

VIRTUAL REALITY AND
VIRTUAL REALITY SICKNESS

Creation of a Virtual Reality Sickness Reduction Tool

Bachelor's thesis

Degree programme in Game Design

2020

South-Eastern Finland
University of Applied Sciences

Author (authors)	**Degree**	**Time**
Graeme Barclay	Bachelor of Culture and Arts	April 2020
Thesis title Virtual Reality and Virtual Reality Sickness Creation of a Virtual Reality Sickness Reduction Tool		87 pages 6 pages of appendices
Commissioned by Self-commission		
Supervisor Marko Siitonen		

Abstract

Virtual reality (VR) games are an increasingly popular entertainment media within the gaming industry. However, virtual reality is hindered by the effects of virtual reality sickness (similar to motion sickness). The objective of this thesis was to establish what aspects of virtual reality games cause VR sickness in order to create a design tool — the Virtual Reality Sickness Reduction Tool (VRSRT) — for virtual reality game developers to use, complete with practical solutions, that could limit the impact of VR sickness when developing virtual reality games. This new design tool was then validated through the creation of a virtual reality game product.

This thesis studied existing virtual reality games via content analysis as well as examined the relevant literature surrounding the topics of virtual reality and VR sickness through a literature review. The research was to show the relationship between VR sickness and virtual reality and the impact it has on the virtual reality experience. Moreover, the research provided many practical solutions for VR sickness and the results contributed to the creation of the VRSRT.

The product design result of this thesis was Homeward, a virtual reality experience game, designed and implemented with the VRSRT born from the research conducted. Essentially, the design tool helps virtual reality game developers reduce the impacts of VR sickness. Overall, the product was a success as the game was designed and implemented using the VR sickness reducing guidelines outlined in the design tool.

The virtual reality game product was examined through playtesting to find out to what extent VR sickness is prevalent in the game product which also evaluated the effectiveness of the VRSRT. However, unforeseen circumstances made additional playtesting of the product impossible as well as unethical. Therefore, more time and resources would have been needed in order to conduct more rigorous playtesting to ensure the design tool and product had the desired impact despite early playtesting showing promise.

Keywords

cybersickness, game design, motion sickness, thesis, virtual reality, virtual reality sickness

CONTENTS

1 INTRODUCTION

Virtual reality (VR) games are an increasingly popular entertainment media within the gaming industry. However, the virtual reality experience in games has been hindered by the effects of virtual reality sickness with 25% to 40% of players saying they experience VR sickness (Mason 2017). The objective of this thesis is to establish what aspects of virtual reality games cause VR sickness, in order to create a design tool that contains practical solutions which could limit the impact of VR sickness when developing virtual reality games. Subsequently, the design tool will be used to design and implement a virtual reality game product.

In order to fulfil the objective of this thesis, a literature review will be performed. The research surrounding the literature will establish a relationship between VR sickness and virtual reality additionally answering questions such as, "what are the impacts of virtual reality sickness on the virtual reality experience?" and "what aspects of virtual reality cause VR sickness?". Moreover, the literature review will help establish what can be done to combat VR sickness.

Existing virtual reality games will be analysed in order to determine what those games do to alleviate the effects of VR sickness. The information gained from the content analysis, coupled with the research from the literature review will then be used to create a design tool — the Virtual Reality Sickness Reduction Tool (VRSRT) — that could help virtual reality game developers reduce the impact of VR sickness in virtual reality games.

The game design tool will be validated through the creation of a virtual reality game product. The game product will be designed and implemented based heavily on the VR sickness solutions outlined by the VRSRT. The virtual reality game product will be examined through playtesting to find out to what extent VR sickness is prevalent in the game, which will, additionally, evaluate the effectiveness of the VRSRT.

2 VIRTUAL REALITY

Virtual reality (VR) is a simulated experience which can be based on reality or fantasy. VR is distinct from augmented reality (AR) — an interactive experience where objects in the real world are enhanced by computer-generated information — and mixed reality (MR) — an interactive experience generated from the merging of real and virtual worlds. There are many practical applications of VR including medical simulation training and military simulation training but for the purpose of this thesis, the focus will be on VR computer games. Virtual reality can be achieved through various medium such as simulation-based driving simulators but since this thesis is focused on VR computer games, head-mounted display (HMD) is the most appropriate form to consider. Furthermore, this thesis will focus on virtual reality on the PC platform.

2.1 Current virtual reality in computer games

The current state of VR in the games industry is strong. According to CCS Insight (2019), the market value of VR is $2.9 billion which is an increase on the previous year's evaluation of $1.8 billion (CSS Insight 2018). The upward trend is projected to continue with the VR market being worth $48.5 billion by 2025 (Grand View Research 2017).

2.2 Current virtual reality hardware

Modern virtual reality headset displays use technology such as motion sensors for the tracking of the head position as well as hand and body position. The headset itself is made up of small high definition screens for stereoscopic display and is generally lightweight and portable enough for convenience as well as ease of development. VR interaction between the player and the virtual world requires unique input devices such as motion controllers. Motion controllers use optical tracking technology from optical sensors for location and navigation data so the player can move somewhat freely depending on the technical specifications of that individual headset. Figure 1 shows the typical set-up of the Oculus Rift VR headset including the headset, optical sensors and motion controllers.

Figure 1. Typical set-up of the Oculus Rift VR headset (Painter 2018)

Despite Kei Studios (2019) arguing that VR headsets are falling in price, the cost to the consumer of purchasing a VR headset, at the time of writing this thesis (March 2020), is sizable. The Oculus Rift S costs €479. The HTC Vive Pro costs €1299. The Valve Index set cost €1079. Virtual reality exists for the PS4 console at a cost of €299. In addition to the cost of the VR equipment, the cost of the hardware required to use the VR equipment increases the cost to the consumer even more.

	Recommended Specs	Minimum Specs
Graphics Card	NVIDIA GTX 1060 / AMD Radeon RX 480 or greater	NVIDIA GTX 1050Ti / AMD Radeon RX 470 or greater
Alternative Graphics Card	NVIDIA GTX 970 / AMD Radeon R9 290 or greater	NVIDIA GTX 960 / AMD Radeon R9 290 or greater
CPU	Intel i5-4590 / AMD Ryzen 5 1500X or greater	Intel i3-6100 / AMD Ryzen 3 1200, FX4350 or greater
Memory	8GB+ RAM	8GB+ RAM
Video Output	DisplayPort™ 1.2 / Mini DisplayPort (with adapter included in the box)	DisplayPort™ 1.2 / Mini DisplayPort (with adapter included in the box)
USB Ports	1x USB 3.0 port	1x USB 3.0 port
OS	Windows 10	Windows 10

Figure 2. The recommended and minimum specifications for the Oculus Rift (Oculus 2020a)

Figure 2 shows the recommended and minimum specifications for the Oculus Rift S. Even at minimum specifications, a computer powerful enough to run the

Oculus Rift S would cost a further €500 to €800. For comparison, a PS4 Pro console costs €399.

It can be seen that the cost of VR hardware is high and is a potential barrier to the enjoyment of virtual reality, so in fairness to the consumer, it is imperative that the virtual reality experience not be hindered further by virtual reality sickness.

2.3 What is virtual reality sickness?

Virtual reality sickness is an undesirable feeling that occurs when exposed to a virtual reality environment with the symptoms including nausea, vomiting, headaches, sweating, drowsiness and disorientation (Merhi et al. 2007, 925). These symptoms are similar to the effects of motion sickness (Lewis 2018). VR sickness, however, is distinct from traditional motion sickness due to the fact that VR sickness is caused by the illusion of visually-induced perceptions of motion in a virtual environment — vection — as opposed to physical, real-world perceptions of motion in motion sickness. The illusion causes conflicts within the vestibular system of the inner ear and the visual system which results in VR sickness. (Stanny et al. 1997, 1139-1141.) VR sickness is also called cybersickness (Arnaldi et al. 2012, Chapter 3). Additionally, motion sickness is a term used to refer to several types of sickness brought on by differences in actual and expected motion (Takov & Prasanna 2019). Motion sickness can be used as an umbrella term for different types of motion-induced sickness such as car sickness, seasickness, centrifugal sickness, space sickness, simulation sickness as well as virtual reality sickness (Arnaldi et al. 2018, Chapter 6). Despite the literature surrounding the topics of VR sickness and motion sickness tending to use the terms interchangeably, they are distinct from each other and, as such, the scope of this thesis is concerned, exclusively, with virtual reality sickness.

3 LITERATURE REVIEW

In order to show the relationship between VR sickness and virtual reality, a literature review will be performed. A literature review is an objective, thorough summary and critical analysis of the relevant available research and non-research literature on the particular topic under study (Hart 2018, Chapter 2).

3.1 Academic based research

In order to carry out this literature review, a number of electronic databases such as XAMK Kaakkuri, Google Scholar, Xlibris, and ProQuest were accessed. The electronic databases' search engine was used where specific keywords and their combinations were inserted in order to find relevant articles. The keywords used were virtual reality, motion sickness, cybersickness, simulation sickness, virtual reality sickness and game design. In addition, a restricted time frame was implemented into the database search in order to obtain contemporary research articles. The abstracts of seemingly relevant articles were reviewed to assess their actual relevance to the topic, then the relevant article's content was critically analysed. A total of sixteen articles were analysed.

The articles used a mixture of quantitative and qualitative research methods. Quantitative research is based on numerical data and uses traditional methods of experiments to produce hard scientific fact and the highest form of evidence vital for evidence-based practice (Sukamolson 2007). Qualitative research uses several diverse approaches which seek to understand human experiences by presenting the uniqueness of each participant's situation, perceptions, motivations, intentions and behaviour (Aspers & Corte 2019, 142).

All sixteen articles analysed were in agreement that virtual reality sickness was a real phenomenon and affected virtual reality games and players. In addition, the analysis of the sixteen academic based research articles showed that VR sickness has several impacts and causes.

The use of virtual reality comes with a sizable risk since VR sickness affects a wide range of virtual reality users with 22% to 56% of users being impacted by VR sickness (Munafo et al 2017). The main impacts of VR sickness are the undesirable feelings of the sickness itself – nausea, headaches, vomiting – reduced enjoyment of VR, shortened time spent in VR and a reluctance to use

VR in the future (Fernandes & Fernier 2016) plus, the risk of developing VR sickness increases the longer one stays playing in the virtual space (Aldaba et al. 2017; Serge & Moss 2016). The differences between real world head movements and virtual world head movements contributes strongly towards VR sickness (Fernandes & Fernier 2016; Palmisano et al. 2017; Tan et al. 2015) as well as the difference in virtual perception of speed in VR compared to staying still in the real world (Aykent et al. 2014). Strong rotational movements in virtual reality cause VR sickness (Colombet et al. 2016) and VR games played in the third-person perspective are less likely to induce VR sickness compared to VR games played in the first-person perspective (Monteiro et al. 2018). Fast-paced action-orientated games cause the most VR sickness (Guna et al. 2019) as does having the field of view setting too high (Cao et al. 2018). The presence of lag, which is a visible delay between the action of a player and the result on screen (Ash et al. 2011, 763) is a significant contributor to virtual reality sickness (Hettinger & Riccio 2006; Luks 2017). Addedly, aggressive changes in speed, unsmooth movement, and having no spatial reference are major causes of VR sickness (Luks 2017). VR sickness is made worse if the quality of the VR hardware is low causing issues such as lag, low-quality images and an overall poor VR experience (Yu et al. 2019). Lower graphical quality contributes to VR sickness more than higher graphical quality games, namely, higher resolutions provided to the player result in fewer incidences of VR sickness (Davis et al 2015). Furthermore, a poorly designed user-interface (UI) is another cause of VR sickness (Kim et al. 2018).

Although the articles dealt effectively with identifying causes of VR sickness, some of the articles were largely theoretical in nature and not all of the articles offered practical solutions or ideas on how to remedy virtual reality sickness. At the same time, however, some of the academic based research articles did produce several practical solutions that could be effectively used in the development of the Virtual Reality Sickness Reduction Tool in order to reduce the impact of VR sickness.

One solution is to lower the field of view (FOV) — the extent of the virtual world that user can see at any given moment (Domanski 2019) — in order to reduce the impact of VR sickness (Fernandes & Feiner 2016). Another solution was to use the highest quality VR headsets possible which can reduce the occurrence of VR sickness since higher quality headsets are more comfortable, tend to have better tracking technology and can process higher quality graphics than poorer quality headsets (Aykent et al. 2014; Yu et al. 2019). Using a third-person perspective over a first-person perspective is another potential solution to reduce VR sickness for players (Monteiro et al. 2018) but playing virtual reality games in the third-person perspective defeats the purpose of virtual reality as an immersive medium. Additionally, using graphics of higher quality and resolution (Davis et al. 2015) as well as designing and implementing a VR-specific user-interface (Kim et al. 2018) could be effective in reducing VR sickness. Furthermore, a solution of introducing "rest frames" as the VR game progresses could be used, where the screen would fade to black for a few seconds allowing the player a rest, thus reducing VR sickness. This allows the user to spend more time in the virtual world uninterrupted by VR sickness (Cao et al. 2018.) Addedly, when designing levels, providing obvious routes for the player to navigate avoids excess movement thus reducing the incidence of VR sickness (Luks 2017).

In addition to these solutions, other, more non-technical, solutions could be implemented but with varying levels of applicability. For example, merely waiting for the technology to improve over time is a potential solution to VR sickness (Hettinger & Riccio 2016) though not a particularly immediate solution. In addition, having virtual reality users take anti-nausea medication before playing VR games could help ease the effects of VR sickness (Luks 2017) but this is, naturally, an impractical solution. A more useful non-technical solution would be the simple suggestion that users take more frequent breaks in order to minimise the occurrence of VR sickness (Aldaba et al. 2017).

3.2 Non-academic based research

To further enhance the literature review, numerous non-academic based sources were accessed. Search engines such as Google and DuckDuckGo were used to search for sources using the search keywords virtual reality, motion sickness, cybersickness, simulation sickness, virtual reality sickness and game design. In all, five sources were analysed — two blogs, one online document and two videos.

Epic Games, creators of the Unreal Engine game engine, displays a VR “best practice” document on their website which aims to help VR developers ensure they create the best VR experience possible. Epic Games argued that the impact of VR sickness has the potential to ruin the VR experience for players as well as developers. Under the “VR and Simulation Sickness” section, many practical solutions to reduce VR sickness are offered. Epic Games implored that lag was a significant cause of VR sickness so it was essential to maintain a well optimised game with a steady framerate in order to avoid lag.

HMD Device	Target Frame Rate
DK1	60 FPS
DK2	75 FPS
Rift Retail	90 FPS
Vive	90 FPS
Gear VR	60 FPS
PSVR	Variable up to 120 FPS

Figure 3. Target frame rates of common VR headsets (Epic Games 2020)

Figure 3 shows the target frame rates of the most common VR headsets on the market with the Oculus Rift and the HTC Vive both requiring a target frame rate of 90 frames per second (FPS). (Epic Games 2020.) Typically, an FPS of 30 is the minimum target FPS in non-VR games where going below the target 30 FPS results in a non-smooth, disjointed series of images being displayed (lag) (Sakar 2014). In virtual reality, the stereoscopic images of the VR headset need to be rendered twice — one for each camera in the headset — meaning maintaining a target FPS of 90 is a difficult task to achieve since it requires powerful hardware but, more importantly, a well optimised, efficient game. Epic Games suggested that the use of strong, vibrant lights in virtual reality can cause VR sickness more quickly and, as such, to use dimmer lights and cooler shades of colour in the virtual environment. In addition, the players must always be in control of the camera since switching from camera to camera or perspective to perspective is a significant contributor to VR sickness. Other solutions included not having the camera shaking when walking or during explosions as this contributes to VR sickness. Elevators should be used instead of traditional stairs since the drastic change in height can induce VR sickness and that player movement speed should be set at a constant and not be overly fast or aggressive. Post-processing techniques such as motion blur should be avoided as the effect directly affects what the player is experiencing, resulting in VR sickness. (Epic Games 2020.)

Statt, in his blog, detailed several virtual reality movement solutions to reduce VR sickness. To help with the disconnect between movement in the virtual world and not moving in the real world, Statt identified that movement via in-game teleportation is a popular solution to avoid VR sickness induced from typical walking in virtual reality. Teleportation involves the player remaining stationary in the virtual world and choosing where in the map they want to move to thus eliminating any traditional walking movement. Another solution offered is to eliminate player movement and have the action move towards the player. (Statt 2016.)

ArviVR, a company that develops virtual reality games, has a blog on their website that offers many solutions to VR sickness based on their own development experience. Just as Epic Games (2020) implored that ensuring the game runs at a steady frame rate is important to reduce VR sickness, ArviVR agreed. However, ArviVR divulged that, in their experience, a drop of 10-15 FPS in virtual reality was largely imperceptible but further drops in FPS contribute greatly to VR sickness. ArviVR also agreed that optimising the game so that it runs as close to 90 FPS as possible is a great standard to strive for as it reduces the speed at which VR sickness sets in. In addition, ArviVR agreed with Epic Games (2020) in that using bright, vivid colours were a cause of VR sickness and that using the 80/20 rule of composition (80% of the picture should be dark, 20% of the picture should be light) reduced VR sickness since the brighter lights fatigued the eyes quicker. Smoother textures were suggested to reduce VR sickness with low-poly stylised graphics being of particular help. The field of view during any kind of motion should be lowered and that moving at a slower but constant speed in a straight line helps reduce VR sickness. Moreover, movement over the Y-axis (up and down movement) is a great contributor to VR sickness and should be limited wherever possible. Surrounding the player, in the virtual world, with a static environment such as a cockpit has the aim of providing the player with something to focus on. However, this solution only helped to delay the onset of VR sickness and is more effectively used when combined with other solutions. The movement solution of teleportation was also proposed, as was the simple, non-technical solution of running in place to trick the body's vestibular system into thinking it was in motion. (ArviVR 2018.)

Virtual Reality Oasis is a YouTube channel with over 234,000 subscribers and the video "How to prevent motion sickness in virtual reality" offered several, albeit non-technical, solutions to VR sickness. Calibrating the headset to suit the individual user makes the virtual reality experience more comfortable thus delaying VR sickness with settings such as height and brightness being useful to individually customise. Short play sessions of 10 to 15 minutes were recommended as well as taking numerous breaks helps reduce the onset of VR sickness. Keeping hydrated and staying cool were also recommended. In addition, not playing VR games when you are ill was suggested as a way to prevent VR sickness. (Virtual Reality Oasis 2019.) The solutions proposed might not be technically useful but could be useful for the players. In addition, developers might consider including the non-technical solutions in their documentation in order to provide a better VR experience for the users.

Valem is another YouTube channel specialising in VR games for the PC platform. The video "How to Design for Motion Sickness" offered many practical solutions for virtual reality developers to use to reduce VR sickness. Valem strongly recommended to optimise the game in order to maintain the FPS, keep lag to a minimum and reduce VR sickness. Avoiding unwanted movement was another strong recommendation by means of not using stairs — use smooth slopes — or not using screen shaking effects. Jumping or falling are common actions within computer games but should be avoided in virtual reality as they are highly conducive to VR sickness. Teleportation was, again, recommended, as is slow, constant movement if motion is necessary. Using a cockpit and lowering the field of view were additional recommendations to reduce VR sickness. More importantly, simulating depth within the virtual world was essential to reducing VR sickness as depth objects provided the player with focal objects which makes the sense of motion more natural and less VR sickness inducing. In addition, the use of VR-specific user-interface elements were recommended where the UI exists as part of the virtual world and not as a canvas overlay as is traditionally used in non-VR UI. The flickering of lights was suggested to be a cause of VR sickness as it increases eye fatigue and discomfort, so the use of flickering was recommended to be limited. Valem agreed with Virtual Reality Oasis (2019) when it came to using short play sessions of ten to fifteen minutes and taking frequent breaks. As such, the ability to pause the game during play was recommended as an essential feature allowing the player to take breaks at will. Interestingly, Valem suggested notifying players in-game to keep hydrated and cool when playing in virtual reality showing that developers can consider non-technical solutions in attempts at reducing VR sickness (Valem 2020.)

3.3 Literature review findings

Through the literature review of both academic and non-academic research the relationship between virtual reality and VR sickness has been established. VR sickness is prevalent, affecting many players of virtual reality games and there is a possibility that VR sickness is an inherent part of virtual reality. However, the impacts of VR sickness on the VR experience have been discovered as, too, have what aspects of virtual reality cause VR sickness. Fortunately, technical and non-technical solutions have been identified with the practical applications undoubtedly being useful in the creation of the virtual reality sickness reduction tool (VRSRT).

4 CONTENT ANALYSIS

Content analysis is a research method used to identify patterns and their effects in communications media data such as books, videos or computer games (Luo 2019; Schmierbach 2009, 147-148). In the case of this thesis, existing virtual reality games will be analysed, using qualitative research methods, in order to determine what those games do to alleviate the effects of VR sickness. In addition, any correlation between the content analysis findings and the literature review findings will be identified so that the best solutions of VR sickness are included in the VRSRT.

In order to carry out the content analysis, a way to categorise virtual reality games in a meaningful way was needed. Oculus, creators of the Oculus Rift headset, have on their online store the comfort rating system. Figure 4 shows the comfort rating system that Oculus uses to categorise VR games — comfortable, moderate, intense and unrated.

When you browse content in the Oculus Store, you can view the comfort rating to see if the experience is right for you. We work closely with developers to make sure the comfort rating accurately matches the experience. If you're new to VR, we recommend starting with content that's rated Comfortable before trying Moderate, Intense or Unrated.

Comfort Ratings

The following comfort ratings can be found in the Oculus Store:

Comfortable experiences are appropriate for most people, although this rating doesn't mean that an experience is going to be comfortable for everyone. These experiences generally avoid camera movement, player motion, or disorienting content and effects.

Moderate experiences are appropriate for many but certainly not everyone. These experiences might incorporate some camera movement, player motion, or occasionally disorienting content and effects.

Intense experiences aren't appropriate for most people, especially those who are new to VR. These experiences incorporate significant camera movement, player motion, or disorienting content and effects.

Unrated experiences may contain intense content, which may not be right for most people, especially those who are new to VR. If you experience motion sickness or other VR effects from an unrated experience, you should select another unrated experience, or try an experience in the Oculus Store that's rated for your comfort level.

Note: When we assign a comfort rating, we're judging the default experience.

Figure 4. Comfort ratings for Oculus Rift games on the Oculus store (Oculus 2020b)

The comfort rating system uses criteria such as camera movement, player motion, visual effects, and potential for disorientation which, being demonstrated by the literature review, are factors that affect VR sickness. Comfortable offers the lowest potential for VR sickness, Intense offers the highest potential for VR sickness and Moderate is in between. Therefore, categorising games based on comfort or, in other words, the potential for VR sickness, seemed appropriate and can be used in the content analysis to categorise VR games. Unrated offers no insights into the potential of VR sickness and was ruled out as unreliable as a categorisation criterion. Using the comfort rating system, a virtual reality game was selected from each of the three categories. One game from the Comfortable category, one game from the Moderate category and one game from the Intense category. Additionally, the highest rated and most popular filters in the Oculus store search function were added in order to obtain the games that were the best of their categories. Following this criterion, the games that were analysed as part of the content analysis were Beat Saber, Fantasynth and Epic Roller Coasters.

4.1 Beat Saber

Beat Saber is a virtual reality rhythm game where the player uses blades to slash cubes to the beat of the soundtrack. It has been wildly successful becoming one of the highest rated and bestselling virtual reality games selling over two million copies (Grubb 2020). With Beat Saber being so popular, highly rated and receiving a Comfortable rating, what aspects of the game help solve the problem of VR sickness?

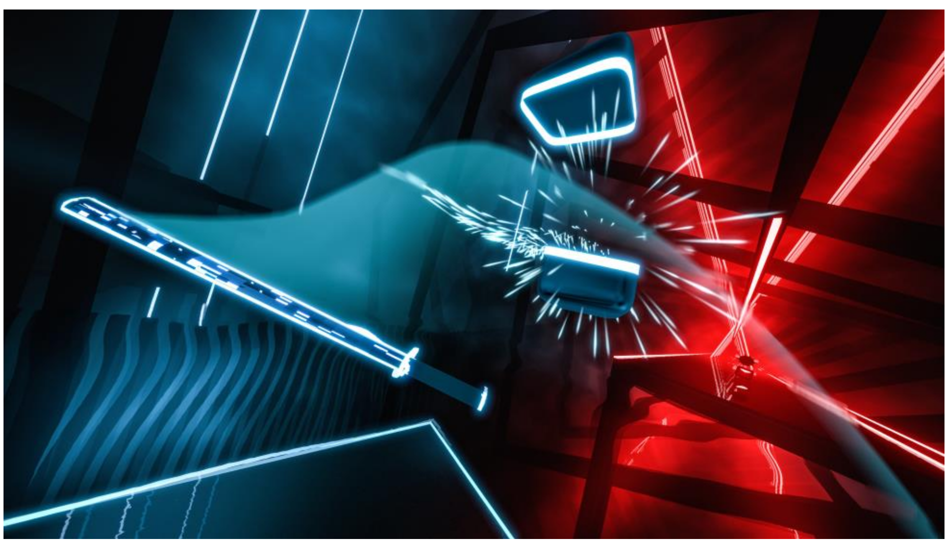


Figure 5. Beat Saber screenshot (Beat Games 2019)

Based on the VR sickness solutions gleamed from the literature review, it can be said that Beat Saber alleviates the threat of VR sickness very well. Figure 5 is an in-game screenshot of a typical level of Beat Saber where the non-blurry, high-resolution, stylised graphics are on show. There are no flickering lights and the use of dimmer, cooler colours following the 80/20 design principle are instantly noticeable. In terms of player movement, the player is located on a stationary platform so there is no player movement that is out of the player's control. The movement that is in the game is heavily integrated into the gameplay where the player must dodge obstacles through side stepping or crouching. It can be hypothesised that this helps negate VR sickness since the real-world movements trick the vestibular and visual system into perceived motion that matches what players see through the headset. In addition, the gameplay objects move towards the player which has advantages in solving VR sickness as the focus of the player is always facing forward and not multi-directional, eliminating unwanted head movement. The user interface is tailor-made for VR in that the UI elements are located in world space which is non-invasive and non-disorientating for the player. The levels themselves are the lengths of songs ranging from five minutes to ten minutes in length meaning that short breaks are possible. Moreover, beat Saber implements a pause system allowing the player to pause the game at any time allowing for break to be taken at will. The most important thing that Beat Saber achieves in combating VR sickness is that there is no lag whatsoever in the game. The game is very well optimised and throughout the analysis was always able to achieve and maintain the target FPS.

4.2 Fantasynth

Fantasynth is a short virtual reality game more akin to an audio-visual experience than a traditional game. As such, there is almost no interaction with the virtual world and is more of a passive virtual reality experience. With Fantasynth receiving a Moderate comfort rating, what aspects of the game contribute to VR sickness and what aspects of the game help battle VR sickness?


Figure 6. Fantasynth screenshot (HelloEnjoy 2020)

Figure 6 shows an in-game screenshot of part of the Fantasynth experience where the graphics are of high-quality, in high-resolution and of a surreal composition. The visual side of the game does follow the 80/20 design principle but there are numerous lights that flash in synchronicity with the beat of the music. The flashing is quite jarring to the eyes escalating to uncomfortable quickly. Initially, the player is completely stationary with the game offering no focal point at which to look meaning the player is constantly turning their head. The environment is pleasing to the eye and immersive, but the excess of head movements could lead to VR sickness. After a few minutes into the game the player suddenly starts moving. The initial lurch is gentle, the acceleration slow and the movement speed is constant so there are some aspects of movement done to limit VR sickness. However, once the player starts moving, they do so as if they are floating through the air. The lack of a moving platform, cockpit or close focal reference is a contributor to VR sickness. The user interface of the game is very minimal only involving one button press to start the game but the interface itself is located in world space and is not disorientating for the player. Fantasynth does use a, somewhat rudimentary, pause system allowing players to take breaks at will. However, the overall length of the game is seven minutes long and although the game has aspects that contribute to VR sickness, the short length of the game means VR sickness might not have the time to manifest. Similarly, to Beat Saber, Fantasynth is a well optimised game with minimal lag and a well-maintained target framerate.

4.3 Epic Roller Coasters

Epic Roller Coasters is a virtual reality game that aims to simulate the experience of riding a roller coaster. As the game is a simulation of a roller coaster amusement park attraction, the interaction with the virtual world is limited. The game received an Intense comfort rating so what aspects of the, if any, alleviate VR sickness?

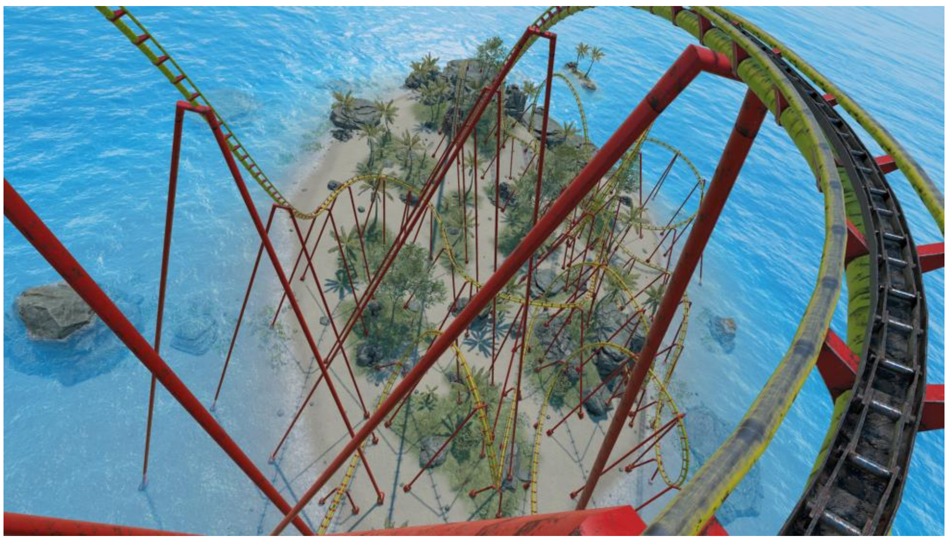


Figure 7. Epic Roller Coasters screenshot (Steam 2020)

Figure 7 shows an in-game screenshot of Epic Roller Coasters where the graphics can be seen to be of high-quality, high-resolution and of realistic rendering. The visual design of the game does not follow the 80/20 design principle showing, almost entirely, a bright colour palette. This coupled with the realistic graphics contribute markedly to VR sickness. The movement system of the game is simple in that the player sits in a roller coaster seat then moves around the virtual world following roller coaster tracks just as it would in an amusement park. Within a few moments of playing the game it becomes apparent why the game received an Intense comfort warning. There is almost constant shaking of the camera, camera movement on all axis and blurring of the graphics when higher speeds are simulated. These factors contribute heavily to VR sickness. Moreover, due to the game being a roller coaster simulator, the speed of the roller coaster is constantly changing from fast to slow and vice versa with aggressive acceleration and braking. In addition, there are sections of the tracks missing causing the roller coaster to jump and fall which is exceptionally disorientating and contributes significantly to VR sickness. Another massive contributor to the VR sickness this game causes is the overall poor performance of the game. The game fails to maintain target FPS, there are frequent lag events suggesting that the game is very poorly optimised. That being said, the game does attempt to help players combat VR sickness in that it integrates a “helmet” option that, when enabled, reduces the field of view so that the player can only visualise the centre of the screen. However, due to all the other contributing factors, overall, the “helmet” option fails to alleviate VR sickness in practice. The user-interface, however, is implemented well as objects in world space and there is a pause system allowing the players to take regular breaks.

4.4 Content analysis findings

In the content analysis of this thesis, three existing virtual reality games were analysed in order to determine what those games do to alleviate the effects of VR sickness. The best example of a virtual reality game combating VR sickness is Beat Saber. Beat Saber is a well-optimised virtual reality game that seems to have been made with VR sickness in mind following the 80/20 design principle, excellent movement mechanics, player-centric camera controls and integrates well the user-interface and pause system. In contrast, Epic Roller Coasters is not a well-optimised experience and substantial aspects of the game's design and execution results in VR sickness. Unneeded camera movements, harsh acceleration and inconstant motion speeds, coupled with bright lighting leads to a VR sickness-laden experience. Through this content analysis, many correlations with the literature review findings can be seen. As such, the identified best solutions will be included in the VRSRT.

5 DESIGN TOOL

The information gained from the literature review, coupled with the research from the content analysis will now be formulated in a meaningful way in order to create a design tool — the Virtual Reality Sickness Reduction Tool (VRSRT).

5.1 Aims of the design tool

A design tool, specifically a game design tool, is any kind of means or apparatus that supports the game design process with the goal to improve the process of game development (Paz & Fernandes 2018). The game design process can be defined as the process of designing the content, rules, gameplay, environment, story and characters of a video game (Colayco 2005). An effective game design tool has the ability to focus attention on a specific aspect or problem in game development (Manker 2012). As such, the focus of the VRSRT is that it is a game design tool that contains practical solutions to the issue of VR sickness. The overall aim of the VRSRT is that it can be used by virtual reality game developers to reduce the impact of virtual reality sickness in virtual reality games.

As a design tool, the VRSRT aims to be a non-complex and easy to use tool that can be integrated into new or existing virtual reality game design development. The tool looks to offer meaningful support and practical solutions to developers searching for ways in which to reduce the impact of VR sickness in their games and will display a simple, easy to read information flow. The design tool is not intended to be a creatively restrictive, must-do list of steps but an aid that facilitates purposeful decision making in the game design process. Nor is it intended to be implemented by complete beginners of virtual reality game design — a basic understanding of virtual reality systems and game design principles are needed to appreciate the VRSRT fully. Moreover, as Neil (2016) states, no design tool can answer all design questions and nor should it; the VRSRT gives final decision-making ability to the game developers. Consequently, the tool, ultimately, gives game developers the freedom to decide.

5.2 Consolidation of research

An essential first step in the building of a game design tool is the consolidation of researched information or data (Almeida & da Silva 2013). Through the consolidation of information gained from the literature review and the content analysis, the most relevant and most important solutions of VR sickness can be ordered and arranged meaningfully for use in the VRSRT.

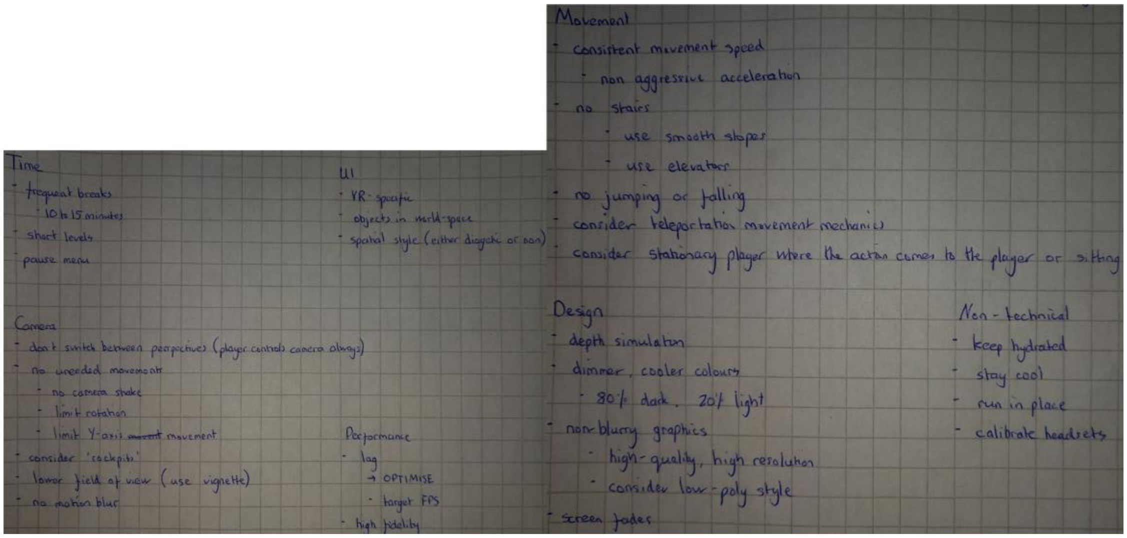


Figure 8. Rough consolidation of information (Barclay 2020)

Figure 8 shows a rough consolidation of the information gained from the literature review and content analysis. The research from the literature review and content analysis was examined for correlation, then arranged into rough categories of similar problem groups (causes of VR sickness) and solutions. The rough groups are Time, UI, Camera, Movement, Design, Performance and Non-Technical.

Appendix 1 shows the same information as in Figure 8 but in an easier to follow table arrangement. Appendix 1 is broken into two columns — the Problem Group column which combines VR sickness causes into a similar group and the VR Sickness Solution column which shows the proposed solutions of VR sickness relevant to that particular problem group.

Naturally, there is some overlap amongst the content of the groups. Moreover, presenting the information in a meaningful and aesthetically pleasing way is also required.

5.3 Creating the design tool

In line with the aims of the game design tool, an effective means in which to arrange and present the information in a meaningful and aesthetically pleasing way is to use an infographic. Infographics are a visual communication medium that can take plentiful amounts of data and display it in a compelling way (Bullas no date) which is appropriate for the VRSRT. The proposed size for the infographic would be that it would fit on an A4 sized document at minimum or in a larger wall-poster size at maximum allowing effective readability, visual attractiveness and functionality of use (Pan 2015).

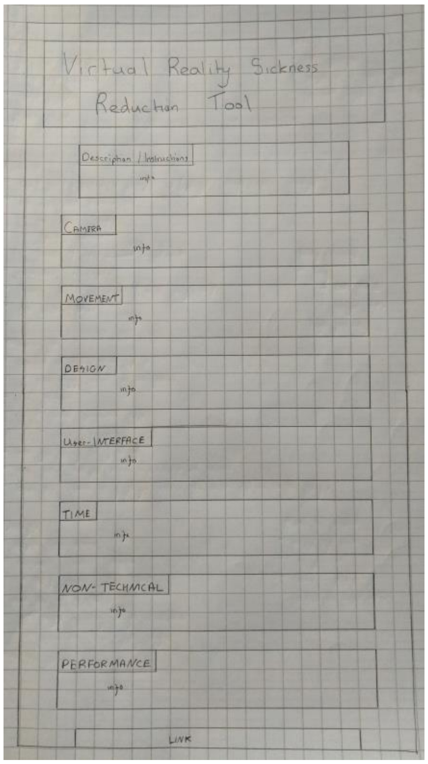


Figure 9. Basic template of the VRSRT (Barclay 2020)

Figure 9 shows the basic template of the VRSRT which demonstrates the simple infographic style design flow chosen. In order to take the basic template of the VRSRT and enhance it into an infographic, the graphic design creation tool Canva was used. Canva is an online tool that allows for the easy creation of professional looking and engaging content (Mansfield 2020).

Through the use of Canva, Figure 9 was able to be enhanced into Figure 10 which shows the template of the VRSRT in a more progressed infographic form.

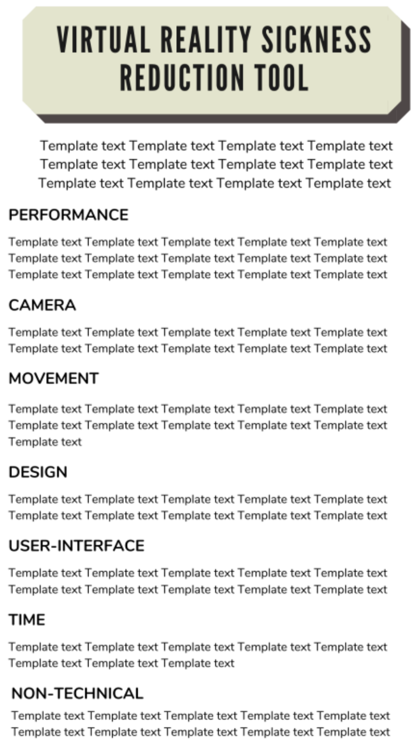


Figure 10. Infographic template of the VRSRT (Barclay 2020)

Diaz-Soloaga (no date) argues that for an infographic to be most effective, simple colour combinations should be used and be used in a consistent way. Many colours and colour combinations were sampled to find a colour scheme that was visually attractive and easily readable in order to make the VRSRT the most effective as aimed (Maudet 2017).

Figure 11. VRSRT colour palette (Barclay 2020)

Figure 11 shows the colours and their respective hexadecimal colour codes that were chosen to be used in the VRSRT.

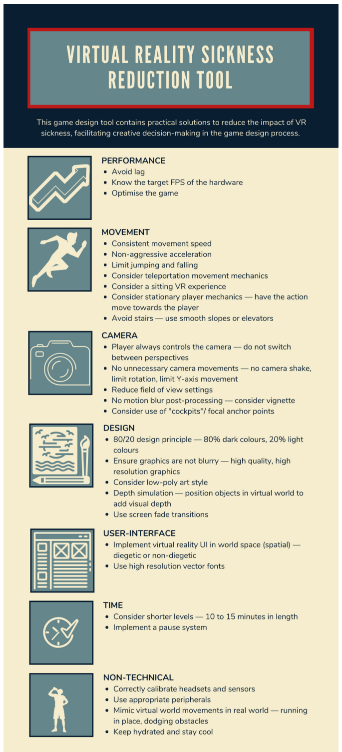


Figure 12. The final version of the VRSRT (Barclay 2020)

Figure 12 shows the final infographic to be used as the VRSRT which has the information gained from the literature review and content analysis presented in an aesthetically pleasing and meaningful way. Appendix 2 shows the final version of the VRSRT in a larger, more detailed image. The tool is readable and should be effective in achieving its aims as a game design tool.

6 VIRTUAL REALITY GAME PRODUCT

The Virtual Reality Sickness Reduction Tool will be validated through the creation of a virtual reality game product. The game product will be designed and implemented based heavily on the VR sickness solutions outlined by the VRSRT. Naturally, the VRSRT is not an all-encompassing game design tool, so other appropriate game design tools will be used in conjunction with the VRSRT.

6.1 Design of the VR game

This section will deal with the design of the virtual reality game product. As previously stated by Colayco (2005) and seconded by Patton (2015), game design is a process involving designing the content, rules, gameplay, environment, story and characters of a video game.

6.1.1 Goals of the project

The setting of goals is a fundamental part of the game design process (Gaming In Training 2015) where the goals need to be clear, realistic and, more importantly, achievable (Comaford 2016). Moreover, due to the project being a one-person project with limited time on a tight schedule, it was essential to plan the project proficiently and effectively in order to meet the goals of the project (Mirabello 2014).

The main goal of the project was to create a virtual reality game where, through the use of the VRSRT, the impact of VR sickness was reduced as much as possible. An additional goal was to evaluate the effectiveness of the VRSRT. The goals of the actual game were that it should be short but fun, engaging, immersive and be playable by those familiar and new to virtual reality games.

6.1.2 Communication

Effective communication is paramount in order to achieve the goals of the project and despite it being a one-person project, a way in which to communicate ideas over time, as well as a way to monitor progress was needed (Lang 2008).

An effective way to monitor progress is to use a collaborative version control tool such as GitHub. GitHub allows users to upload content to an online repository and can be used to update the game over time as well as revert to older versions if needed (GitHub 2020).

A useful way to communicate ideas, especially early on in a project, is to create a game design document (Bakker 2009). Traditionally, game design documents are filled with details about the game such as art style, concept art, character designs and story arcs and are used to communicate those details to large teams (Freeman 1997). Ruswick (2017) however, argues that for reduced scale projects and smaller teams a traditional game design document is superfluous and that a redesigned, simplified one-page game design document is more than necessary for effective communication.

Ruswick (2017) also supplies a one-page game design document template for others to use. The one-page game design document will be used as part of the VR game product as a communication tool and as a way to generate game design ideas in a structured way.

6.1.3 One-page game design document

The one-page game design document was used in conjunction with the VRSRT in the design phase of the VR game product.

Game Identity / Mantra:

Virtual reality experience game where the player will be immersed in an emotional journey to find a new home.

Design Pillars:

Thoughtful, Immersive, Melancholy

Genre/Story/Mechanics Summary:

The game is a VR experience where players will go on a journey into unique environments in an effort to find a new home.

Features:

Short virtual reality experience, low instances of VR sickness, story-telling VFX

Interface:

Virtual reality controllers (Oculus Rift controllers), VR experience (low interactivity)

Art Style:

Low-poly art style

Firewatch (2016), Gone Home (2016), The Long Dark (2017)

Music/Sound:

Ambient, slow, melancholic

Development Roadmap / Launch Criteria:

Platform: PC, Oculus Rift, Oculus Store

Audience: Generally all allowed, newcomers.

Milestone 1: Planning complete - 14/02/20
Milestone 2: Design Complete - 28/02/20
Milestone 3: Implementation complete - 09/03/20

Milestone 4: Polish complete - 23/03/20

Launch Day: 14/04/20

Figure 13. Completed one-page game design document (Barclay 2020)

Figure 13 shows the completed one-page design document for the VR game product which details the general overview of what the game is trying to achieve, what the story is, what the mechanics are, what the art style is and what are the milestones of the game product. The one-page game design document was referred to often during the project as it was a useful tool for holding the basic information about the project when a quick refresh was needed (Game Design Ed 2015).

6.1.4 Theme, tone and story

The game product was determined to be a thoughtful yet melancholic virtual reality experience game where the player would be immersed in a unique world and go through an emotional journey to find a new home hence the title "Homeward".

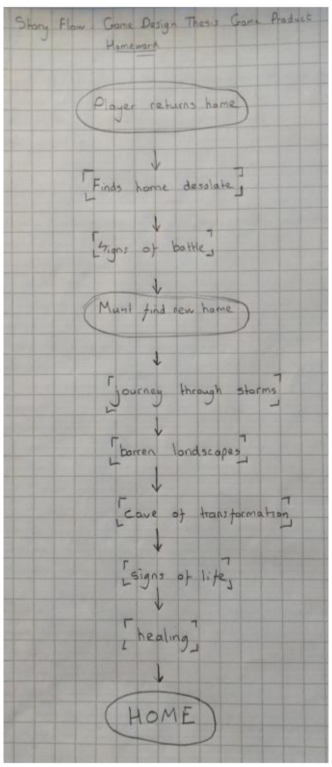


Figure 14. Story flow diagram (Barclay 2020)

Figure 14 is the story flow diagram which shows the story progression of the game in the initial design phase. The story of the game was meant to be a prominent feature and is usually a central aspect to the enjoyment of a game with Chandler (2005) saying that story and characters can be a driving force that propels players through the game and keeps them interested in what happens. However, in virtual reality games, there is the possibility that the story may be overshadowed by the virtual reality aspect of the game as VR can still be a novelty, especially to newcomers. Therefore, great emphasis was placed on telling a story that was interesting, immersive and, ultimately, thought-provoking but not rigid or too denotative. Consequently, a story that could be interpreted individually by each player — in essence, players would come to their own conclusions about the story and what the game was about — was incorporated. To facilitate the story, it was decided to have very few text objects in the game allowing for greater focus on an individual player experience.

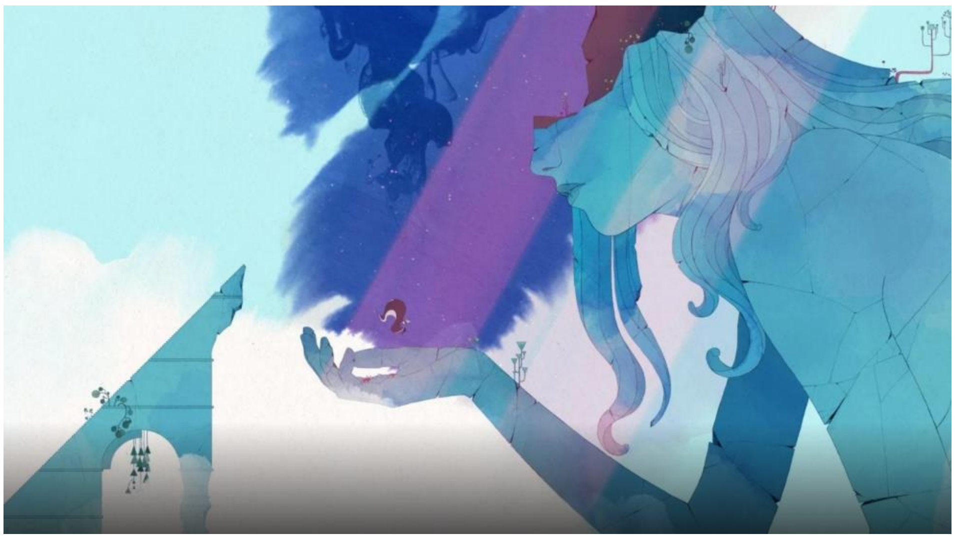


Figure 15. GRIS screenshot (Nomada Studio 2018)

The thoughtful yet melancholic tone was chosen to be included in the game as it was deemed to be important for the overall story that the player experiences. Several inspirations were taken from existing games in order to set the tone.

Figure 16. Shadow of the Colossus screenshot (Team Ico 2005)

GRIS (Figure 15), Shadow of the Colossus (Figure 16) and Journey (Figure 17) were inspirations for the tone of the game product as these games were melancholic in execution and thought-provoking as an experience.

Figure 17. Journey screenshot (thatgamecompany 2012)

The New York Film Academy (2017) argues that the ethics of video games are even more debatable than in film or TV and, as such, should be held to a higher standard so efforts were made to not have content in the game that would lead to potential ethical issues. Therefore, the story of the game product was constructed in a way to not cause harm to the players (Takahashi 2004).

The VRSRT integrated well and was useful when it came to designing the theme, tone and story. The tool achieved its aims of being non-restrictive, easy to use and offered a lot of freedom in the design of the theme, tone and story stage.

6.1.5 Art design/style & colour

The Virtual Reality Sickness Reduction Tool offers solutions that are directly applicable to the art design/style that can be incorporating in the game product. The VRSRT implores that graphics should be non-blurry, therefore the graphics were decided to be of high-quality and high-resolution in the game product. Moreover, the VRSRT offers a suggestion to consider the use of the low-poly art style in order to reduce VR sickness. Consequently, the low-poly art style is what was decided to be the art style of the game and the design of the graphics of the game would follow suit.

Figure 18. The Long Dark screenshot (Hinterland Games 2017)

Low-poly art is where polygons — simple two-dimensional shapes comprised of straight lines and angles — are arranged side-by-side to create a clean, minimalist art style (Shader 2015). The art style has become increasingly popular in computer games particularly with lower-budget indie titles due to the nostalgic feel of the style as well as the lower production cost aspects (Couture 2016).

Figure 19. Firewatch screenshot (Campo Santo 2016)

This might give the impression that the graphics born from the low-poly art style are of lower quality. However, screenshots from the games The Long Dark (Figure 18), Firewatch (Figure 19), and Gone Home (Figure 20) show modern games utilising the low-poly art style where it can be seen that the graphical quality is non-blurry, of high-quality and of high-resolution. In addition, when the low-poly style is used in games, the graphics can be visually appealing. Inspiration was taken from the games shown in Figure 18, 19 and 20 on how the game product should look and tried to imitate the graphical quality of those games.

Figure 20. Gone Home screenshot (The Fullbright Company 2016)

The low-poly art style is potentially advantageous, especially when applying the style in virtual reality games, in that game objects are more efficiently rendered compared to higher quality, higher-poly graphics which is of benefit in VR games where optimisation is key to maintaining target FPS (ArviVR 2018).

The VRSRT suggests using the 80/20 design principle and adopting dimmer, cooler colours when it comes to use of colour within the game. Colour, itself, is a very powerful design choice that can elicit certain emotions and reactions from the player (Chapman 2017a). Therefore, choosing dimmer, cooler colours that evoke a sense of melancholy and thoughtfulness, as to be in congruence with the tone of the game, were chosen for the colour palette.

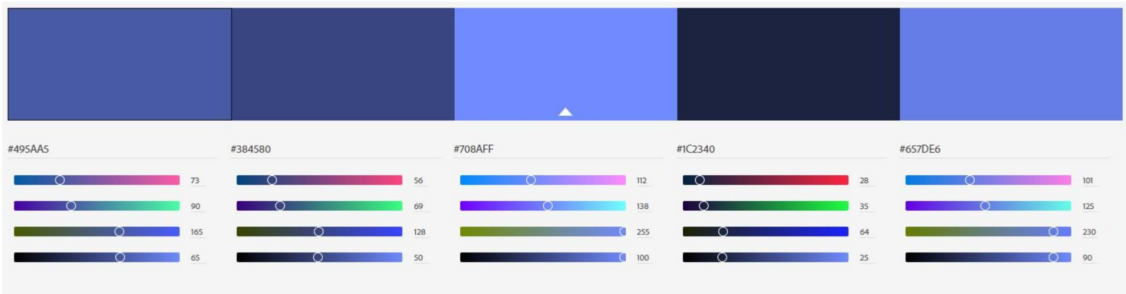


Figure 21. Shades of blue colour palette (Adobe Color 2020a)

Chapman (2017b) suggests that colours that combine shades of blue can work very harmoniously together bringing out certain emotions. Therefore, attempts were made to create that melancholic, thoughtful tone from shades of blue for the game product as shown in Figure 21.

Figure 22. Blue analogous colour palette (Adobe Color 2020b)

Adding colours outside of a defined colour palette can have a visually striking effect if done correctly (Chapman 2017c) so an additional analogous colour palette of blue (Figure 22) was created for moments or objects in the game that required further impact.

6.1.6 Gameplay mechanics

For the design of the gameplay mechanics of the game product, the Virtual Reality Sickness Reduction Tool offers solutions that are available to be integrated into the game. Gameplay mechanics can be defined as the ways in which a player interacts with the game world (Sicart 2008).

As such, the first-person VR perspective was chosen over the third-person VR perspective as the player perspective for a more immersive experience where the player experiences what the character of the game experiences (Gorisse et al.

2017). In line with the VR sickness solutions in the VRSRT, the chosen perspective would not be changed mid-game, allowing the player to have full control of the camera. Additionally, there would be no unnecessary camera movements per the VRSRT.

The movement system of the game would be that the player in the real world would sit on a chair which would be mirrored in the virtual world, as recommended by the VRSRT, and this chair would be located on a small boat. The small boat would move through the virtual world with the boat additionally acting as a focal anchor “cockpit”. The boat would move through animated water at a consistent movement speed in a linear trajectory which has the benefits of eliminating jumping/falling mechanics, avoiding aggressive acceleration as well as bypassing any stairs. Moreover, the boat would facilitate the telling of the story of Homeward.

The design of the game mechanics would be that the game product would be more akin to Fantasynth than Beat Saber or Epic Roller Coasters, namely, limited direct player interaction with the game world and more of a passive VR experience. This design allows the story of the game to take more of the player’s attention, thereby immersing the player in the world. The length of the game product aimed to be less than fifteen minutes in keeping with the recommendations laid out by the VRSRT and a pause system would also be implemented.

6.1.7 Level design

Level design refers to where the levels of the game are laid out with emphasis on an effective way which facilitates easy flow of gameplay (Ryan 1999a). In addition to this, the story and narrative of the project would be incorporated into the level design so that the story would be the driving factor of the navigation through the levels of the game.

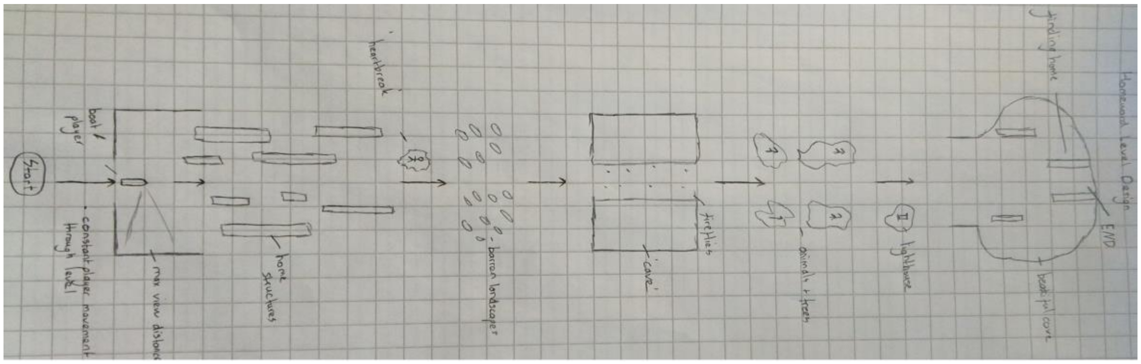


Figure 23. Initial level design layout (Barclay 2020)

Figure 23 shows the initial level design layout that was designed, which was replicated faithfully in the final versions of the project. It can be seen that there is a clear path for the player (Ryan 1999b) which is driven heavily by the movement system as well as gameplay events — such as "heartbreak" and "cave" — that inform the player on where the journey is going next. Moreover, Figure 23 shows that attempts were made to simulate depth, just as the VRSRT recommends, demonstrated by the placed objects in the virtual world.

It was decided early on that the level design phase should incorporate the modular approach to level design for use in the implementation stage. Modular level design refers to the creation and reuse of game objects in order to create the levels. The modular approach allows for rapid creation of levels although can cause the levels to be repetitive. (Burgess & Purkeypile 2013.) This approach proved to be beneficial for the game product as it allowed a one-person team to create immersive levels and saw to avoiding the levels seeming repetitive by being creative with the modular game objects.

6.1.8 Sound design

Sound in a powerful tool, especially in games, and can be used to generate emotional responses from players as well as disseminate information (Callighan 2019). The general way that sound was to be implemented in the game product was to use sound effects at specific points in order to highlight emotional moments and also have an immersive background audio track to convey the desired thoughtful, melancholic tone.

Interestingly, the research from the literature review and content analysis does not mention sound in relation to VR sickness even though there would seem to be a relationship between the vestibular system (the ear) and sound. Consequently, this is one aspect that the VRSRT needs to be improved upon as it fails to mention sound at all. More research can be done in this area — explore the relationship between sound and VR sickness.

6.1.9 User-interface design

The user interface is the way the user interacts with the game which can be through peripherals ranging from a mouse to motion controllers but refers also to the information that appears on a screen (Stonehouse 2014). Using the suggestions from the VRSRT, the user-interface will use high-resolution vector fonts, be virtual reality specific where the UI will exist as objects in the virtual world — also known as spatial UI (Andrews 2010) — as opposed to traditional UI which exist on an artificial canvas overlaid on the camera layer.

In addition, the design aim for the game product user-interface was for it to be simple — simple for the player to understand and simple in implementation — yet functional.

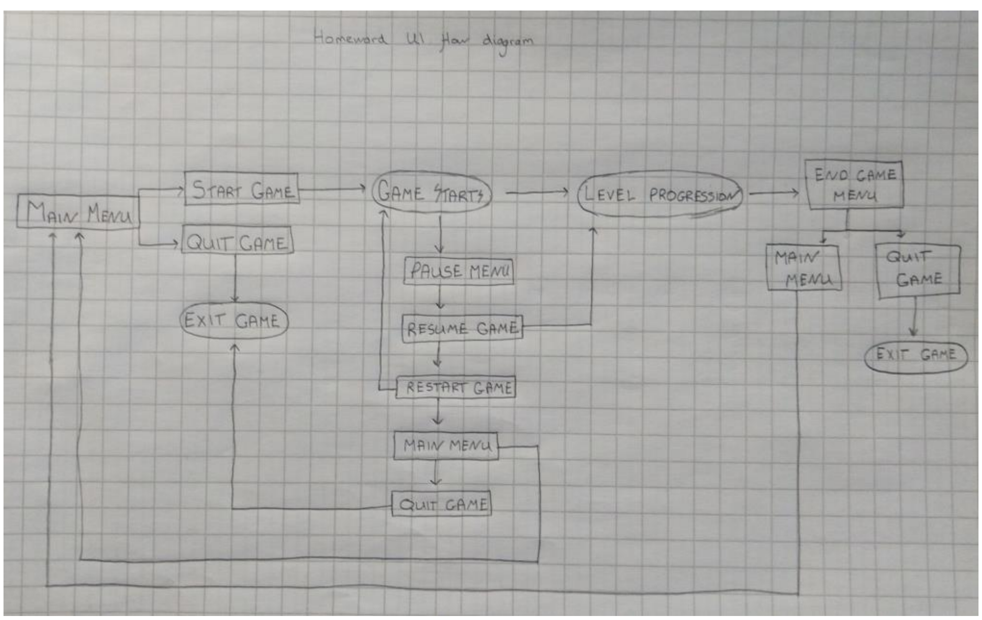


Figure 24. User-interface flow diagram (Barclay 2020)

Figure 24 shows the UI flow diagram for the user-interface design which highlights the simplicity of the design. Moreover, Figure 24 shows that even though the user-interface would be simple, it would still function and perform well.

6.2 Implementation of the VR game

The implementation phase involved taking what had been done in the design phase then, essentially, building the game product.

6.2.1 Project set up

Referring to the one-page game design document (Figure 13), the development platform will be the PC and the game product will be developed specifically for the Oculus Rift VR headset. The one-person development team decided this was the most practical way to develop the game product as an Oculus Rift VR headset was available for use and the developer had existing knowledge of that headset as well as experience developing games for the PC platform. Moreover, it was surmised that the PC platform combined with the Oculus Rift would produce a game product that would fulfil the goals of the product to a high degree allowing rigorous testing of the VRSRT.

The Unity game engine is a software program that allows developers to build video games (Unity 2020a) and was chosen to be used to develop the game project because the engine is free to use, effective and supports virtual reality integration specifically for the Oculus Rift VR headset. Unity uses C# as a programming language which acts as a communication medium between humans and computers allowing the control of computer behaviour (Microsoft 2019).

Unity has many versions of the software which are being updated consistently. The version of Unity used to develop the game product was the 2018.4 Long Term Support (LTS) series which offers a stable version of Unity as well as support updates for an extended period. Moreover, this version of Unity was found to work very well with the Oculus Integration asset that is necessary to be used for VR development with Oculus VR headsets and Unity.

Component	
Graphics Card	AMD Radeon R9 390x
CPU	AMD FX8350
Memory	16GB RAM
Video Output	DisplayPort 1.2
USB Ports	1x USB 3.0 port
OS	Windows 10

Figure 25. Specifications of the development computer (Barclay 2020)

Figure 25 is a table showing the hardware specifications of the computer used for the development of the game product. When compared to Figure 2, which shows the recommended specifications of the Oculus Rift, it can be seen that the development computer meets the minimum hardware specifications.

6.2.2 Virtual reality integration

Virtual reality development within Unity is not enabled by default and requires several steps to be performed before development can begin. Within Unity, under Project Settings in the XR tab, the Virtual Reality Supported checklist must be enabled, as shown in Figure 26.

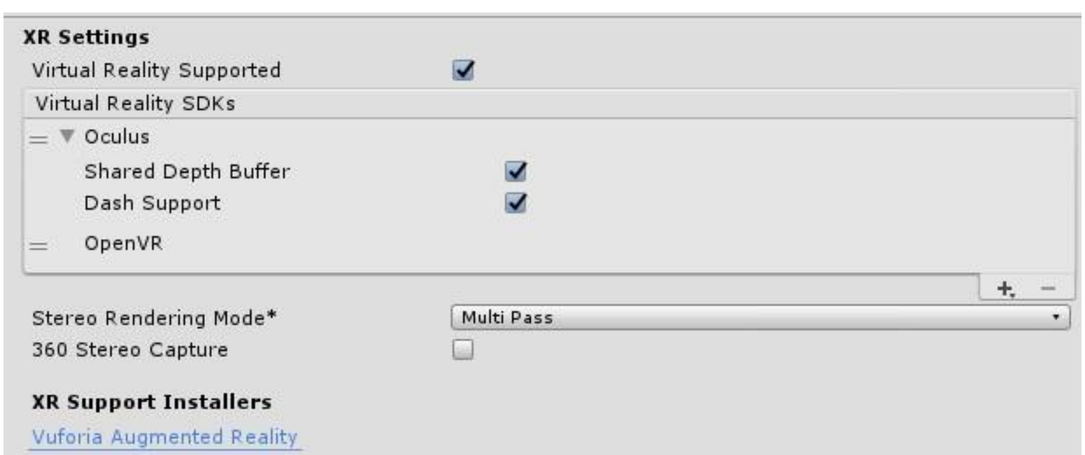


Figure 26. XR settings in Unity (Barclay 2020)

Following the previous step comes importing the Oculus Integration asset from the Unity Asset Store. The Asset Store is a library of resources and assets — ranging from models to whole Unity projects — available to download that are created by Unity as well as members of the community through the Asset Store tab in the Unity editor (Unity 2020b). The Oculus Integration asset allows virtual reality development within Unity using the Oculus VR device and contains valuable tools such as the VR camera controller that will be used extensively in the game project.

In order to allow testing of the game product within the Unity editor, settings within the Oculus Desktop App have to be changed as detailed in Figure 27.

How do I allow content from unknown sources to run on my Oculus Rift S or Rift?

Some developers may release content that doesn't appear in the Oculus Store. This content isn't reviewed by Oculus for the following reasons:

- Security
- Comfort
- Content
- Health and safety

Although we don't review this content, you can still run it on your Oculus Rift S or Rift if the developers allow it.

To allow content from unknown sources:

1. Open the Oculus app on your PC.
2. Select **Settings** in the left menu.
3. Select the **General** tab.
4. Next to **Unknown Sources**, adjust the toggle and then confirm to allow content from unknown sources.

Figure 27. Oculus unknown sources instructions (Oculus 2020c)

Now that the necessary steps have been taken to allow VR development to occur in the Unity editor, implementation of the game product can progress.

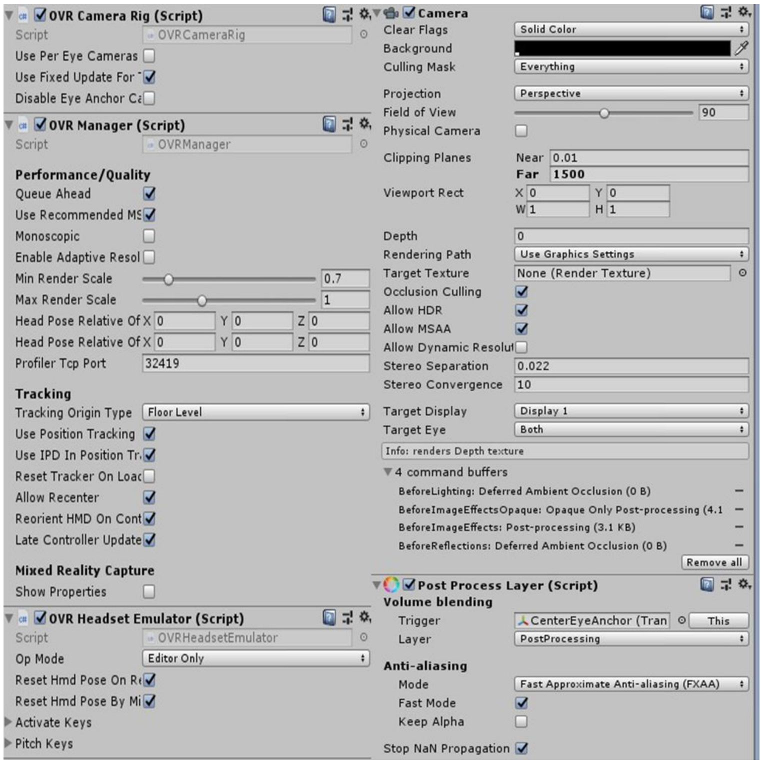


Figure 28. VR camera settings (Barclay 2020)

The Oculus Integration asset contains a prefab — a reusable game object template — for a virtual reality camera called the OVRCameraRig which will allow the player to see the virtual world in the first-person perspective and is, essentially, the player in virtual space. Figure 28 shows the settings for the VR camera used in the game product. As stated in the 6.1.6 Game mechanics section and in the VRSRT, the first-person perspective was chosen, and the VR camera settings facilitate that choice. For more accurate player tracking, the Tracking Origin Type settings were set to Floor Level. This allows the height of the individual player to be tracked meaning the player has full control of the camera. In addition, as suggested in the VRSRT, the field of view settings are available to be lowered in the VR camera settings. The FOV settings for the VR camera were set to 90.

6.2.3 Creation of game assets

The creation of the game assets relied heavily on the design choices established in section 6.1.5, namely, to use the low-poly art style for the visual aspects of the game product. It emerged that creating the 3D models and the texturing required, combined with the amount of 3D models needed, through one-person development would be too time consuming and, most-likely, impossible to complete the game product on time. 3D modelling is the process of developing an object in three-dimensional space using 3D modelling software (Billing 2020). Texturing is the process of adding high definition detail including surface texture and colour information to a 3D model (Kerr 2019). Consequently, it was deemed necessary to find and use free assets from the Unity Asset Store to fulfil the need.


Figure 29. Low-poly assets by Broken Vector (Broken Vector 2020)

High-quality, high-resolution 3D models that were fully textured in the low-poly art style were found on the Unity Asset Store and were free to use. Broken Vector is an Asset Store vendor specialising in low-poly stylised assets and their Low-Poly Cliff Pack, Low-Poly Dungeon Pack, Low-Poly Brick Houses Pack, Free Low-Poly Pack and Low-Poly Shaders Pack were used in the creation of the game product. Figure 29 shows some of the Broken Vector low-poly assets used in the game product where the quality of the models and textures can be seen.

Figure 30. Simplistic Low-Poly Nature assets (Acorn Bringer 2018)

Additional assets were sourced from Acorn Bringer and Walter Palladino, both Asset Store vendors offering free low-poly assets. The Simplistic Low-Poly Nature asset by Acorn Bringer (Figure 30) was used for the animal and nature assets including some models that were animated such as the fish model. Animation is the process used to make digital assets, like 3D models, move in three-dimensional space (Bloop 2020).

Figure 31. Martial Arts Low-Poly Free Models Pack assets (Palladino 2018)

The Walter Palladino-created Martial Arts Low-Poly Free Models Pack was used for the human character assets in the game product (Figure 31).

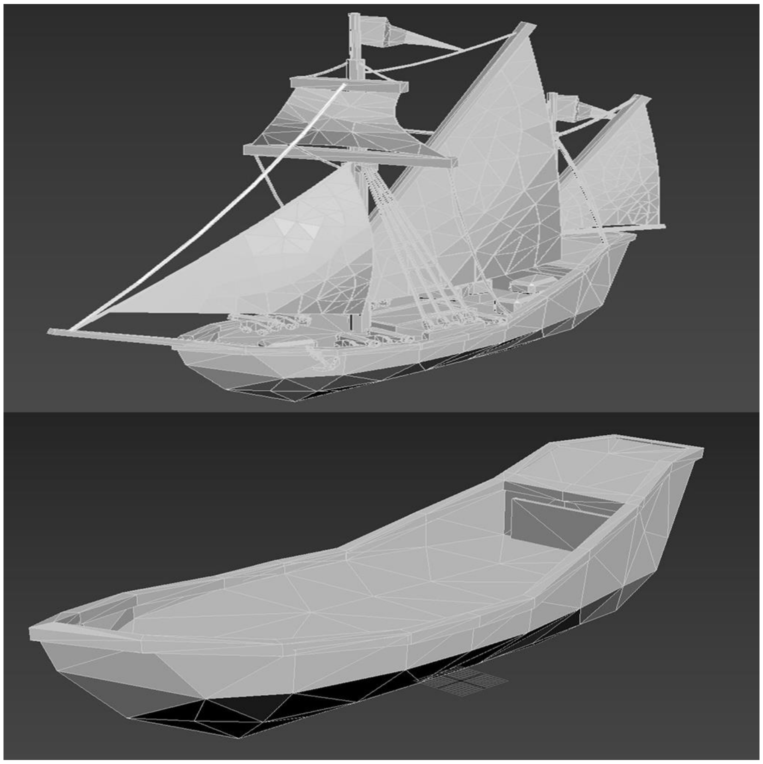


Figure 32. Original ship model modified to make a boat model (Barclay 2020)

The 3D model assets from the Asset Store were then modified to fit as needed in the game product. Figure 32 shows how a ship model can be modified in 3D software in order to create a boat model that was needed for the game product.

Figure 33. The boat model in-game (Barclay 2020)

Figure 33 shows the final model of the modified ship model as it appears in-game. This boat model is used in-game as the focal anchor “cockpit” — suggested by the VRSRT — as well as the movement medium through which the player navigates the virtual world.

6.2.4 Creating the levels

Following the level design layout from section 6.1.7 and Figure 23, general game assets were placed together in a modular way in order to build the broad layout of the levels thereby creating the virtual world for the game product. Figure 34 shows the broad level layout for the first level of the game product in the Unity editor.

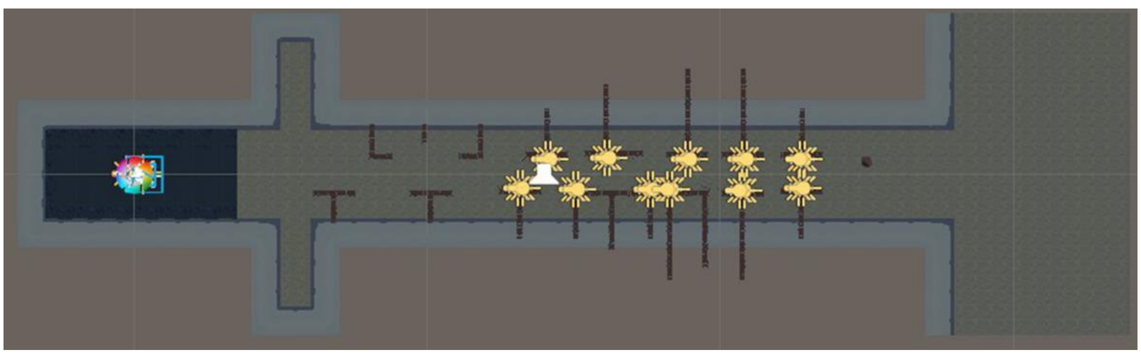


Figure 34. Isometric view of the first level layout in the Unity editor (Barclay 2020)

Altogether, there are five levels in the game product plus the Main Menu and Credits scenes. Figure 35 shows the isometric layout of the rest of the levels used in the game product.

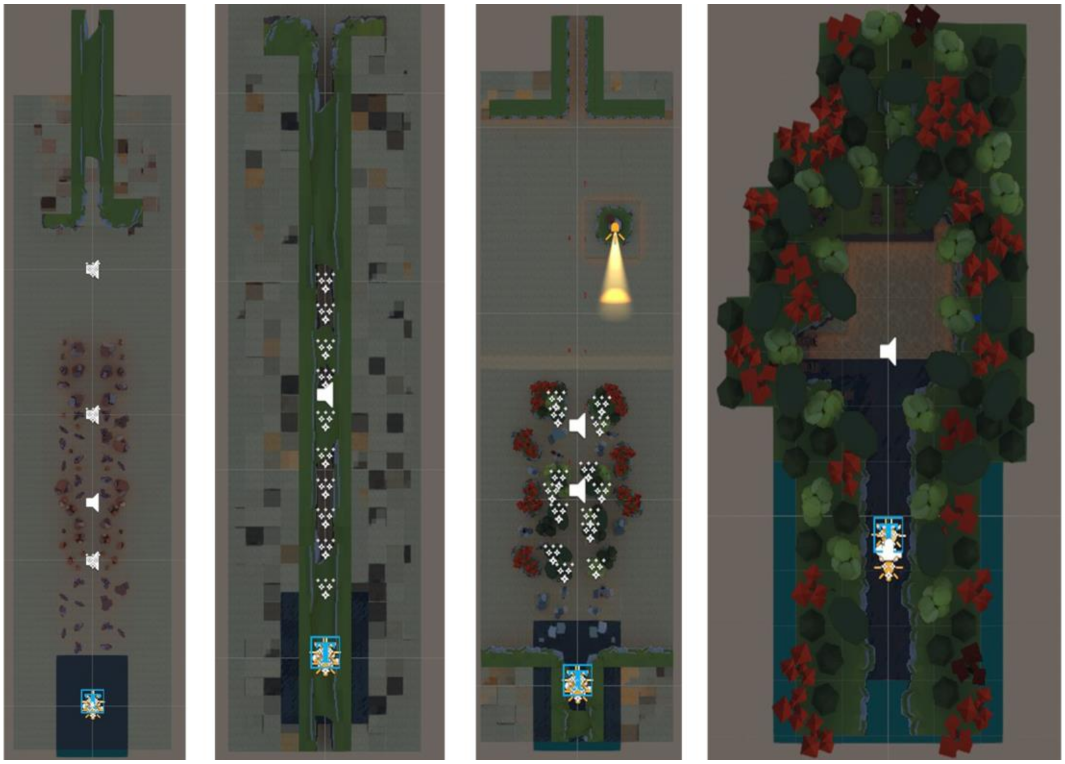


Figure 35. Isometric view of level layout (levels two to five) in the Unity editor (Barclay 2020)

There are several reasons as to why to levels were divided. The main reason was optimisation, as recommended by the VRSRT. By breaking the game into five levels, the target FPS of 90 was easier to maintain than having one large level. Additionally, it allowed the levels to be short in length and permitted the player to have breaks. Moreover, screen fades were used as scene transitions which is also recommended by the VRSRT with the aim to reduce the impact of VR sickness.

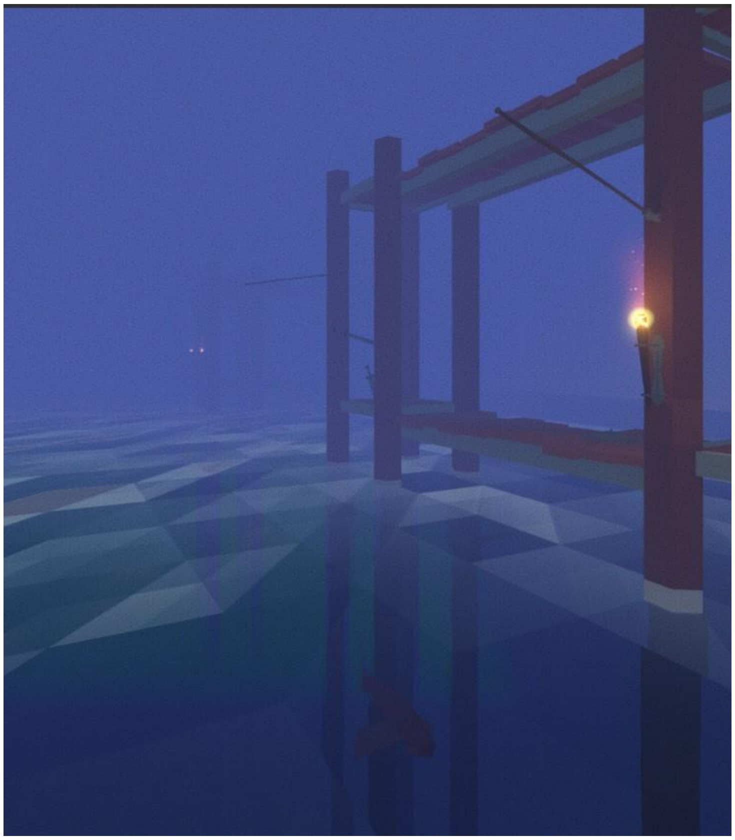


Figure 36. Screenshot from the first level (Barclay 2020)

Upon completion of the broad layout of the level, more specific game assets were used to populate the environment. Figure 36 depicts how the first level looks from the perspective of the player while in-game.


Figure 37. Screenshot from the fourth level (Barclay 2020)

The assets were used in such a way as to simulate depth as the VRSRT recommends in order to reduce the impact of VR sickness. For example, objects such as the shoreline and larger rocks were placed further away from the player at the edge of visible distance whereas objects that were required to progress the story were located closer to the player as demonstrated by Figures 37 and 38.

Figure 38. Screenshot from the fifth level (Barclay 2020)

From the various screenshots of the game, it can be seen that the colour palettes of Figures 21 and 22 have been used to create the tone within the virtual world as designed. Moreover, this placement of game assets helped create a realistic and plausible game environment (Burgee & Purkeypile 2013).

6.2.5 User-interface construction

The user-interface created was made to be virtual reality specific (spatial UI) as per section 6.1.9 using suggestions from the VRSRT. Within Unity, a user-interface canvas was created, and the render mode was changed from Screen-Space Overlay to World Space thereby making the UI spatial. In addition, the Event Camera was linked to the Center Eye Camera of the VR camera in order for the player to see the user-interface. Figure 39 shows the UI canvas game object settings as they appear in the Unity editor.

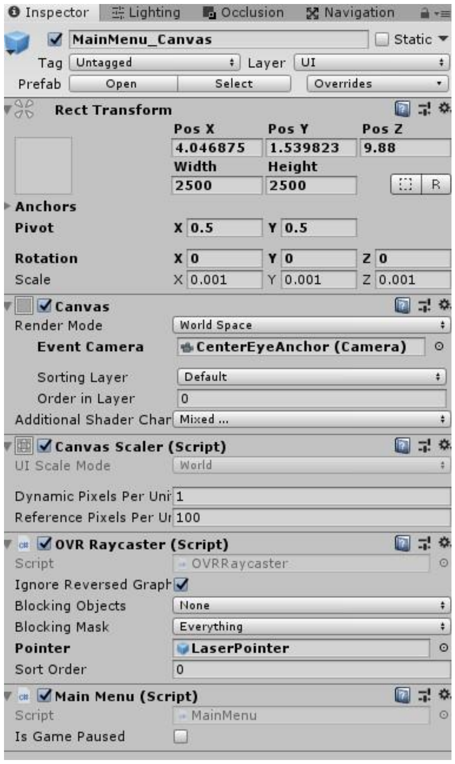


Figure 39. User-interface canvas settings (Barclay 2020)

After the UI settings were made VR specific, the user-interface was ready to be built. Simple buttons were created that contained text that was understandable and predictable — interacting with the “Play Game” button would play the game — where users would know exactly how to operate the user interface of the game product (Slashcev 2019).

Figure 40. Main menu UI (Barclay 2020)

The font used for the text is the Origram font due to the font being geometric in shape, free to use and scaled well as a high-resolution vector font (Dias no date). Moreover, the Origram font seemed to fit in with the overall low-poly art style that the game product used. Figure 40 shows the main menu UI, the Origram font and the laser pointer interaction system.

In order to interact with the buttons in the virtual world, a simple laser pointer system was implemented where the player points the Oculus Motion Controller at the desired button on the UI then presses the select button on the controller.

Figure 41. Pause menu UI (Barclay 2020)

Similar steps were taken to create the pause menu system which was integrated in order to allow players to pause the game and take frequent breaks if desired as recommended by the VRSRT. Figure 41 shows the pause menu UI as it looks like in-game.

From Figures 40 and 41, it can be seen that the user-interface is simple yet functional and achieves the design goals whilst incorporating suggestions from the VRSRT.

6.2.6 Implementation of the code

Implementing the code was challenging but necessary in order to get the game product to function. The total number of scripts used in the game product was thirty-nine and ranged from simple movement scripts to more complicated object spawners. The code was written using a code editor program called Visual Studio.

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class PlayerMovement : MonoBehaviour
{
    [SerializeField]
    public float _movementSpeed;

    // Start is called before the first frame update
    void Start()
    {

    }

    // Update is called once per frame
    void Update()
    {
        transform.position += Time.deltaTime * transform.forward * _movementSpeed;  //Player moves in the Z axis at a speed defined by movementSpeed.
    }

    private void OnTriggerEnter(Collider other)
    {
        if (other.tag != "Player")
        {
            Destroy(other.gameObject, 0f);
        }
    }
}
```

Figure 42. Player movement script (Barclay 2020)

Figure 42 shows a simple example of the code used to move the boat — and player — through the virtual world. As suggested by the VRSRT, the movement speed is consistent and does not have aggressive acceleration. The movement is along the Z-axis which is the forward axis in Unity at a speed of 1.2 meters per second. The movement speed had to be balanced as to not be too fast that it would aggravate VR sickness and not too slow that it would be unexciting for the player experience.

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class SkullSpawnManager : MonoBehaviour
{
    [SerializeField]
    private GameObject[] spawnedSkull;

    [SerializeField]
    private Transform[] spawnPoints;

    // Start is called before the first frame update
    void Start()
    {
        StartCoroutine(SkullSpawnRoutine(30.0f));
    }

    // Update is called once per frame
    void Update()
    {

    }

    IEnumerator SkullSpawnRoutine(float delay = 0.0f)
    {
        if (delay != 0)
        {
            yield return new WaitForSeconds(delay);

            while (true)
            {
                GameObject skull = Instantiate(spawnedSkull[Random.Range(0, 2)], spawnPoints[Random.Range(0, 12)]);

                skull.transform.localPosition = Vector3.zero;

                yield return new WaitForSeconds(Random.Range(8f, 16f));
            }
        }
    }

}
```

Figure 43. Object spawn manager (Barclay 2020)

Figure 43 is the code used in level two to spawn skull game objects that interact with the player. This example of code uses Coroutines to delay the spawning of the objects as well as spawn the objects at random times and random preselected locations giving the level a more dynamic feel.

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.SceneManagement;
using UnityEngine.UI;
using TMPro;

public class UIManager : MonoBehaviour
{
    [SerializeField]
    private OVRInput.Controller m_controller;

    public OVRInput.Button pauseButton;

    public bool isGamePaused = false;

    [SerializeField]
    private GameObject gamePauseCanvas;

    // Start is called before the first frame update
    void Start()
    {
        gamePauseCanvas.SetActive(false);

        isGamePaused = false;

        Time.timeScale = 1.0f;

        AudioListener.pause = false;
    }

    // Update is called once per frame
    void Update()
    {
        if (OVRInput.GetDown(pauseButton) && isGamePaused == false)
        {
            PauseGame();
        }
    }

    public void PauseGame()
    {
        Time.timeScale = 0.0f;

        isGamePaused = true;

        AudioListener.pause = true;

        gamePauseCanvas.SetActive(true);
    }

    public void UnPauseGame()
    {
        Time.timeScale = 1.0f;

        isGamePaused = false;
```

Figure 44. User-interface manager (Barclay 2020)

Figure 44 shows part of the code used in the functionality of the user-interface. Several IF statements are implemented in order to allow the controllers to function. In addition, the code shows how the game is paused and resumed as well as how to enable and disable desired game objects.

6.2.7 Visual effects

Visual Effects (VFX) is the process of creating imagery through multiple technologies combining design, 3D modelling and animation together (Maio 2020). Typically, within games, there are two main types of VFX — gameplay and environmental. Gameplay VFX involves effects integral to the gameplay such as explosions and gunshots in a shooting game. Environmental effects involve effects to do with the in-game environment such as rain, wind and mist for example (Ordonez 2017.) The game product was several gameplay VFX such as a heart-breaking but had many more environmental VFX.

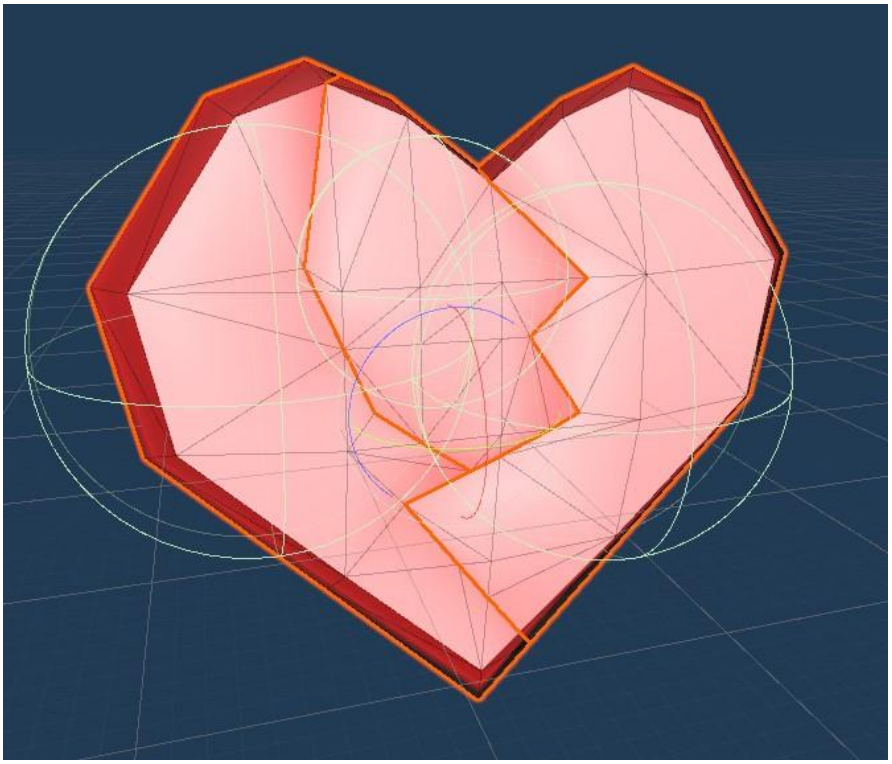


Figure 45. Heart model showing colliders (Barclay 2020)

The heart-breaking effect was a combination of the physics system of Unity, coding, and the particle system. When the player crosses a particular trigger in the virtual world, it causes the original heart game object to disable, making it invisible, while simultaneously spawning a new heart that had been cut into three pieces. These three pieces all have colliders and rigid bodies attached to them (Figure 45) and when the object spawns, the physics system of Unity explodes the individual pieces outwards (Figure 46).


Figure 46. Heart-break VFX (Barclay 2020)

The environmental effects in the game product used mainly the particle system to create the VFX. The environmental VFX included rain, ripples, splashes, lighting, fireflies, nebulae, embers and falling leaves. Figure 47 shows the lightning VFX, the rain VFX and the embers VFX used in the game product.


Figure 47. Various particle effects (Barclay 2020)

One of the most important environmental VFX used in the game product was the water. The water would be present with the player throughout the whole experience and much effort was put into the effect to maximise the quality of the effect. To facilitate the desired quality of the effect, an asset from the Asset Store was used — the Amplify Shader Editor (ASE).

Shaders, generally, are used to compute rendering effects on a computer which involves complex math and code (ShaderCat 2016). Amplify Shader Editor simplifies shaders into a node-based shader creation tool that allows the production of professional quality effects (Amplify Creations 2020).

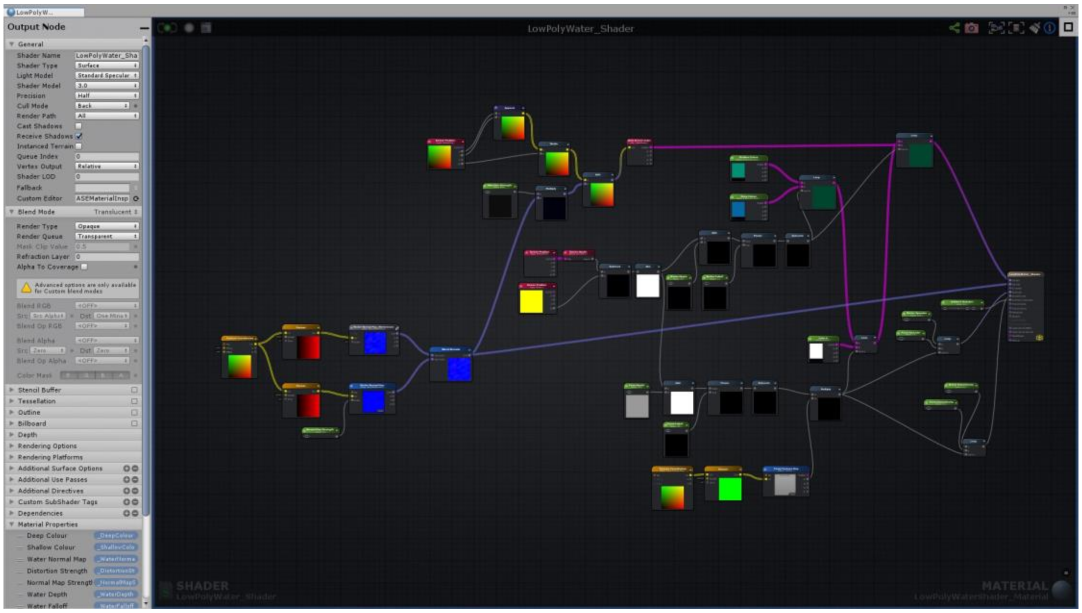


Figure 48. Amplify Shader Editor water shader (Barclay 2020)

Figure 48 shows the user-interface of ASE which integrates seamlessly into the Unity editor interface. Figure 48 also shows the nodes and connections used to produce the water shader needed to create the water VFX for the game product. Figure 49, conversely, shows part of the traditional shader code used for the same water shader, highlighting how complex traditional shader code can be and revealing how much easier using ASE can be to create shaders.

```
// Made with Amplify Shader Editor
// Available at the Unity Asset Store - http://u3d.as/y3X
Shader "LowPolyWater_Shader"
{
    Properties
    {
        _DeepColour("Deep Colour", Color) = (0,0,0,0)
        _ShallowColour("Shallow Colour", Color) = (0,0,0,0)
        _WaterNormalMap("Water Normal Map", 2D) = "bump" {}
        _DistortionStrength("Distortion Strength", Float) = 0
        _NormalMapStrength("Normal Map Strength", Float) = 0.2
        _WaterDepth("Water Depth", Float) = 0
        _WaterFalloff("Water Falloff", Float) = 0
        _AmbientOcclusion("Ambient Occlusion", Range( -2 , 2)) = 0
        _FoamDepth("Foam Depth", Float) = 0
        _FoamFalloff("Foam Falloff", Float) = 0
        _FoamTextureMap("Foam Texture Map", 2D) = "white" {}
        _WaterSpecular("Water Specular", Float) = 0
        _FoamSpecular("Foam Specular", Float) = 0
        _WaterSmoothness("Water Smoothness", Float) = 0
        _FoamSmoothness("Foam Smoothness", Float) = 0
        [HideInInspector] _texcoord( "", 2D ) = "white" {}
        [HideInInspector] __dirty( "", Int ) = 1
    }

    SubShader
    {
        Tags{ "RenderType" = "Opaque"  "Queue" = "Transparent+0" "IgnoreProjector" = "True" }
        Cull Back
        GrabPass{ }
        CGPROGRAM
        #include "UnityStandardUtils.cginc"
        #include "UnityShaderVariables.cginc"
        #include "UnityCG.cginc"
        #pragma target 3.0
        #if defined(UNITY_STEREO_INSTANCING_ENABLED) || defined(UNITY_STEREO_MULTIVIEW_ENABLED)
        #define ASE_DECLARE_SCREENSPACE_TEXTURE(tex) UNITY_DECLARE_SCREENSPACE_TEXTURE(tex);
        #else
        #define ASE_DECLARE_SCREENSPACE_TEXTURE(tex) UNITY_DECLARE_SCREENSPACE_TEXTURE(tex)
        #endif
        #pragma surface surf StandardSpecular keepalpha
        struct Input
        {
            float2 uv_texcoord;
            float4 screenPos;
        };

        uniform sampler2D _WaterNormalMap;
        uniform half _NormalMapStrength;
        uniform half4 _ShallowColour;
        uniform half4 _DeepColour;
        UNITY_DECLARE_DEPTH_TEXTURE( _CameraDepthTexture );
        uniform float4 _CameraDepthTexture_TexelSize;
        uniform half _WaterDepth;
        uniform half _WaterFalloff;
        uniform half _FoamDepth;
```

Figure 49. Shader code for the water shader (Barclay 2020)

Figure 50 shows the way the water looks in-game using the water shader created. The colour of the water uses the colour palette (Figure 22) decided on in section 6.1.5 to emphasise the tone of the story and incorporates the low-poly art style to fit into the overall look of the game product.

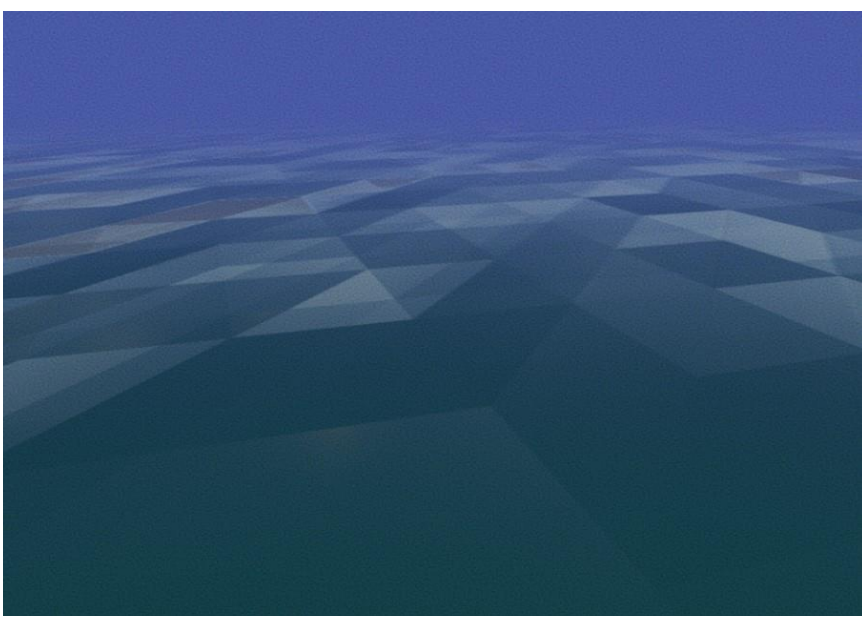


Figure 50. Water shader as is seen in-game (Barclay 2020)

Throughout the creation of VFX assets, care was always taken to heed the recommendations of the VRSRT.

6.2.8 Sound

The way that sound was used in the game product was to use sound effects at specific points in order to highlight emotional moments and also have an immersive background audio track to convey the desired thoughtful, melancholic tone.

The sound effects came from assets from the Asset Store where large collections of audio clips are available. Sound effects taken from the Asset Store include the sounds of objects breaking which were used to suggest the breaking of the heart (Figure 46). Other audio taken from the Asset Store are the thunder and rain sounds used in the second level, the wind sounds used in the fourth level, and the animals sounds used in the fifth level.

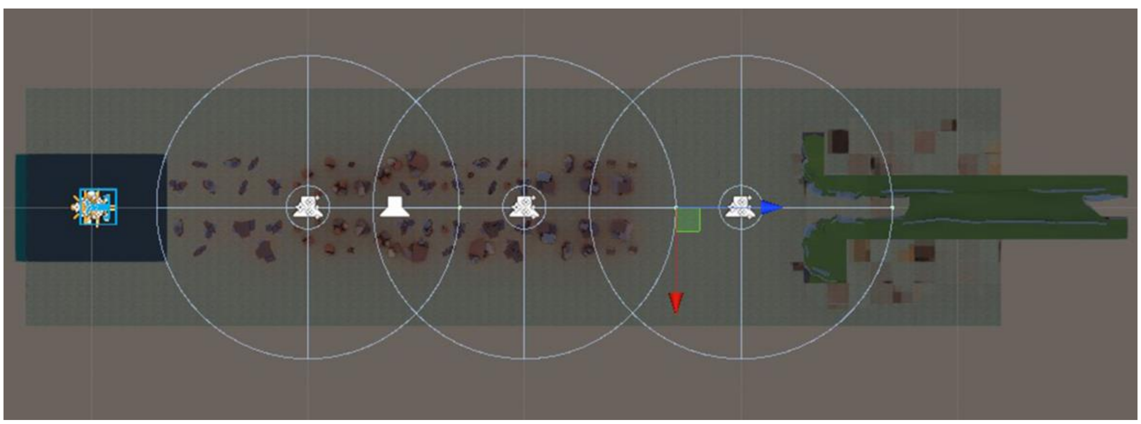


Figure 51. Audio range indicators in the second level (Barclay 2020)

The sound for the game product was implemented through a combination of code, triggers, colliders and Unity editor settings. Figure 51 shows an isometric view of the second level of the game product where the audio range indicators can be seen.

Figure 52. Audio component in the Unity editor (Barclay 2020)

Using distance/ range in audio, combined with virtual reality can create a very immersive feeling and can connect the player to the virtual world. Figure 52 shows the rain audio component used in combination with Figure 51 with the setting configured to using distance/range, so the sound gradually gets louder or quieter depending on the location of the player.

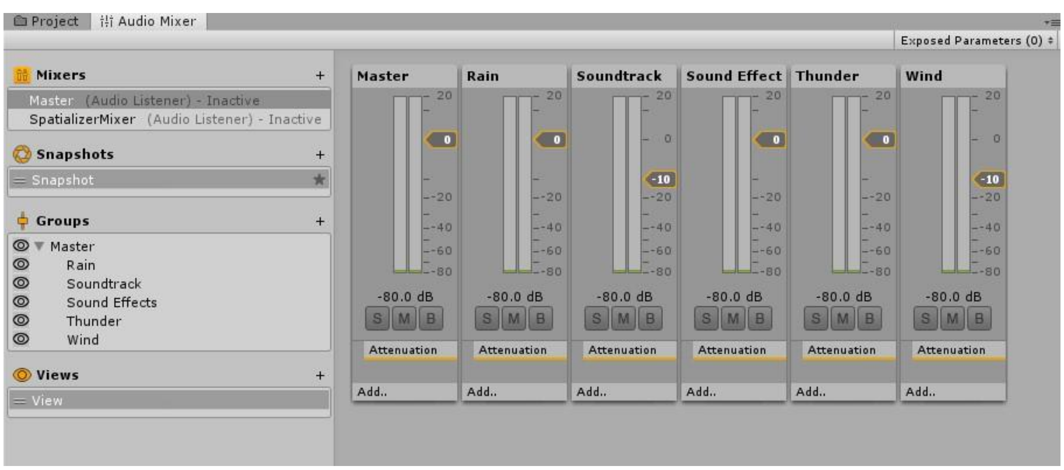


Figure 53. Audio mixers in the Unity editor (Barclay 2020)

Additional sound settings can be accessed by using audio mixers found in the Unity editor (Figure 53). Additionally, it provides a level of control for the developer permitting fine tuning of audio clips.

6.2.9 Visual tweaks

In order to get the visual theme and tone of the game product project to look as planned, it was necessary to tweak the visual aspects of the Unity game engine. Unity has a feature called post-processing which allows for the improvement of the visual aspects of the game.

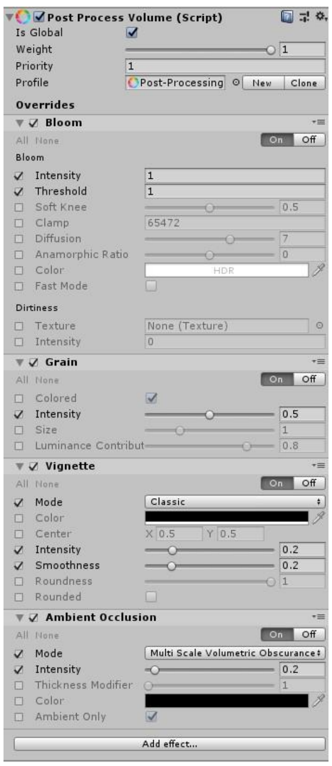


Figure 54. Post-processing settings (Barclay 2020)

Within the post-processing feature, several effects were applied to the visual aspects of the game product in order to improve visual quality. Effects such as bloom, grain, vignette and ambient occlusion were used. Figure 54 shows the post-processing settings used in the game project.

Figure 55. Image on the left is post-processing enabled, image on the right is post-processing disabled (Barclay 2020)

Figure 55 shows a comparison between post-processing effects being enabled and post-processing effects being disabled. Whilst subtle in appearance, the image with post-processing enabled has more depth and impact which greatly helped in achieving the thoughtful, melancholic tone of the game product.

There is a post-processing effect called motion blur that is available for use as part of the post-processing feature. However, motion blue was not used in the game product on recommendation of the VRSRT as motion blur contributes to VR sickness.

6.2.10 Optimisation

The VRSRT tool advises to optimise the game and this is an important suggestion as the more a game is optimised the easier it is to maintain the target FPS and avoid lag thereby reducing the impact of VR sickness. From Figure 3 it can be seen that the target FPS for the Oculus Rift is 90 FPS and efforts were made to optimise the game product in order to maintain this target FPS.

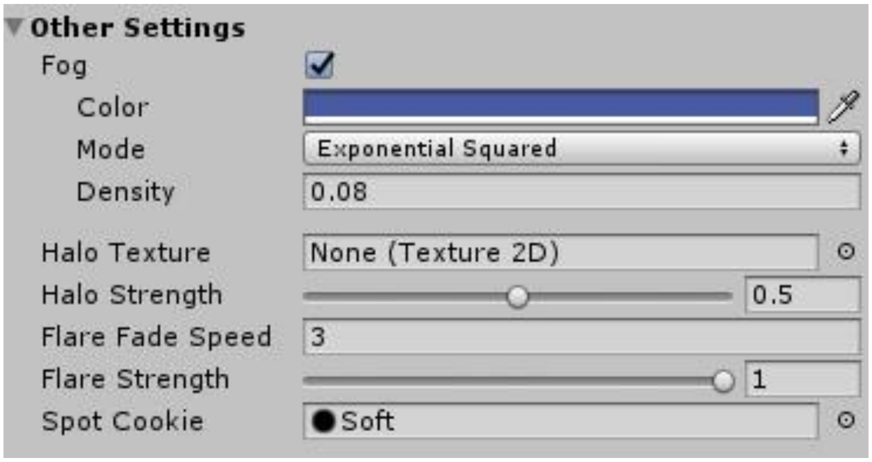


Figure 56. Fog settings (Barclay 2020)

The game product utilises a particular Unity lighting feature called fog. Figure 56 shows the fog settings used in the game product. Within the game product, fog was used as a visual design choice to suit the tone of the game but also to obscure distant objects in the game — with a maximum viewing distance of thirty meters — meaning that because players cannot see further than thirty meters there was no need to render anything over that distance thereby optimising performance. This was of most use in the X and Y axes since the Z-axis was the movement axis that the player moved through the virtual world. To optimise that aspect, a collider was set up to follow thirty-five meters behind the player which destroyed game objects that were not needed anymore and was done without the player being able to visualise said destruction thereby ensuring immersion in the virtual world.

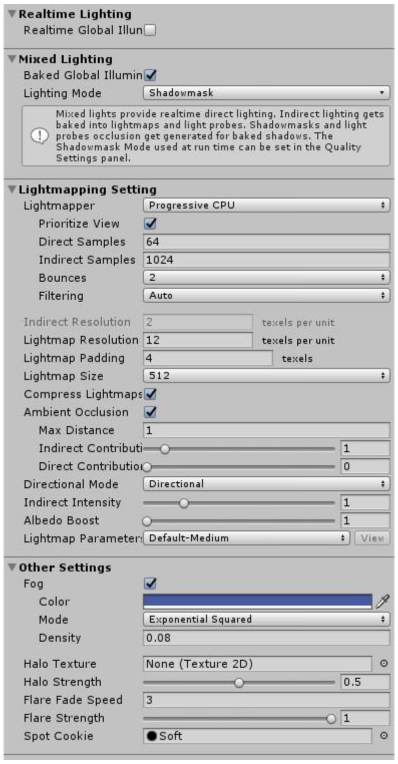


Figure 57. Lighting settings (Barclay 2020)

Lighting was optimised in the game product by switching the majority of the realtime lights to baked lighting. Realtime lighting is very performance consuming and the more realtime lights there are in a scene, the more of an impact on FPS they have (Trammell 2016). Baked lighting takes all of the lighting information generated by lights in the scene and superimposes the lighting information on to the textures of the game objects in the scene. This technique saves the lighting information allowing the realtime lights to be removed from the scene thereby optimising performance. (Pluralsight 2014.) Figure 57 shows the lighting settings for the game product specifying the use of the baked lighting technique.

Low-Poly Shaders by Broken Vector were used on their models to optimise the game. Broken Vector (2017) claimed that their shaders were more efficient at shader calculations than normal shaders due to their shaders performing the shader calculation for every vertex instead of every pixel. When testing the shaders in the game product, the Low-Poly Shaders, on average, were more efficient than standard shaders by 6 FPS making them slightly more efficient than standard shaders in this particular game product.

As previously mentioned in sections 6.1.5 and 6.2.4, other steps were taken to optimise the game product such as the use of the low-poly art style and dividing the game into smaller levels. When testing the game product, using the computer with the specifications shown in Figure 25 — which is by no means a powerful computer by the standards of today — the FPS never fell below 90 FPS suggesting the game product was sufficiently well optimised.

6.3 Evaluation of the VR game

The virtual reality game product will be examined through playtesting to find out to what extent VR sickness is prevalent in the game which will, additionally, evaluate the effectiveness of the VRSRT.

6.3.1 Playtesting

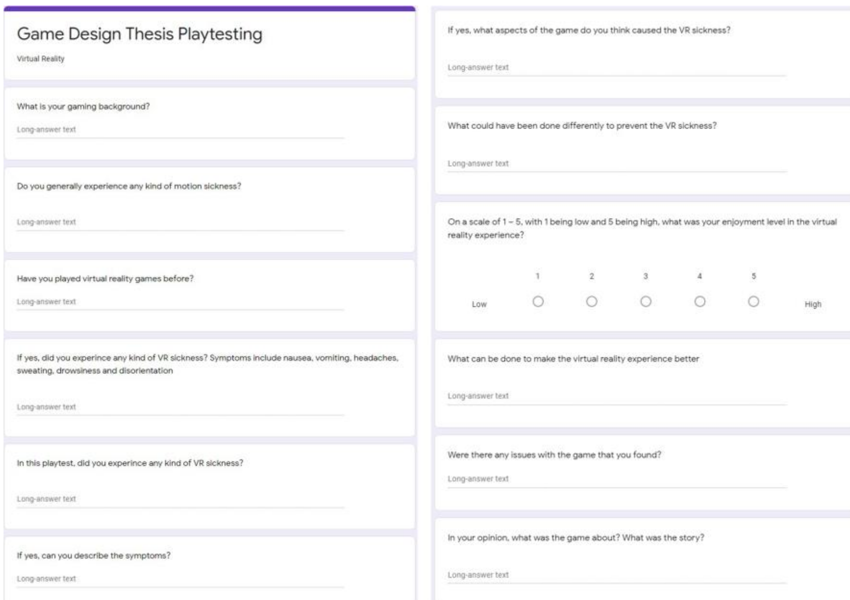
Playtesting is the process where games are played and tested for flaws or issues before the game is released. Playtesting is an essential part of the game design process and is invaluable in identifying risks to the success of the product as well as ensuring the game is of the highest quality for users. (St. John 2013.) Webber (2018) argues that not all games should be tested in the same way and they should be tested for specific reasons depending on what is trying to be learned. In the case of the Homeward game product, the main reason for playtesting is to establish to what extent VR sickness is prevalent in the game. As such, the playtesting was catered around finding out the answer to that question. Naturally, other issues will be explored such as what aspects of the game caused the VR sickness and what can be done to make the virtual reality experience better. Boller (2013) suggests that for self-made games or games made by a small team, the total number of playtesting hours should be 30 to 40 hours.

Throughout the development of the game product, self-testing and informal playtesting among friends did occur to ensure the functionality of the game as a whole. However, formal playtesting is more desirable at it allows playtesters to be more objective (Boller 2013). In section 6.1.1, a goal of the game product was that it could be playable by those familiar and new to virtual reality games. Therefore, the target audience range was wide allowing a broad spectrum of potential types of playtesters for the game product. St. John (2013) encourages the use of playtesters that are new to a particular genre promoting feedback on the game given from a fresh perspective.

The recruiting process for the playtesting involved sending out invitations on various forums, social media and through word of mouth with the goal of having as many playtesters as possible test the game. Once testers were committed to testing the game, they were invited to test the game either at the XAMK campus or at a secondary location. Arrangements were in the process of being made with International Game Developers Association (IGDA) chapters — Kotka, Lahti, Helsinki — who hold monthly gatherings and demo corners. The arrangements were to facilitate a large number of potential playtesters for the game product in March 2020. However, the advent of the COVID-19 pandemic and the resulting social distancing recommendations supplied by XAMK (2020) and the Finnish Government (2020), resulted in IGDA cancelling their monthly gatherings and, as such, the playtesting opportunities were cancelled too. Moreover, the XAMK testing location became unavailable due to the lockdown making additional playtesting of the product extremely difficult where pushing for playtesting during a pandemic was deemed unnecessarily risky and unethical.

The playtesting process for the game product was that testing environment was made to be relaxed where emphasis was made to put the playtesters at ease. A small introduction was used to explain what was expected of the playtester but no explanation of the game itself was given as to evaluate if the playtesters found the game intuitive or not (Webber 2013). Playtesters were told they were able to think aloud so that the tester could take notes. Following a full playthrough of the game product, an in-person interview was conducted with a questionnaire asking specific questions concerning the game product and VR sickness. Due to the need for the in-person interview as well as the limitations of only having one VR headset at each testing location, the use of online testing was deemed impractical and was not used.

The in-person interview and questionnaire were designed to be short and get to the heart of the issue (Rockholz 2014) — to what extent VR sickness is prevalent in the game. The questions asked by the interviewer were based on the questionnaire in order to generate useful data, keep the answers on topic and to prevent overly long answers (MotionTwin no date; Patton 2017).



Game Design Thesis Playtesting

Virtual Reality

What is your gaming background?

Long-answer text

Do you generally experience any kind of motion sickness?

Long-answer text

Have you played virtual reality games before?

Long-answer text

If yes, did you experince any kind of VR sickness? Symptoms include nausea, vomiting, headaches, sweating, drowsiness and disorientation

Long-answer text

In this playtest, did you experince any kind of VR sickness?

Long-answer text

If yes, can you describe the symptoms?

Long-answer text

If yes, what aspects of the game do you think caused the VR sickness?

Long-answer text

What could have been done differently to prevent the VR sickness?

Long-answer text

On a scale of 1 – 5, with 1 being low and 5 being high, what was your enjoyment level in the virtual reality experience?

1 2 3 4 5

Low ○ ○ ○ ○ ○ High

What can be done to make the virtual reality experience better

Long-answer text

Were there any issues with the game that you found?

Long-answer text

In your opinion, what was the game about? What was the story?

Long-answer text

Figure 58. Playtesting questionnaire (Barclay 2020)

Figure 58 shows the playtesting questionnaire used in the in-person interview following the playtesting session. Appendix 3 shows the playtesting questionnaire in a larger, more detailed set of images. The questionnaire was created using Google Forms, then printed off for the interviewer to use during the interview.

6.3.2 Analysis of playtesting data

Compiling the playtesting data and presenting it allows for the easy analysis of the data, where conclusions can be reached (Khalifa 2019). Playtesting yielded a total number of eleven playtesters but, despite the small sample size, some insights can be gleamed from the data.

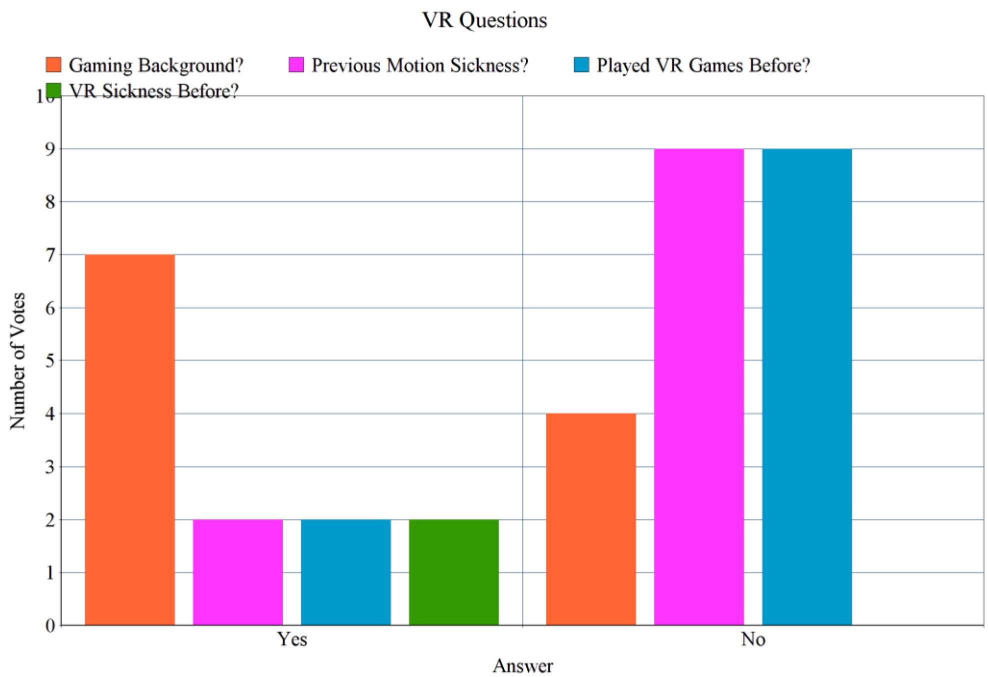


Figure 59. General VR questions and the answers (Barclay 2020)

Figure 59 is a bar graph of some of the general questions from the playtesting questionnaire. From the graph, it can be seen that there is a mix of playtesters with gaming backgrounds (7) and non-gaming backgrounds (4) and that most playtesters (9) had not suffered from motion sickness before. Interestingly, those that had played VR games before (2), both of them experienced VR sickness in the previous games they played, slightly hinting at the relationship between VR and VR sickness.

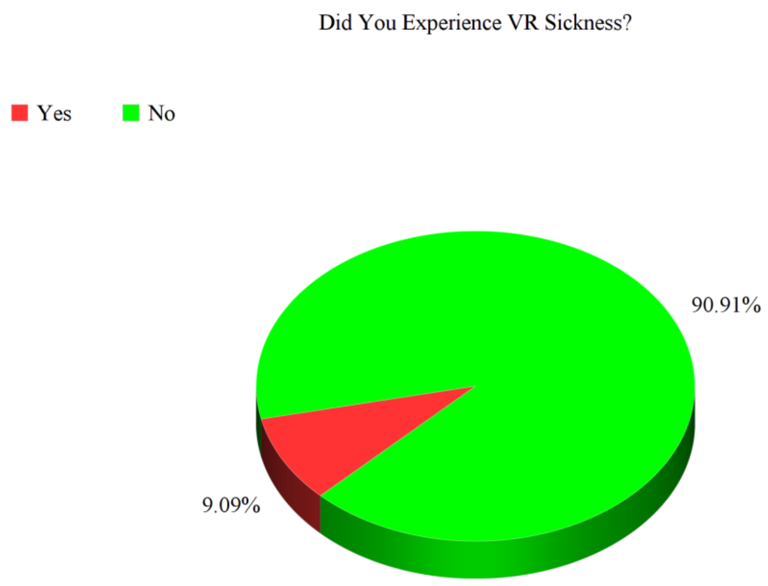


Figure 60. Pie chart showing VR sickness experienced (Barclay 2020)

Figure 60 is a pie chart showing how the playtesters answered to the question of if they experienced VR sickness in the playtesting of the game product. From the chart it can be seen that only 9.09% — in other words 1 playtester — experienced VR sickness from the game product. The VR sickness symptoms experienced were nausea and a spinning head. Interestingly, the playtester that experienced VR sickness in the playtesting also had previous experience with VR sickness in other games and additionally suffered from motion sickness in their regular life possibly suggesting they were susceptible to motion sickness in general. 90.91% (10 playtesters) experienced no VR sickness which might be able to suggest that the game product has a low prevalence of VR sickness and that the design tool is effective.

All in all, 11 playtesters were able to give feedback on the game product resulting in roughly 7 hours of playtesting — fewer than the 30 to 40 hours recommended by Boller (2013). Of course, 11 playtesting results are not enough to be of statistical significance or offer projections for the general population (Andersen 2018) but the process did offer valuable feedback and show potential promise for the justification of future testing. Therefore, more time and resources would be needed in order to conduct more rigorous playtesting with additional playtesters.

6.3.3 Successes of the product

The playtesting process offered useful insights for the game product in general. Figure 61 is a bar graph which shows that 7 playtesters, on a scale of 1 to 5, with 1 being low and 5 being high, ranked the game product as 5, 3 ranked the game product a 4 and 1 playtester who experienced VR sickness ranked the game product a 2. The results from Figure 61 combined with the results of Figure 60 might suggest that using the recommendations from the VRSRT can reduce the impact of VR sickness as well as produce an enjoyable VR experience game product though, of course, more research would be needed to confirm that hypothesis.

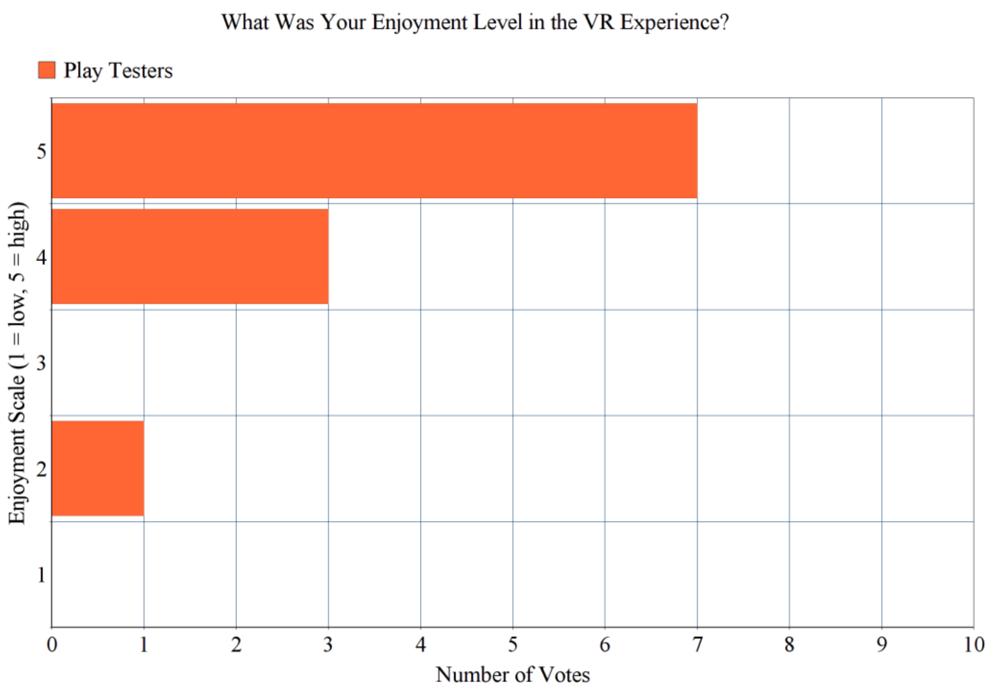


Figure 61. Bar graph showing the enjoyment level of the VR experience (Barclay 2020)

Other positive aspects of the game product that the playtesting discovered was that the game, overall, was a fun experience and the playtesters appreciated the thoughtful, melancholic tone of the story. The playtesters offered their own interpretations of the meaning of the story with most (6) deducing it was about returning home, some (3) thought it was about death and others (2) thought it was about love. The diversity in interpretation was a welcome discovery and achieved an aim described in section 6.1.4 of having players interpret the story in their own way.

6.3.4 Criticisms of the product

In contrast to the positive feedback given about the game product, playtesting did reveal some shortcomings.

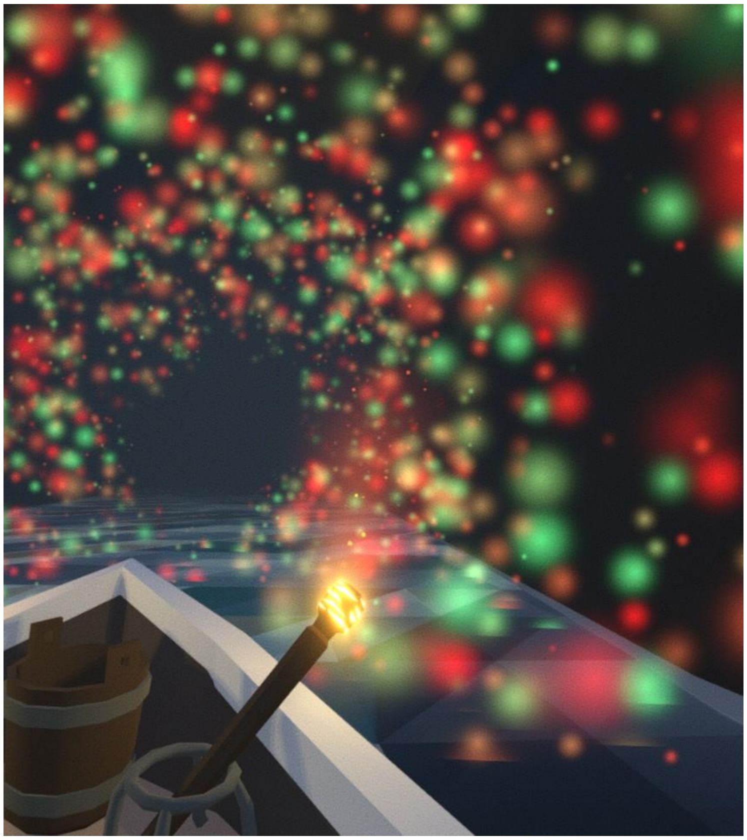


Figure 62. Spinning particle effect (Barclay 2020)

In terms of the virtual reality aspects of the game product, the playtester who experienced VR sickness said that they felt nauseous after the third level where there is a spinning particle effect (Figure 62). Other playtesters (6) felt that this spinning effect could be a potential cause of VR sickness even though they did not experience VR sickness. In addition, some (3) of the playtesters mentioned that they experienced a blurry, distortion effect present on the edges of the boat which persisted through the whole experience which they found distracting. The playtester who experienced VR sickness did not mention any blurry distortion effects being an issue. In the fifth level, playtesters (4) mentioned that the boat stops too abruptly, and that jarring stop might cause VR sickness. The playtester who experienced VR sickness did mention the boat stopping abruptly as a potential VR sickness factor in their experience. Most (9) of the playtesters would have like to see more interaction with the virtual world but understood that it was not necessary to enjoy the experience of the game product.

In more general game enjoyment terms, playtesters (4) thought that the game was slightly too long and that certain parts of the game could be shortened. Others (6) mentioned that the user-interface was functional but blended into the background too much making the UI blurry. In addition, some (4) noticed glitches with the audio where the sound would go quiet for a few seconds before resuming. Most (7) of the playtesters suggested that it would be more immersive if the transitions between the levels did not exist and wanted to have one large immersive level.

6.3.5 Potential improvements of the product

The issues raised in the previous section 6.3.4 can be looked at more in-depth, in order to improve the game product.

The spinning particle effect can be improved by slowing down the spinning and limiting the rotation then testing to see if there is still a potential VR sickness contributor. However, it could be just that some effects affect some users more than others. Additional research to investigate the contribution that a spinning effect would have on VR sickness is needed.

The blurry distortion effect on the edges of the boat was investigated and it was deemed that the water shader was the cause of the distortion. By editing some of the strength of the distortion nodes, the blurry effect was able to be scaled back thereby improving the game product.

The issue with the boat stopping too abruptly was able to be improved quite easily by gradually decreasing the boat speed over time until the transition was smooth.

More interaction within the game would be an excellent addition but the scope of the game product meant that there was not enough time to implement a functional interaction system. In the future, VR interaction and the relationship with VR sickness is a definite area for further research.

The length of the game in total is roughly twenty minutes depending on how the user engages with the menu system and pause system. There are areas of the level layout that could be streamlined and areas of open water that could be condensed in order to shorten the length of the game product to improve the experience.

The user-interface of the game can be improved by editing the colour scheme of the UI. Complimentary colours could be used in order to create a clear difference between the background and the UI.

The issues with the audio stemmed from the fact that the audio clips were implemented to loop and at the end of the track to the start of the track there would be no audio because it was in the process of looping. This could be improved upon by using audio software to seamlessly loop the audio track together thereby eliminating the drop in audio.

One large level did pose an issue and while it would be more immersive, the limitations of the hardware made it very difficult to achieve. In addition, the VRSRT recommended that shorter levels were used in order to reduce the impact of VR sickness which seemed to have work according to the small sample of playtests. Perhaps through further optimisation or more powerful hardware, it would be possible to create on large seamless level. The potential effect this would have on VR sickness would then need to be measured through further playtesting.

Another improvement that could be made was in the fifth level. During the playtesting the interviewer noticed that many playtesters would not see the heart coming towards the player. By missing this event, there as the potential the story was not being fully understood. Therefore, potential improvements to the fifth level would be to introduce audio clues and a particle effect in order to draw attention toward the heart game object.

6.3.6 Evaluation of the VRSRT as a game design tool

The broad aim of the Virtual Reality Sickness Reduction Tool was that it can be used as a design tool by virtual reality game developers to reduce the impact of virtual reality sickness in virtual reality games. Through the creation of the game product, the VRSRT was validated as it showed that designing and implementing a game based on the recommendations given by the VRSRT was possible. Furthermore, the effectiveness of the VRSRT as a design tool was examined via the playtesting of the game product which established to what extent VR sickness was prevalent.

During the game product design process, the recommendations given by the VRSRT were used heavily in order to design many aspects of the game with the intention of reducing the impact of VR sickness as much as possible. The low-poly art style was a direct recommendation taken from the VRSRT as was the choice of colour used in the game product. The gameplay mechanics were influenced by the VRSRT in the way that the player experiences the virtual world, moves through the virtual world, and interacts with the virtual world. The level design took recommendations from the VRSRT in the way that it placed objects in the virtual world to create depth and plausible environment. The user-interface design incorporated all aspects that were suggested by the VRSRT where the UI was fully VR specific and spatial in nature.

In the implementation process, the recommendations given by the VRSRT were taken in a practical way. For example, the VR camera settings were adjusted to ensure the correct calibration for user comfort. In addition, the assets used had to be of high quality and high resolution as suggested by the VRSRT. Furthermore, the UI used solutions from the VRSRT where the fonts used were high-resolution vector fonts and a functional pause menu was implemented. The recommendations made by the VRSRT was used in post-processing, where the effect of motion blur was not utilised. Moreover, the VRSRT emphasised that optimisation of the game was important, so every effort was made to optimise the game product in order to maintain the target FPS.

The VRSRT was used and consulted often, either as a stand-alone design tool or used in conjunction with other design tools. The VRSRT worked seamlessly with the one-page design document where effective communication was achieved. In addition, the versatility of having the VRSRT as a physical or digital version meant that using Unity and the VRSRT together was comfortable.

The VRSRT in the design and implementation process proved to be an easy, non-complex affair. However, what can be said about the effectiveness of the VRSRT? Through the playtesting of the game product, the general effectiveness of the VRSRT was certainly hinted at in the positive direction due to the fact that only one of the playtesters experienced VR sickness and that the majority of playtesters has a positive experience playing the game product. For a more definitive answer as to the effectiveness of the VRSRT, more research must be conducted. Therefore, additional playtesting of the game product should take place when it is safe to do. Ideally, additional research could involve a scenario where real-world virtual reality developers use the VRSRT in the design and implementation of their virtual reality games followed by an evaluation on how prevalent VR sickness is in the games. If the results so far are considered preliminary, then the outlook of the effectiveness of the VRSRT could be said to be positive, at least in the extent of justifying additional research.

One potential improvement to the VRSRT exists that can be contemplated for the future. Once additional research has been conducted concerning the relationship between VR sickness and sound, the results should be incorporated into the VRSRT.

The evidence surrounding the Virtual Reality Sickness Reduction Tool leans in the direction that, overall, the tool seemed to have potential in being beneficial in reducing the impact of VR sickness in virtual reality games.

7 CONCLUSION

The objective of this thesis was to establish what aspects of virtual reality games cause VR sickness, in order to create a design tool that could limit the impact of VR sickness when developing virtual reality games.

In order to fulfil the objective of this thesis, a literature review was performed. Sixteen academic articles were analysed in total combined with five non-academic sources, identifying many aspects of virtual reality games that cause VR sickness ranging from blurry graphics, inconsistent speed and unnecessary camera movement to the field of view being too high, low-quality hardware, lag and a poorly designed user-interface. In addition, the main impacts of VR sickness were discovered as being the undesirable feelings of the sickness itself – nausea, headaches, vomiting – which had the extended effects of reducing enjoyment of the virtual reality experience, shortening the time spent in VR and a reluctance to use VR in the future. Furthermore, the literature review helped establish what could be done to combat VR sickness with optimisation of the game being of great importance. Additional practical solutions to reduce the impact of VR sickness included lowering the field of view settings, utilising a low-poly art style in the game, consider using a “cockpit” focal point, use of teleportation movement mechanics and following the 80/20 design principle.

To further determine what could be done to combat VR sickness, existing virtual reality games were analysed through content analysis. Three VR titles were examined — chosen through Oculus’ own comfort rating system — and discovered additional practical ways in which to reduce the impact of VR sickness. Such ways included the importance of maintaining the target FPS of the VR headset. In addition, the content analysis revealed many correlations with the literature review findings.

The information gained from the content analysis, coupled with the research from the literature review was then consolidated in order to create an infographic design tool — the virtual reality sickness reduction tool (VRSRT). As a design tool, the VRSRT aimed to be an easy to use tool that could be integrated into new or existing virtual reality game development that offered meaningful support and practical solutions to developers searching for ways in which to reduce the impact of VR sickness in their games. The design tool was not intended to be a creatively restrictive, must-do list of steps but an aid that facilitates purposeful decision making in the game design process, ultimately, giving the game developers the freedom to decide.

The VRSRT was then utilised through the creation of a virtual reality game product called Homeward. Through the creation of the game product, the VRSRT was validated as it showed that designing and implementing a virtual reality game based heavily on the recommendations given by the VRSRT was, in fact, possible. Subsequently, this led to the game product being examined through playtesting to find out to what extent VR sickness was prevalent in the game, which, additionally, evaluated the effectiveness of the VRSRT.

Playtesting was initially intended to be larger in scope and scale but unforeseen circumstances meant that, all in all, only eleven playtesters were able to give feedback on the game product. Naturally, eleven playtesters is a small sample size meaning the results were not to be of great statistical significance but the playtesting process did offer valuable feedback and show potential promise.

Through playtesting of the game product, the general effectiveness of the VRSRT was alluded to, due to the fact that there was a low prevalence of VR sickness and that the majority of playtesters has a positive experience playing the game product.

For a more definitive answer as to the effectiveness of the VRSRT, more research must be conducted. To achieve this, additional playtesting of the game product should take place in addition to real-world virtual reality developers testing the VRSRT in their own games followed by an evaluation on how prevalent VR sickness is in those games. If the results so far are considered preliminary, then the outlook of the effectiveness of the VRSRT could be said to be positive, at least to the extent of justifying additional research.

Despite the shortcomings of the limited playtesting results, this thesis can be considered an overall success as it has achieved the objective that it set out to, namely, in the establishment of what aspects of virtual games cause VR sickness and the subsequent creation of the VRSRT design tool for which further research is encouraged.

REFERENCES

Aldaba, C. N., White, P. J., Byagowi, A. & Moussavi, Z. 2017. Virtual reality body motion induced navigational controllers and their effects on simulator sickness and pathfinding. *Engineering in Medicine and Biology Society.* 39, 4175-4178.

Almeida, M. S. O. & da Silva, F. S. S. 2013. A systematic review of game design methods and tools. PDF document. Available at: https://link.springer.com/content/pdf/10.1007%2F978-3-642-41106-9_3.pdf [Accessed 26 March 2020].

Amplify Creations. 2020. Amplify Shader Editor. WWW document. Available at: http://amplify.pt/unity/amplify-shader-editor/ [Accessed 03 April 2020].

Andersen, I. 2018. Statistical analysis to complement casual game development. Blog. Updated 31 May 2018. Available at: https://www.gamasutra.com/blogs/IanAndersen/20180531/319073/Statistical_Analysis_to_Complement_Casual_Game_Development.php [Accessed 5 April 2020].

Andrews, M. 2010. Game UI discoveries: what players want. Blog. Updated 23 February 2010. Available at: https://www.gamasutra.com/view/feature/4286/game_ui_discoveries_what_players_.php?print=1 [Accessed 25 March 2020].

Arnaldi, B., Guitton, P. & Moreau, G. 2018. Virtual reality and augmented reality: myths and realities. 1st edition. London: John Wiley & Sons.

ArviVR. 2018. Combating VR sickness: debunking myths and learning what really works. Blog. Updated 22 March 2018. Available at: https://vr.arvilab.com/blog/combating-vr-sickness-debunking-myths-and-learning-what-really-works [Accessed 23 March 2020].

Ash, A., Palmisano, S., Govan, D. G. & Kim, J. 2011. Display lag and gain effects on vection experienced by active observers. *Aviation, Space, and Environmental Medicine.* Vol.82, 763-769.

Aspers, P. & Corte, U. 2019. What is qualitative in qualitative research? *Qualitative Sociology.* 42, 139-160.

Aykent, B., Yang, Z., Merienne, F. & Kemeny, A. 2014. Simulations sickness comparison between a limited field of view virtual reality head mounted display and a medium range field of view static ecological driving simulator. *Driving Simulation Conference Europe.* 2014, 65-71.

Bakker, J. 2009. A GDD template for the indie developer. Blog. Updated 6 April 2009. Available at: http://www.gamasutra.com/blogs/JasonBakker/20090604/84211/A_GDD_Template_for_the_Indie_Developer.php [Accessed 22 January 2020].

Billing, J. 2020. Introduction to 3D modelling. Blog. Available at: https://academy.autodesk.com/course/126271/introduction-3d-modeling [Accessed 2 April 2020].

Bloop. 2020. What is 3D animation compared to 2D animation? Blog. Available at: https://www.bloopanimation.com/what-is-3d-animation/ [Accessed 2 April 2020].

Boller, S. 2013. Final step in learning game design: playtest, playtest, playtest. Blog. Updated 25 September 2013. Available at: http://www.theknowledgeguru.com/final-step-learning-game-design-playtest-playtest-playtest/ [Accessed 5 April 2020].

Broken Vector. 2017. Low Poly Shaders. WWW document. Updated 27 November 2017. Available at: https://assetstore.unity.com/packages/vfx/shaders/low-poly-shaders-85262 [Accessed 2 April 2020].

Bullas, J. No date. 9 awesome reasons to use infographics in your content marketing. Blog. Available at: https://www.jeffbullas.com/9-awesome-reasons-to-use-infographics-in-your-content-marketing/ [Accessed 27 March 2020].

Burgess, J. & Purkeypile, N. 2013. Skyrim's modular level design. Blog. Available at: http://blog.joelburgess.com/2013/04/skyrims-modular-level-design-gdc-2013.html [Accessed 30 March 2020].

Callighan, E. 2019. Eight essential ways to use sound in video games. Blog. Updated 9 October 2019. Available at: https://www.gamesindustry.biz/articles/2019-10-08-eight-ways-to-use-sound-in-video-games [Accessed 31 March 2020].

Cao, Z., Jerald, J. & Kopper, R. 2018. Visually induced motion sickness reduction via static and dynamic rest frames. *Virtual Reality and 3D User Interfaces.* 2018, 105-112.

CCS Insight, 2018. Virtual reality and augmented reality device market worth $1.8 billion in 2018. Blog. Updated 9 April 2018. Available at: https://www.ccsinsight.com/press/com-pany-news/3451-virtual-reality-and-augmented-reality-device-market-worth-18-billion-in-2018/ [Accessed 19 March 2020].

CCS Insight, 2019. Virtual and augmented reality headset shipments ready to soar. Blog. Updated 6 August 2019. Available at: https://www.ccsinsight.com/press/company-news/virtual-and-augmented-reality-headset-shipments-ready-to-soar/ [Accessed 19 March 2020].

Chapman, C. 2017a. Color theory for designers, part 1: the meaning of color. Blog. Updated August 2017. Available at: https://www.smashingmagazine.com/2010/01/color-theory-for-designers-part-1-the-meaning-of-color/ [Accessed 26 March 2020].

Chapman, C. 2017b. Color theory for designers, part 2: understanding concepts and color terminology. Blog Updated August 2017. Available at: https://www.smashingmagazine.com/2010/02/color-theory-for-designers-part-2-understanding-concepts-and-terminology/ [Accessed 26 March 2020].

Chapman, C. 2017c. Color theory for designers: how to create your own color schemes. Blog. Updated August 2017. Available at: https://www.smashingmagazine.com/2010/02/color-theory-for-designer-part-3-creating-your-own-color-palettes/ [Accessed 26 March 2020].

Comaford, C. 2016. Games get goals met: here's how. Blog. Updated 12 November 2016. Available at: https://www.forbes.com/sites/christinecomaford/2016/11/27/got-games-gamify-goals-to-boost-results/#6faedad32b03 [Accessed 29 March 2020].

Couture, J. 2016. Why are so many devs employing a retro low-poly mid.1990s aesthetic? Blog. Updated 1 June 2016. Available at: https://www.gamasutra.com/view/news/273904/Why_are_so_many_devs_employing_a_retro_lowpoly_mid1990s_aesthetic.php [Accessed 30 March 2020].

Kim H.K, Park, J., Choi, Y. & Choe, M. 2018. Virtual reality sickness questionnaire (VRSQ): Motion sickness measurement index in a virtual reality environment. *Applied Ergonomics* 69, 66-73.

Colayco, B. 2005. So you wanna be a game designer. Blog. Updated 22 July 2005. Available at: https://www.gamespot.com/articles/so-you-wanna-be-a-game-designer/1100-6129276/ [Accessed 20 January 2020].

Colombet, F., Kemeny, A. & George, P. 2016. Motion sickness comparison between a CAVE and a HMD. *DSC Europe VR.* 2016, 201-206.

Davis, S., Nesbitt, K. & Nalivaiko, E. 2015. Comparing the onset of cybersickness using the oculus rift and two virtual roller coasters. *CRPIT.* Vol. 167, 3-14.

Dias, N. No date. Origram font. WWW document. Available at: https://www.1001fonts.com/origram-font.html#styles [Accessed 3 April 2020].

Diaz-Soloaga, C. No date. How to choose the perfect color scheme for your inforgraphic. Blog. Available: https://visme.co/blog/infographic-color-schemes/ [Accessed 28 March 2020].

Domanski, K. 2019. The secrets of FOV. Blog. Updated 3 April 2019. Available at: http://www.theastronauts.com/2019/04/the-secrets-of-fov/ [Accessed 22 March 2020].

Epic Games. 2020. Virtual reality best practices. WWW document. Available at: https://docs.unrealengine.com/en-US/Platforms/VR/DevelopVR/ContentSetup/index.html [Accessed 23 March 2020].

Fernandes, A. S. & Feiner, S. K. 2016. Combating VR sickness through subtle dynamic field of view modification. *IEEE Symposium on 3D user interfaces.* 2016, 201-210.

Finnish Government. 2020. Government, in cooperation with the President of the Republic, declares a state of emergency in Finland over coronavirus outbreak. WWW document. Updated 16 March 2020. Available at: https://valtioneuvosto.fi/en/artikkeli/-/asset_publisher/10616/hallitus-totesi-suomen-olevan-poikkeusoloissa-koronavirustilanteen-vuoksi [Accessed 4 April 2020].

Freeman, T. 1997. Creating a great design document. WWW document. Updated 12 September 1997. Available at: http://www.gamasutra.com/view/feature/131632/creating_a_great_design_document.php [Accessed 20 January 2020].

Game Design Ed. 2015. The game design process. Blog. Updated 28 May 2015. Available at: http://www.gamecareerguide.com/features/1415/the_game_design_.php?page=1 [Accessed 22 January 2020].

Gaming In Training. 2015. Setting goals and objectives. Blog. Updated 10 March 2015. Available at: https://gamingintraining.wordpress.com/2015/03/10/setting-goals-and-objectives/ [Accessed 24 January 2020].

GitHub. 2020. The human side of software. WWW document. Available at: https://github.com/features [Accessed 29 March 2020].

Gorisse, G., Christmann, O., Amato, E. A. & Richir, S. 2017. First and third person perspectives in immersive virtual environments: presence and performance analysis of embodied users. WWW document. Updated 17 July 2017. Available at: https://www.frontiersin.org/articles/10.3389/frobt.2017.00033/full [Accessed 30 March 2020].

Grand View Research. 2017. VR market research report 2018-2025. WWW document. Available at: https://www.grandviewresearch.com/press-release/global-virtual-reality-vr-market [Accessed 21 March 2020].

Grubb, J. 2020. VR darling beat Beat Saber surpasses 2 million copies sold. Blog. Updated 17 March 2020. Available at: https://venturebeat.com/2020/03/17/vr-darling-beat-saber-surpasses-2-million-copies-sold/ [Accessed 24 March 2020].

Guna, J., Gersak, G., Humar, I., Song, J., Drnovsek, J. & Pogacnik, M. 2019. Influence of video content type on users' virtual reality sickness perception and physiological response. *Future Generation Computer Systems.* Vol.91, 263-276.

Hart, C. 2018. Doing a literature review. 2nd edition. London: SAGE Publications Ltd.

Hettinger, L. J. & Riccio, G. E. 2006. Visually induced motion sickness in virtual environments. *Virtual and Augmented Reality.* Vol.1, 306-310.

Kei Studios. 2019. VR headsets are falling in price. Blog. Available at: https://kei-studios.com/vr-headsets-are-dropping-in-price-is-this-good-or-bad-news-for-virtual-reality/ [Accessed 19 March 2020].

Kerr, C. 2019. A brief history of 3D texturing in video games. Blog. Updated 1 May 2019. Available at: https://www.gamasutra.com/view/news/341847/A_brief_history_of_3D_texturing_in_video_games.php [Accessed 2 April 2020].

Khalifa, A. 2019. ELIMINATION from design to analysis. Blog. Updated 16 May 2019. Available at: https://www.gamasutra.com/blogs/AhmedKhalifa/20190516/342719/ELIMINATION_from_Design_to_Analysis.php [Accessed 5 April 2020].

Lang, T. 2008. 5 ways game designers communicate. Blog. Updated 28 October 2008. Available at: https://www.gamecareerguide.com/features/634/5_ways_game_designers_.php [Accessed 29 March 2020].

Lewis, C. 2018. The negative side effects of virtual reality. Blog. Updated 7 March 2018. Available at: http://resourcemagonline.com/2018/03/the-negative-side-effects-of-virtual-reality/87052/ [Accessed 19 March 2020].

Luks, R. 2017. Examining motion sickness in virtual reality. PDF document. Available at: https://is.muni.cz/th/qam5p/ms-vr-digital.pdf [Accessed 21 March 2020].

Luo, A. 2019. What is content analysis and how can you use it in your research? Blog. Updated 31 October 2019. Available at: https://www.scribbr.com/methodology/content-analysis/ [Accessed 24 March 2020].

Maio, A. 2020. What is VFX? Defining the term and creating impossible worlds. Blog. Updated 8 March 2020. Available: https://www.studiobinder.com/blog/what-is-vfx/ [Accessed 3 April 2020].

Manker, J. 2012. Designscape – a suggested game design prototyping process tool. Blog. Available at: https://www.eludamos.org/index.php/eludamos/article/view/vol6no1-8/6-1-8-html [Accessed 26 March 2020].

Mansfield, M. 2020. What is Canva and how do I use it for my business? Blog. Updated 20 February 2020. Available at: https://smallbiztrends.com/2015/09/what-is-canva-for-business.html [Accessed 28 March 2020].

Mason, B. 2017. Virtual reality has a motion sickness problem. PDF document. Updated 7 March 2017. Available at: https://www.sciencenews.org/article/virtual-reality-has-motion-sickness-problem [Accessed 20 March 2020].

Maudet, N. 2017. Designing design tools. Blog. Updated 11 December 2017. Available at: https://designing-design-tools.nolwennmaudet.com/ [Accessed 26 March 2020].

Merhi, O., Faugloire, E., Flanagan, M. & Stoffregen, T. A. 2007. Motion sickness, console video games and head mounted displays. *Human Factors and Ergonomics Society.* Vol.49, 920-934.

Microsoft. 2019. C# guide. WWW document. Available at: https://docs.microsoft.com/en-us/dotnet/csharp/ [Accessed 19 January 2020].

Mirabello, J. 2014. How long does it take to make an indie game? Blog. Updated 4 July 2014. Available at: https://www.gamasutra.com/blogs/JosephMirabello/20140407/214931/How_Long_Does_It_Take_to_Make_an_Indie_Game.php [Accessed 2 February 2020].

Monteiro, D., Liang, H., Xu, W., Brucker, M., Nanjappan, V. & Yue, Y. 2018 Evaluating enjoyment, presence and emulator sickness in VR games based on first- and third-person viewing perspectives. *Computer Animation & Virtual Worlds.* Vol. 29, 3-4.

MotionTwin. No date. Playtesting your indie game: dos and don’ts. Blog. Available at: https://motion-twin.com/en/post/5082/playtesting-your-indie-game-dos-and-don-ts [Accessed 5 April 2020].

Munafo, J., Diedrick, M. & Stoffregen, T. A. 2017. The virtual reality head mounted display oculus rift induces motion sickness and is sexist in its effects. *Experimental Brain Research.* 235, 889-901.

Neil, K. 2016. Game design tools: can they improve game design practice? PDF document. Updated 12 July 2016. Available at: https://tel.archives-ouvertes.fr/tel-01344638/document [Accessed 26 March 2020].

New York Film Academy. 2017. What beginners should know about ethics in game design. Blog. Updated 2 November 2017. Available at: https://www.nyfa.edu/student-resources/what-beginners-should-know-about-ethics-in-game-design [Accessed 28 January 2020].

Ordonez, F. G. O. 2017. VFX for games explained. Blog. Updated 11 May 2017. Available at: https://80.lv/articles/vfx-for-games-explained/ [Accessed 3 April 2020].

Palmisano, S., Mursic, R. & Kim, J. 2017. Vection and cybersickness generated by head and display motion in the oculus rift. *Displays.* Vol. 46, 1-8.

Pan, J. 2015. 8 reasons why you should use infographics. Blog. Updated 1 October 2015. Available at: https://www.cyberclick.es/numericalblogen/8-reasons-why-you-should-use-infographics [Accessed 27 March 2020].

Patton, A. 2015. Three phases of game design. Blog. Updated 13 January 2015. Available at: http://thegamehaschanged.net/three-phases-of-game-design/ [Accessed 6 February 2020].

Patton, S. 2017. The definitive guide to playtest questions. Blog. Updated 27 April 2017. Available at: https://www.schellgames.com/blog/the-definitive-guide-to-playtest-questions [Accessed 5 April 2020].

Paz, I. L. & Fernandes, F. 2018. A literature review for game design frameworks towards educational purposes. PDF document. Available at: http://gamilearning.ulusofona.pt/wp-content/uploads/full_P2L_Proceedings-321-332.pdf [Accessed 26 March 2020].

Pluralsight. 2014. Tips for creating better games and working more efficiently in Unity. Blog. Updated 30 March 2014. Available at: https://www.pluralsight.com/blog/film-games/tips-for-creating-better-games-and-working-more-efficiently-in-unity [Accessed 4 April 2020].

Rockholz, W. 2014. 10 insightful playtest questions. Blog. Updated 18 April 2014. Available at: https://www.gamasutra.com/blogs/WesleyRockholz/20140418/215819/10_Insightful_Playtest_Questions.php [Accessed 5 April 2020].

Ruswick, T. 2017. Game design document: one page + super easy. Video clip. Updated 23 July 2017. Available at: https://www.youtube.com/watch?v=q96lz725gIw [Accessed 29 March 2020].

Ryan, T. 1999a. Beginning level design, part 1. Blog. Updated 16 April 1999. Available at: https://www.gamasutra.com/view/feature/131736/beginning_level_design_part_1.php [Accessed 25 January 2020].

Ryan, T. 1999b. Beginning level design, part 2: rules to design by and parting words. Blog. Updated 23 April 1999. Available at: https://www.gamasutra.com/view/feature/131739/beginning_level_design_part_2_.php [Accessed 25 January 2020].

Sakar, S. Why frame rate and resolution matter: a graphics primer. Blog. Updated 5 June 2014. Available at: https://www.polygon.com/2014/6/5/5761780/frame-rate-resolution-graphics-primer-ps4-xbox-one [Accessed 23 March 2020].

Schmierbach, M. 2009. Content analysis of video games: challenges and potential solutions. *Communication Methods and Measures.* Vol.3, 147-172.

Serge, S. & Moss, J. 2015. Simulator sickness and the oculus rift: a first look. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* 59, 761-765.

ShaderCat. 2016. What is a shader? WWW document. Updated 21 March 2016. Available at: https://www.shadercat.com/what-is-a-shader/ [Accessed 3 April 2020].

Sicart, M. 2008. Defining game mechanics. WWW document. Updated December 2008. Available at: http://gamestudies.org/0802/articles/sicart [Accessed 31 March 2020].

Slashcev, A. 2019. Stop teaching the player. Let him teach the game. Blog. Updated 29 April 2019. Available at: https://www.gamasutra.com/blogs/AntonSlashcev/20190429/341591/Stop_teaching_the_player_Let_him_teach_the_game.php [Accessed 27 January 2020].

Stanny, K.M., Kennedy, R. S. & Drexler J, M. 1997. Cybersickness is not simulator sickness. *Human Factors and Ergonomics Society.* Vol.41, 1138-1143.

St. John, V. 2013. Best practices: five tips for better playtesting. Blog. Updated 23 January 2013. Available at: https://www.gamasutra.com/view/feature/185258/best_practices_five_tips_for_.php [Accessed 5 April 2020].

Statt, N. 2016. How game designers find ways around VR motion sickness. Blog. Updated 13 October 2016. Available at: https://www.theverge.com/2016/10/13/13261342/virtual-reality-oculus-rift-touch-lone-echo-robo-recall [Accessed 23 March 2020].

Stonehouse, A. 2014. User interface design in video games. Blog. Updated 27 February 2014. Available at: http://www.gamasutra.com/blogs/AnthonyStonehouse/20140227/211823/User_interface_design_in_video_games.php [Accessed 29 January 2020].

Sukamolson, S. 2007. Fundamentals of quantitative research. WWW document. Available at: https://s3.amazonaws.com/academia.edu.documents/48405070/Suphat_Sukamolson.pdf [Accessed 21 March 2020].

Takahashi, D. 2004. Ethics of game design. Blog. Updated 27 December 2004. Available at: https://www.gamasutra.com/view/feature/2181/ethics_of_game_design.php [Accessed 4 February 2020].

Takov, V. & Prasanna, T. 2019. Motion sickness. WWW document. Updated 24 November 2019. Available at: https://www.ncbi.nlm.nih.gov/books/NBK539706/ [Accessed 22 March 2020].

Tan, C. T., Leong, T. W., Shen, S., Dubravs, C. & Si, C. 2015. Exploring gameplay experiences on the oculus rift. *CHI PLAY* 15, 252-263.

Trammell, K. 2016. Big idea: “Baking”. Blog. Updated 3 May 2016. Available at: https://cgcookie.com/articles/big-idea-baking [Accessed 4 April 2020].

Unity. 2020a. This is why creators choose Unity. WWW document. Available at: https://unity.com/our-company [Accessed 1 April 2020].

Unity. 2020b. What is the Unity Asset Store and how do I purchase assets? WWW document. Available at: https://support.unity3d.com/hc/en-us/articles/210142503-What-is-the-Unity-Asset-Store-and-how-do-I-purchase-Assets- [Accessed 2 April 2020].

Valem. 2020. How to design for motion sickness. Video clip. Updated 13 January 2020. Available at: https://www.youtube.com/watch?v=DR8QVy2LIj4 [Accessed 23 March 2020].

Virtual Reality Oasis. 2019. How to prevent motion sickness in virtual reality. Video clip. Updated 2 January 2019. Available at: https://www.youtube.com/watch?v=NcSdPbL-cIY [Accessed 23 March 2020].

Webber, A. M. 2018. How to make a game: playtesting advice from game designers. Blog. Updated 11 April 2018. Available at: https://geekandsundry.com/how-to-make-a-game-playtesting-advice-from-game-designers/ [Accessed 5 April 2020].

XAMK. 2020. XAMK’s guidelines concerning coronavirus. WWW document. Updated 1 April 2020. Available at: https://www.xamk.fi/en/bulletins/information-on-coronavirus-and-travelling/ [Accessed 4 April 2020].

Yu, M., Zhou, R., Wang, H. & Zhao, W. 2019. An evaluation for VR glasses system user experience: The influence factors of interactive operation and motion sickness. *Applied Ergonomics* 74, 206-213.

LISTS OF FIGURES

Figure 13. Completed one-page game design document. Barclay, G. 2020. One-page design document. Ruswick, T. 2017. Original document available at: https://docs.google.com/document/d/1npEvqcMZSp0IX2hWw6Qq0WqJVfmVqS_YOGFWnnwfh-A/edit [Accessed 29 March 2020].

Figure 14. Story flow diagram. Barclay, G. 2020.

Figure 15. GRIS screenshot. Nomada Studio. 2018. GRIS. WWW document. Available at: https://devolverdigital.com/games/gris [Accessed 30 March 2020].

Figure 16. Shadow of the Colossus screenshot. Team Ico. 2005. These Shadow of the Colossus screenshots will take your breath away. WWW document. Available at: https://twinfinite.net/gallery/shadow-of-the-colossus-screenshots/ [Accessed 30 March 2020].

Figure 17. Journey screenshot. Thatgamecompany 2012. Journey. WWW document. Available at: https://thatgamecompany.com/journey/ [Accessed 30 March 2020].

Figure 18. The Long Dark screenshot. Hinterland Games. 2017. The Long Dark. Available at: https://www.thelongdark.com/ [Accessed 30 March 2020].

Figure 19. Firewatch screenshot. Camp Santo. 2016. Firewatch. Available at: http://www.firewatchgame.com/ [Accessed 30 March 2020].

Figure 20. Gone Home screenshot. The Fullbright Company. 2016. Gone Home. Available at: https://gonehome.game/ [Accessed 30 March 2020].

Figure 21. Shades of blue colour palette. Adobe Color. 2020a. Adobe color wheel. Available at: https://color.adobe.com/create [Accessed 31 March 2020].

Figure 22. Blue analogous colour palette. Adobe Color. 2020b. Adobe color wheel. Available at: https://color.adobe.com/create [Accessed 31 March 2020].

Figure 23. Initial level design layout. Barclay, G. 2020.

Figure 24. User-interface flow diagram. Barclay, G. 2020.

Figure 25. Specifications of the development computer. Barclay, G. 2020.

Figure 26. XR settings in Unity. Barclay, G. 2020.

Appendix 1/1

Rough Consolidation of Information Table

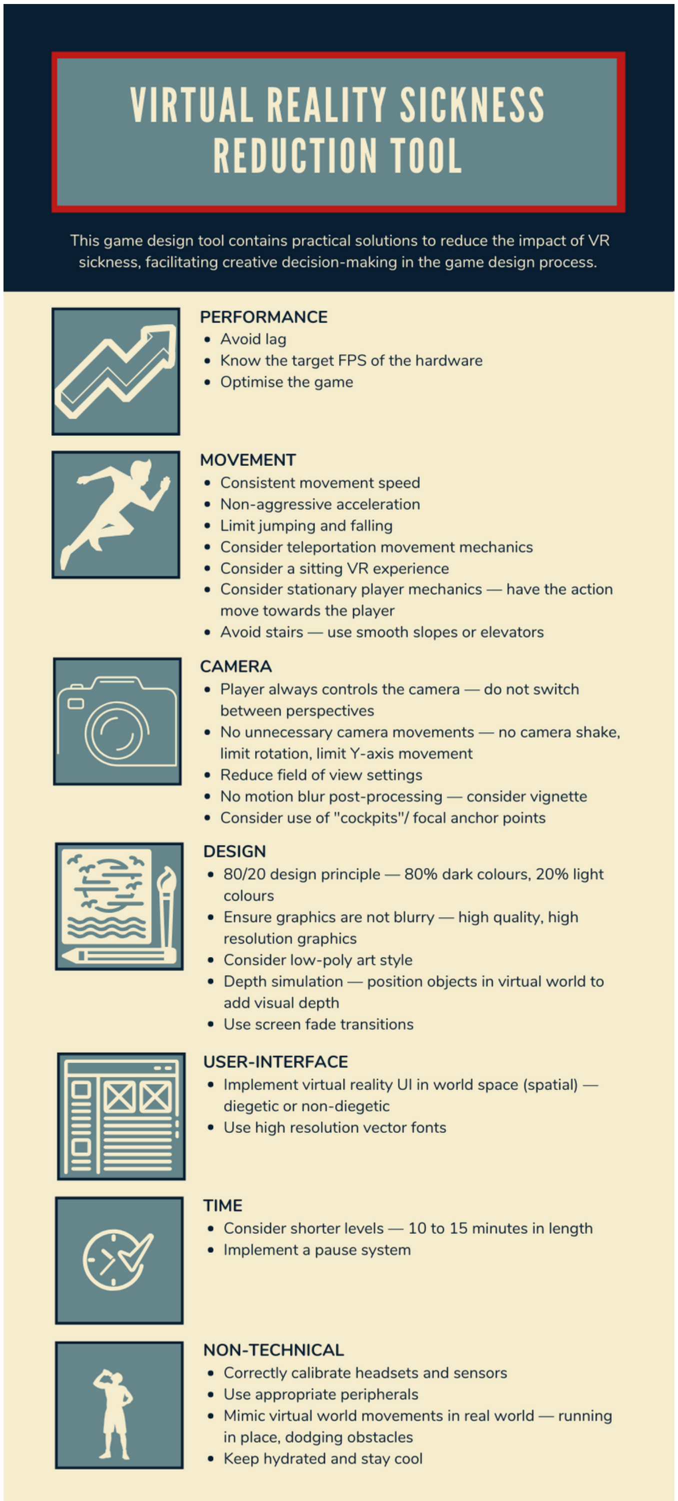
PROBLEM GROUP	VR SICKNESS SOLUTION
Camera	Player always controls the camera — do not switch between perspectives No unnecessary camera movements — no camera shake, limit rotation, limit Y-axis movement Lower field of view No motion blur post-processing — consider vignette Consider use of “cockpits”/ focal points
Movement	Consistent movement speed Non-aggressive acceleration No stairs — use smooth slopes or elevators Limit jumping and falling Consider teleportation movement mechanics

	Consider stationary player mechanics — have the action move towards the player Consider a sitting VR experience
Design	80/20 design principle — 80% dark colours, 20% light colours, consider dimmer and cooler colours Ensure graphics are not blurry — high quality, high resolution Consider low-poly style graphics Depth simulation — position objects in virtual world to add visual depth Consider screen fade transitions
User-Interface	Implement virtual reality UI in world space (spatial) — can be diegetic or non-diegetic Use high resolution, vector fonts
Performance	Know the target frames per second (FPS) of the hardware Avoid lag

	Optimise the game
Time	Consider short levels — 10 to 15 minutes in length Allow for frequent breaks Implement a pause system
Non-Technical	Correctly calibrate headsets and sensors Keep hydrated Stay cool Do not play VR games when ill Use appropriate peripherals Mimic virtual world movements in real world — running in place, dodging obstacles

Appendix 2

Virtual Reality Sickness Reduction Tool



Appendix 3/1

Game Design Thesis Playtest Questionnaire

Game Design Thesis Playtesting

Virtual Reality

What is your gaming background?

Long-answer text

Do you generally experience any kind of motion sickness?

Long-answer text

Have you played virtual reality games before?

Long-answer text

If yes, did you experince any kind of VR sickness? Symptoms include nausea, vomiting, headaches, sweating, drowsiness and disorientation

Long-answer text

In this playtest, did you experince any kind of VR sickness?

Long-answer text

If yes, can you describe the symptoms?

Long-answer text

If yes, what aspects of the game do you think caused the VR sickness?

Long-answer text

What could have been done differently to prevent the VR sickness?

Long-answer text

On a scale of 1 – 5, with 1 being low and 5 being high, what was your enjoyment level in the virtual reality experience?

	1	2	3	4	5	
Low	○	○	○	○	○	High

What can be done to make the virtual reality experience better

Long-answer text

Were there any issues with the game that you found?

Long-answer text

In your opinion, what was the game about? What was the story?

Long-answer text