Creating a Realistic VR Military Simulation

A Study of Immersion and Presence

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Abstract

In recent years, a lot of money has been invested in virtual reality and its military applications, both for research and to produce various VR-based products. The military is one of the largest investors, as they are constantly on the search for fresh ideas and breakthroughs. Virtual reality simulator training has the broadest military use, which is critical since "on-the-job" training for a genuine combat is difficult to show. The ultimate goal of this project was to create a fully functional military VR simulation that could provide the most realistic and immersive experience possible for the user. The application was assessed on usability, given a System Usability Scale (SUS) score of 86.1, with user's comments giving qualitative proof of which aspects of the system, such as weapon weight and sound design, contributed to their sense of immersion and presence. The experiment effectively proved that users were completely engrossed in the programme and were exposed to an authentic environment that elicited genuine emotions.

A short video clip of the final artefact demonstration is available on YouTube (Robinson, 2022c) containing footage of handling, reloading, firing both the L85A2 and Glock-17 at the target that has been moved back using the switch, and demonstrating the weight and sound de-sign of the weapons.

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1 Introduction

There have been many VR shooters in the last two and a half years. There has been something for everyone, from zombie-slaying horrors (Arizona Sunshine - Vertigo Games, 2022) to sci-fi adventures through the galaxy (Space Pirate Trainer, 2019), to serious military simulations like Onward VR (Downpour Interactive, 2022) and hunting dinosaurs on a deserted island (Island 359, 2018).

However, these games have been developed with the intention of providing a fun experience for users with no drawbacks. There's a sense of immersion and presence in the worlds created by the developers, but this comes with a sacrifice of "true" realism. All of the drawbacks that come with firing a weapon are not present in any of them, in order to make the experience fun for the user. For example, there is no ringing in ears after firing as this wouldn't be fun in during gameplay. The guns never jam, it may be a rare occurrence but adding such a feature would add to the realism. Then adding a mechanic where the user can disassemble the gun and clean it would reduce the chances of this happening. Finally, the guns themselves have no feeling of weight to them.

Thus, the use and level of immersion in VR has always been a major factor when developing experiences. When users first encounter immersive VR, they have a significant reaction. The sensation of seeing stereoscopic visuals jump out of the screen, picking up a virtual object with their actual hand, and discovering that head motions affect their vision of the virtual world are all distinct.

Bowman and McMahan (2007) described immersive VR as a special and unique experience. Despite this, practitioners are using relatively few examples of immersive VR systems in the real world. What measurable benefits can immersion provide? High-end VR technologies, such as head-mounted displays, multiscreen stereoscopic projection displays, 3D tracking systems, and advanced input devices are still quite expensive.

There have been many iterations of military simulations in the past. However, most of the current virtual weapons training systems used in the UK consist of what's known as "Meggitt Training Systems" (Samantha, 2015).

This involves firing a dummy weapon at a screen, like how old-arcade shooters worked. It could be argued that compared to a VR experience, the immersion of firing at a blank screen (even with haptic feedback) is extremely low. Thus, the development of a simulation that can run on relatively cheap and portable equipment such as the Oculus Quest would be far more beneficial and cost-effective.

A computer creates sensory impressions that are given to the human senses in a virtual environment system. The amount of immersion and sense of presence in VR is determined by the type and quality of these perceptions. "Ideally the high-resolution, high-quality and consistency over all the displays, information should be presented to all of the user's senses" (Slater et al., 1994). Furthermore, the environment should react genuinely to the activities of the user. However, reality differs significantly from this ideal scenario. Many apps only excite one or a few senses, and they frequently provide low-quality, unsynchronized data.

The following chapters in this document will detail the research into immersive VR, what features increased immersion in users while also ensuring the user doesn't experience too much VR sickness. As well as the documentation of the design, development, testing, evaluation, and review of the artefact.

2 Background and Literature Review

2.1 Background of Virtual Reality

Virtual reality (VR) is a virtual experience that can be both comparable and dissimilar to the actual world. Entertainment (especially video games), education (such as medical or military training), and business are all examples of virtual reality applications (such as virtual meetings). Augmented reality and mixed reality, sometimes known as extended reality or XR, are two further sorts of VR-style technologies. Currently, conventional virtual reality systems provide realistic visuals, sounds, and other sensations that imitate a user's physical presence in a virtual environment using virtual reality headsets or multi-projected environments.

Virtual reality allows users to look about, move around, and interact with virtual elements and objects, providing experiences that wouldn’t be possible in our reality. Virtual reality headsets with a small screen in front of the eyes are usually used to get this effect, but it may also be achieved in specially constructed rooms with several huge screens. Virtual reality usually includes audio and video feedback, but haptic technology may also provide additional sensory and physical feedback.

In 1962 Heilig built a prototype for Sensorama, a multisensory simulator which was a "pre-recorded film in colour and stereo" along with "binaural sound, scent, wind and vibration experiences" (Tomasz Mazuryk and Gervautz, 1999). Heilig's could be considered one of the forefathers of VR innovation, as his simulation had "all of the features of such an environment, but it was not interactive" (Tomasz Mazuryk and Gervautz, 1999). Interactivity in modern VR is assumed to be a necessity in order to produce a sense of immersion in the user, improving the overall experience.

Ivan Sutherland's The Swords of Damocles eight years later brought the first head-mounted display (HMD) to life. The "stereo view that was refreshed accurately according to the user's head position and orientation"(Tomasz Mazuryk and Gervautz, 1999) was supported by this HMD. Two miniature LCDs are placed in front of the user's eyes by HMDs, and these pictures are presented to the user based on their current location and orientation determined by a tracker. HMDs are most commonly found in today's VR headsets, such as the Oculus Quest and HTC Vive. Mazuryk and Gervautz go on to say that HMDs may be classified into two categories: opaque and see-through. Opaque HMDs are used in a variety of applications to replace the user's perspective with visuals of the virtual environment. HMDs with see-through lenses, on the other hand, "superimpose computer-generated pictures on actual things." Augmented Reality (AR) or Mixed Reality (MR) are terms used to describe this type of technology. The study of several HMDs looked at various technologies that may be utilised in this endeavour. Instead of augmenting the real world, an opaque HMD will transfer the user into the development of a virtual world, allowing for a more immersive experience within a safe atmosphere, since an enhanced city scene may become dangerous and would not produce an authentic setting.

2.2 Virtual Reality and Immersion/Presence

The use and level of immersion in VR has always been a major factor when developing experiences. When users first encounter immersive VR, they have a significant reaction. The sensation of seeing stereoscopic visuals jump out of the screen, picking up a virtual object with their actual hand, and discovering that head motions affect their vision of the virtual world are all distinct.

Bowman and McMahan (2007) investigated the importance and usage of immersion in “Virtual Reality: How Much Immersion Is Enough?”. In which, “What measurable benefits can immersion provide?” is discussed as well as it would being difficult to justify the price and development complexity that immersive VR necessitates if all these technologies deliver for the user is stunning graphics and a unique user experience.

Studies conducted by (Bowman and McMahan, 2007) revealed the “positive effects of immersion on spatial understanding” as well as “higher levels of immersion, particularly stereoscopy, can contribute to improved interaction task performance”.

In this study, several factors led to a better level of immersion, with display size and resolution having a substantial impact on task completion time, with the greatest results coming from a big, high-resolution display. The bigger screens with broader field-of-visions (FOVs) made it easier to navigate and find their way around the environment, preventing users from becoming disoriented, while the high-resolution displays allowed users to see text annotations from a wider distance, reducing search time.

The combination of a broad field of view and higher resolution results in a Virtual Experience that is less congested and easier to understand.

Training in a virtual environment is a suitable compromise between traditional classroom-based training and real-world training activities because it offers a better level of realism, greater flexibility, and lower expense than real-world exercises. The success of virtual reality military training has recently prompted the use of virtual reality technology for other sorts of training, particularly in the medical industry.

The paper "Virtual Reality medical training system for anatomy education" by Falah et al., (2014) describe techniques used in order to increase immersion. Dissection of various cardiac structures to disclose underlying geometry was the key feature; numerous layers of geometry were built. The 3D models were created with interactivity in mind, including the ability to alter and detach portions of the geometry. The polygon-based modelling approach allows for the creation of distinct and distinct structures.

A similar system was planned to be implemented into this project, allowing the users to disassemble, clean and reassemble guns. Providing a deeper learning experience that can be easily accessed without the need for an actual physical weapon, there could be a very good case for a program like this for the cadet units that do not have the access or facilities to store weapons. So, to have a system people can train on and give feedback would be very beneficial.

Papers such as "Virtual reality and its military utility" (Lele, 2011) discuss how significant expenditures have been made in this field, both for research and for producing various VR-based products. With the military being one of the most significant investors, as they are always on the lookout for new ideas and innovations. VR simulator training being the area with the widest applicability in the military, which is important as "on the job" training for a real gunfight is extremely hard to demonstrate.

A report published in by the North Atlantic Treaty Organisation titled "Virtual Reality: State of Military Research and Applications in Member Countries" (NATO, 2003) discuss what the requirements are for Virtual Reality systems to meet military human performance objectives.

The main conclusions of the report stating that:

> "The key to the effectiveness of virtual reality for military purpose is the man-machine interface or human-computer interaction. Military personnel must be able to perform their tasks and missions using virtual reality sensory display devices and response devices. These devices must display an environment that provides the appropriate cues and responses needed to learn and perform military tasks. Human factors issues include: determining the perceptual capabilities and limitations of sensory display devices; designing terrain data bases and other displays to meet task performance needs; understanding the human and task performance compromises required by current technologies; evaluating transfer of training and knowledge from the virtual to the real world; and considering the causes and solutions to simulator sickness that can occur in virtual reality." (NATO, 2003)

Despite the report being from 19 years ago, a lot of the concepts are still relevant to this project to create a VR Military Simulation. It needs to be able to provide an immersive learning experience using interactions with objects in a virtual environment.

Virtual reality technology has advanced significantly in recent years, with applications in product design, education and training, military aircraft, entertainment, and leisure. Virtual reality has become increasingly important in the military as science and technology have progressed. The paper "Virtual Reality and Its Application in Military" (Liu et al., 2018) examines the present state of virtual reality hardware and software, as well as its military uses, before attempting to assess potential future military applications. It could be argued that the type of VR headset affects the user's immersion, with each model providing a different resolution per eye, refresh rate and field of view.

Table 1. (UL Benchmarks, 2022) comparing specifications of different VR headsets

Manufacturer - Model	Resolution per Eye	Refresh rate (Hz)	Field of view (degrees)

HTC Vive	1080 × 1200	90	110
HTC Vive Pro	1440 × 1600	90	110
Oculus Quest	1440 × 1600	72	95
Oculus Quest 2	1832 × 1920	72	90
Oculus Rift	1080 × 1200	90	110
Oculus Rift S	1280 × 1440	80	110
Valve Index	1440 × 1600	144	130
Windows Mixed Reality	1440 × 1440	90	95

The table above from UL Benchmarks shows the varying specifications for different VR headsets. A study was conducted by (Ragan et al., 2015) on "the effects of the training system's field of view (FOV) and visual realism for visual scanning tasks". The results of the study showed that while the size of the FOV during training appears to have little influence on strategy learning or training transfer, it can have a substantial effect on task performance. Because a broader FOV allowed users to see ahead, anticipate impending sections of the environment, and plan the visual scanning pattern, the FOV had an impact on detection performance during training.

Thus, having a broader FOV would increase the user's immersion and sense of presence due to the increased realism of the simulation. Unfortunately, this is not an easy variable to control as it depends on which headset the user owns, the headsets with higher resolution, refresh rate and FOV coming at a greater cost.

2.3 Conclusion

The goal of the literature study was to gain a basic grasp of how technology has evolved throughout history. The basic functions of virtual reality have been defined, and this project will focus on using immersive gun engagement to teach soldiers. Research examines the ways used to promote user immersion; both software and hardware aspects can influence this; some can be adjusted, while others cannot.

3 Methodology

3.1 Project Management

Project management is described as the "application of processes, methods, skills, knowledge, and experience to achieve specific project objectives according to the project acceptance criteria within agreed parameters" (APM, 2012).

3.1.1 Aims and Objectives

Project management was employed to ensure that clear objectives were set. Within the project proposal, a single specific goal was identified for this research:

"The overall aim of this project is to develop a fully functioning military VR simulation, capable of providing the user with the most realistic and immersive experience possible."

In order for this target to be achieved, the goal was split up into 5 realistic and manageable sub-goals,

1. To "Create an immersive virtual environment for the simulation to be experienced in". In order to achieve this, various assets, tools, and software will be used to produce a realistic-looking gun range environment.
2. To "Add realistic gun interactivity to the simulation". The steps to achieve this include, adding recoil to the guns, giving the guns a feeling of weight, full re-loading, and gun disassembly/cleaning.
3. To "Enhance the simulation with high quality sound design". Finding non-copyrighted sound effects will be essential in order to achieve maximum immersion. Also adding the sounds of ear ringing after firing the gun.
4. To "Include a variety of guns for the user to experiment with". Many VR shooters include various guns, however, due to time constraints, adding too many guns may lead to project failure. So, the aim is to have 1-2 guns with full functionality, then plan to add more if possible.
5. To "Research the importance of immersion". This will play an important part in ensuring the simulation provides the best experience possible.

3.1.2 Methodologies

There are many methodologies that exist in the project management landscape, it could be argued that the two main sides consisting of traditional types like Waterfall, and agile types going on to "spark several specific sub-frameworks and methodologies, such as scrum, kanban, and lean." (Teamwork, 2021)

Choosing the right methodology for a project may drastically affect the system's success; without a management system in place, the project may lose focus and become misdirected. The ideal methodology choice for the project management side of things would be Waterfall, as it ensures that the separate sections are completed one after the other, ensuring that no details are missed when producing the artefact. The aim of the traditional project management strategy is to maximise efficiency and effectiveness in executing the initial comprehensive project plan, or, to put it another way, to complete the project on time, on budget, and within scope (Špundak, 2014).

Table 2. Differences between traditional and agile approach (Špundak, 2014).

Characteristic	Waterfall methodology	Agile methodology
Requirements	clear initial requirements; low change rate	creative, innovative; requirements unclear
Users	not involved	close and frequent collaboration
Documentation	formal documentation required	tacit knowledge

Project size	bigger projects	smaller projects
Organisational support	use existing processes; bigger organisations	prepared to embrace agile approach
Team members	not accentuated; fluctuation expected; distributed team	collocated team; smaller team
System criticality	system failure consequences serious	less critical systems
Project plan	linear	complex; iterative

Another reason to choose Waterfall instead of Agile is because this artefact is an addition to existing legacy products with well-defined features that must interact with known or existing products. When the project is bound by cost and/or time, and the requirements and scope are clearly known, the Waterfall methodology wins out. In these situations, the Waterfall technique provides a set of methods based on the notion of prior phase approval. For example, the final testing of the artefact cannot be conducted until a substantial portion of the development has been completed.

3.1.3 Gantt Chart

The time frame for the simulation development is as follows:

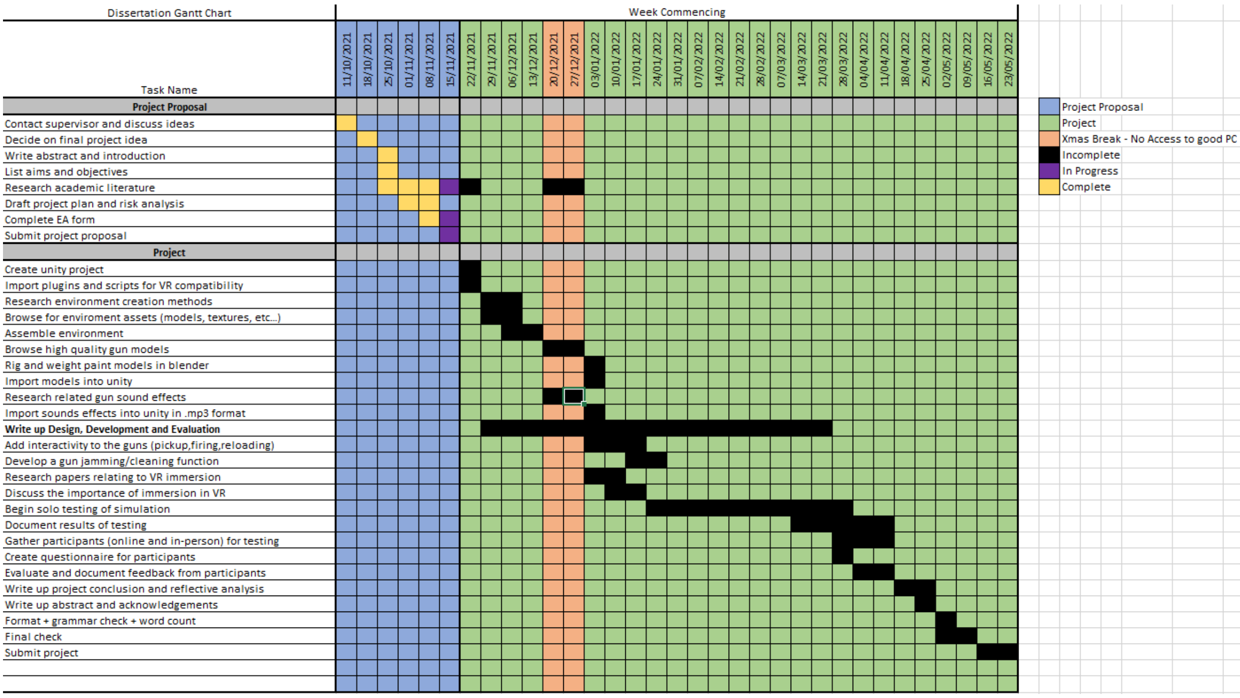

Fig. 1. A Gantt chart showing the predicted time allocation for the project.

The Gantt chart was used to represent a period of events in the initial project proposal document. This method of time management is a remarkable approach to manage the use of time within the project, as well as the efficient use of Project Management (PM). By rigorously planning and coordinating time for this project, an estimate of when different components of the project would be done and how long it would take was already in place. By controlling time in this manner, each part of the project was given its own portion with sufficient time to complete it. The Gantt chart was followed rather carefully in this project, and each phase of the project was finished within the timeframe.

The Waterfall model assumes that “once the initial requirements are set and every goal has been cleared of any ambiguities, there is an unobstructed road which the development team will follow towards finishing the project.” (Andrei, 2019). The most obvious issue in the Waterfall methodology is that customers' opinions on particular features might change, requiring some, if not all, stages to be re-evaluated. This results in increased expenses and time spent on various aspects of the project, thereby lowering customer satisfaction. This isn't to say that this method should never be used. This artefact has no clear consumers at this point in time and level of development as an actual product. On the other hand, further development of this artefact may lead to it being a commercially viable product.

3.2 Software Development

To begin researching into the methods that would be used to create this artefact, two interviews were conducted, asking two members of the RAF. The topics mainly surrounding the current weapons training methods used to instruct new recruits, as well as “everyone having to do an annual refresher, and before they deploy into the field” (Lyman, 2022)

3.2.1 Interview 1

The first interview questioned “an RAF Air Traffic Controller, currently working on a new program to introduce new ATC equipment throughout defence” (Lyman, 2022).

There are members of the Royal Air Force, Royal Navy and British Army stationed all over the UK. However, not all of them are in combat roles, this interviewee being an example working in air traffic control. “No matter the branch, everyone has to do an annual refresher and before they deploy” (Lyman, 2022). Due to this, the quality of training they receive on that annual occasion must be of the highest quality, especially if they’re about to deploy, as it could mean the difference between life and death in a real combat situation. Therefore, the VR training solution should offer the best training solution possible using current hardware and software available, providing a realistic and responsive experience to the user.

Fig. 2. Trainees firing at the DCCT from a sitting position (Royal Navy, 2020)

These training sessions are usually conducted over the whole day, consisting of different drills, loading, unloading, weapon handling, and live firing. There are many different situations simulated using the DCCT and live fire, including: “ranges of 25m and 100-200m; standing, prone, kneeling and sitting positions; firing off shots then taking a grouping size to see accuracy/score.” (Lyman, 2022). The guns used in the training sessions are the UK military standard SA80-A2 rifle, which will be used in the simulation along with the Glock-17 pistol.

3.2.2 Interview 2

The second interview questioned “an RAF Regiment SNCO working within the Force Protection Training Flight at RAF Marham as a training development Sergeant. Having the roles within this job to manage the Dismounted Close Combat Trainer (DCCT)” (Freeman, 2022). They have been a weapons instructor for 15 years.

They currently do not use VR for weapons training, but they do have some systems which enable them to use computers to aid in training. The main system is the DCCT, in which they conduct weapon training 3-4 times a week. However, an individual is required to conduct training every 6 months to stay current with the weapon system if “the RAF feels there is a risk of an individual going out of date if they are not going to use the weapon” (Freeman, 2022). If this is not deemed a risk, then the individual would normally conduct training annually. Thus, being able to train users annually/bi-annually virtually would provide a huge benefit and save on costs of setting up real training facilities and weapons/ammunition.

All the real weapon handling is done on live weapons, and all the drills are done in the classroom. Personnel can go through an online refresher, but it involves clicking on the portion of the weapon and then simulating what must be done. Personnel in the RAF are required to complete annual training on the DCCT to fire the weapon system. If personnel are deploying, they must shoot a moving target and a limited night vision target on the DCCT, then zero the weapon and fire their yearly personal weapon test live on the range. The distance and range would be determined by the deployment location. Features like this could be implemented into this VR artefact to improve on what already exists in the DCCT. For example, being able to change the distance of the target, as well as changing the lighting of the environment to simulate different situations for the user to train in.

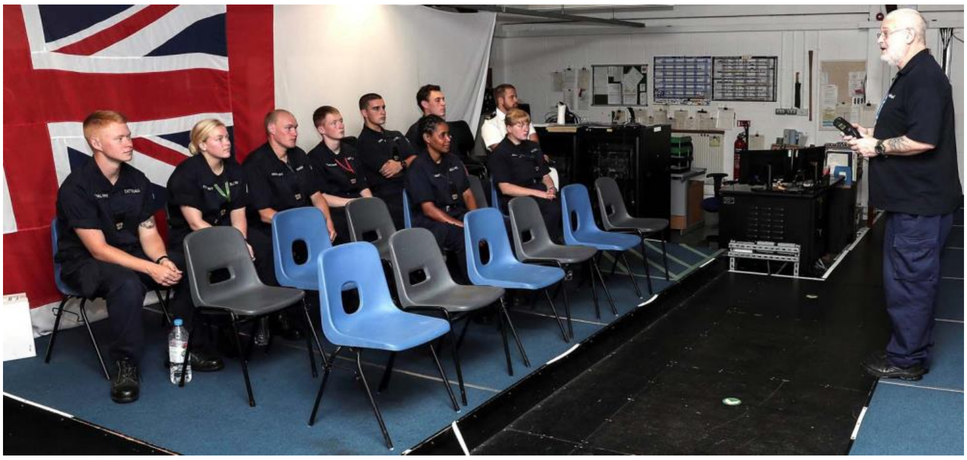

Fig. 3. Trainees being taught the system in a classroom (Royal Navy, 2020)

The DCCT has the benefit of being able to mimic night and moving targets across a live range. These shots must take place on specific ranges or in the evening, putting a significant strain on the training staff. They “may utilise the DCCT whenever they want because they own and operate it” (Freeman, 2022). Online training solutions that only show images of a weapon can assist individuals recall drills they're doing, but they can't aid with the actual handling of a weapon, which is crucial. Live ranges are the finest potential training option, but they come with maintenance costs as well as ammunition and other costs. The DCCT is far less expensive to operate than a live range, thus having a VR simulation would also be cheaper to run and maintain for training.

All weapon systems are included in the DCCT, including the Glock-17 pistol, the L85A2, the UGL, the Sharpshooter rifle, the GPMG, the Heavy Machine Gun, and the Grenade Machine Gun. This device may also be equipped with a variety of sights. This features a thermal sight, which will show the firer in thermal what is on the screen in front of them. Each 'fire team' has its own projector and screen in the system. The DCCT is divided into two 5-person "fire teams." In scenario mode, a single joystick is used to manoeuvre about the computer, with the firer remaining stationary on the firing point. The 'firing team' also features a commander with a joystick and a commander's sight, which allows the commander to have a full 360-degree view of the battlefield by moving the sight to where the firers must shift their positions on the ground. From the main computer desk, the person controlling the system may overrule and move the individuals about. We don't need to move the firers about in lane training, which is what we do every day, because they are static shoots. All the equipment is how it would be in real life. For example, the weight of the gun. This would be difficult to replicate in a virtual environment as you cannot modify the weight of the VR controllers without some form of third-party hardware.

“The graphics on the DCCT shoots we conduct are very basic and I believe that a PS3 has better graphics, but the DCCT also has the option to shoot at a video recording. This feature is then like being in a film and gives you feedback of if you have hit but the video never changes. So, you could shoot someone 3-4 times and they would continue to run across the screen.” (Freeman, 2022). Ensuring that the graphics are an improvement to the current system, as well as adding real-time feedback to the user to make them feel more immersed will be crucial in the development of the artefact. The DCCT also “has sensors on the weapons for understanding the pressure applied to the trigger and the angle of the weapon as well as feedback onto the screen so the user can see where the barrel is pointing in relation to their sights” (Freeman, 2022). It can be argued that implementing pressure sensor for when the user pulls the trigger and the angle of the gun are of utmost important when developing a VR shooter, as they some of the main functions of operating a gun in a virtual space.

Finally, the idea of adding a mode where a trainee can disassemble and reassemble the gun for training purposes would allow for more depth as the user would be able to “understand where their hands should be and what they should be doing at what point would be massively useful for all the drills to be conducted with the weapon as then this would save the instructor time when it came to conducting actual training on the weapon” (Freeman, 2022). All the weapon handling exams would then be able to be completed after a brief training session.

3.2.3 Methodologies

Again, Selecting the correct methodology for undertaking a project may make or break the system's success; without a management system in place, there will be no focus for the project, and it will likely become side-tracked. This project utilised the Agile Methodology; this style of Management offered the project structure so that the design, development, and testing could be completed efficiently and successfully. This section will examine why this methodology was chosen and how it compares to other approaches in order to determine whether the most efficient and successful approach was used.

The main features of any agile methods are “are simplicity and speed concentrating only on the functions needed at first hand, delivering them fast, collecting feedback and reacting to received information” (Abrahamsson et al., 2017). It is commonly used to increase project pace and flexibility by allowing adjustments during the process rather than taking a linear approach. Accepting modifications as they occur during the project's development enables for flexibility when requirements priorities vary, and new features are added. As a result, any improvements made allowed the project to avoid any delays and continue to progress. Elements of the user interaction with the firearms, for example, must be adjusted later in the design/development phase of the paper to facilitate a greater sense of presence. Such improvements/rehashing of the interaction wouldn’t be possible with a waterfall methodology, as the development would have already moved passed that element of the artefact.

Another methodology that could be used is the Waterfall methodology, it is a linear process that “emphasizes the sequential dependability on the previous deliverable” (Wilfred Van Casteren, 2017). A dependability which holds back system design”. As a result, Waterfall commits to features early, making it exceedingly difficult, if not impossible, to adapt to change. Before any progress can be achieved, careful planning and consideration of certain functions must be undertaken, resulting in a lengthier delivery time owing to the complicated preparation. Because of the systematic management approach, this would result in a well-organised project with a defined strategy from the outset, guaranteeing that the timeframe remains short. Even though Waterfall has a more precise plan management method than

Agile, the ability to adapt are a must for this type of project since features may be added and updated on a regular basis in order to achieve the study's goal.

The Spiral methodology is said to be a “structured model because it has well defined structure for developing software. It is also known as Meta model. It is best suited for complex and mission critical projects. Each trip around the spiral traverses four basic quadrants:

1. Plan the next iteration
2. Determine objectives, alternatives, and constraints of the iteration.
3. Develop and verify deliverables from the iteration.
4. Evaluate alternatives; Identify and resolve risks.” (Chandra, 2015)

This form of software development is separated into smaller/riskier portions, and requirements may be changed during development, among other benefits. However, setting up this approach is difficult, and the objectives must be well specified. Thus, due to researcher unfamiliarity and short time frame associated with this project, Spiral was not chosen to prevent time wasted having to set up and plan out each quadrant.

In conclusion, the Agile Methodology was thought to be the greatest fit for this project since it accepts any changes that may arise throughout development, allowing the research to avoid delays and continue progress. Furthermore, by breaking the goal down into manageable chunks, testing was carried out throughout each step, resulting in the rapid discovery and resolution of software defects. Waterfall and Spiral techniques were not appropriate for this project because they limit flexibility and create a development backlog.

3.3 Toolset and Machine Environment

3.3.1 Unity

As of the starting date of this project, the Unity version being used for the creation/development of this artefact is 2020.3.20f1 (Unity Technologies, 2022a).

Unity is a real-time, user-friendly programming platform/game engine that was chosen as the primary environment for this project. It is described as to able to “Achieve stunning, realistic graphics and lighting effects that let you push the boundaries of high-fidelity VR without sacrificing performance.” (Unity Technologies, 2022b). It is also necessary for the construction of the artefact to be able to see advancements in real-time, as assets can be placed instantly, allowing for quick development of scenes and weapons for this artefact. Assets may also be readily modified using Unity's transform interface, which allows for the efficient administration of any animations and action scripts related with the assets. Because each figure in the scenario has a separate animation model and code style, this was very helpful when altering them.

Unity also allows for seamless testing and deployment of scenarios from the Unity editor to the VR headset. With the ability to “target virtual reality devices directly from Unity, without any external plug-ins in projects. It provides a base API and feature set with compatibility for multiple devices. It provides forward compatibility for future devices and software” (Unity Technologies, 2018). However, Unity has some restrictions when creating realistic items/environments compared to Unreal Engine having “a slight edge over Unity in the quality of its visual effects. It can create photorealistic visualizations that immerse gamers and allow them to travel freely in a stunning new world and incorporate high-quality assets from a variety of sources” (Evercast, 2021).

Unreal Engine (Epic Games, 2019) and CryEngine (Crytek, 2022) are other possible game engines that could have been used for the development of this artefact. Unreal Engine is a free software that could be argued that it “has better characteristics for the different types of graphics and is better than other games actually” (Anurag, 2018). On the other hand, CryEngine is a paid software that also offers high quality graphics using “The engine's advanced rendering tool which is well optimised and produces great visuals” (Dealessandri, 2020). The community for Unity is also far greater than Unreal Engine and CryEngine, meaning for debugging it would have been easier to find solutions for any errors that may have occurred.

However, the photorealism of both alternate engines may cause the simulation to stutter, as for VR, the scene is rendered twice in both screens inside the headset. This may reduce the sense of presence for the user as what is being displayed inside the headset isn’t matching their own movements, which may also induce VR sickness. Also due to researcher familiarity and short time frame associated with this project, Unity was selected to prevent time wasted having to learn an entirely new game engine.

3.3.2 Blender

As of the starting date of this project, the Blender version being used for the creation/development of this artefact is 2.79b. (Community B.O, 2018)

Blender is a free all-in-one application. It can 3D model, rig, animate, UV-map, texture, light, and render, among other things. It's open-source software that's been tested by the community and can handle a whole CG workflow. There is also a huge online community surrounding Blender, with many forums and addons dedicated to supporting the creative process of creating/editing 3D models.

Also, some alternatives to Blender include “Autodesk 3DS Max” (Autodesk, 2021) and “Cinema 4D” (Maxon, 2019). However, despite both of these tools considered the industry standard, they are unsuitable for this project owing to their requirement of payment in order to access them. Paying a high price for these services is out of the budget for this artefact, therefore a free software is the preferred option as the budget can then be used for purchasing high quality guns and environments. These platforms could also be considered challenging for new users, taking a long time to get used to all of the available tools which are outside of the scope needed for this artefact.

For the simple task of editing gun models to be compatible Unity and interactive in VR, Blender is the software of choice. Also due to researcher familiarity and short time frame associated with this project Blender was selected to prevent time wasted having to learn an entirely new 3D modelling software.

3.3.3 Microsoft Visual Studio 2019

Visual Studio 2019 (Microsoft, 2018) was the Integrated Development Environment (IDE) used to develop the C# code which is integrated with the VR simulation. The ability to integrate with Unity, allowing for “a premium debugging experience to the Unity game engine. Identify issues quickly by debugging your Unity games in Visual Studio (VS) being able to set breakpoints and evaluate variables and complex expressions.” (Microsoft, 2020). It is also the default script editor installed when Unity is installed, the creation of a new project also “automatically creates and maintains a Visual Studio .sln and .csproj file” (Unity Technologies, 2021b).

Notepad++ was another option, it is a free "source code editor and Notepad replacement that supports several languages. Running in the MS Windows environment" (Ho, 2022). This basic coding programme is simple to use and does not require any further knowledge. However, it lacks the productivity capabilities of Visual Studio and does not enable code debugging, which means mistakes are not discovered until the code is compiled. On the other hand, Microsoft also offers Visual Studio Code, which is a simplified version of VS but does not allow code debugging that’s integrated with Unity.

Ultimately, Microsoft's Visual Studio 2019 was the ideal option for this project since it connects flawlessly with the Unity Engine and has a range of productivity tools that help with the artefact’s code development.

3.3.4 Oculus Rift CV1

The Oculus Rift CV1 was a headset released in 2016, it is described as providing “a virtual reality experience to users by plugging in to a powerful PC. The PC then runs virtual reality games and other experiences through a wire to the headset. The effect is a shockingly real sense of immersion, so-called ‘presence’ that makes you feel as though you're actually wherever you're looking at” (Gilbert, 2016). It is the improved versions of the previous DK1 and DK2 prototypes.

Fig. 4. Oculus Rift CV1 headset (Amos, 2021)

Some of the disadvantages of this headset are that it needs to be connected to a PC, through a HDMI cable, to display images onto the screens inside of the headset. This may reduce the user’s sense of immersion as they may have to deal with the wire hanging from the headset getting caught on their arms and/or legs.

Fig. 5. Oculus Quest 2 headset (Currys, 2022)

Another possible VR headset that could’ve been used is the Oculus Quest 2 which is described as an “all-in-one VR with just a headset and controllers, with 6DOF that tracks the head and body and translates them into VR with realistic precision. No external sensors required” (Meta, 2022). The two displays inside the Quest 2 are of a higher resolution than the CV1. However, the graphics processor is internal, meaning that the number of polygons that can be displayed on the screen at one time is reduced, meaning that any simulations developed that have a high-poly count will cause the Quest 2 to lag. This may reduce the sense of presence for the user as what is being displayed inside the headset isn't matching their own movements, which may also induce VR sickness.

In conclusion, the Oculus CV1 is the better option as it has no limit to what can be displayed on-screen, it is only limited by the power of the graphics card that it is connected to, meaning that the environment and guns in the scene can be the highest quality and there will be no bottlenecks when it comes to developing the artefact. Also due to the researcher owning a Oculus Rift CV1 headset, testing can be easily conducted without the need to borrow any equipment.

3.4 Research Methods

Two weighted methods, sound design

3.4.1 System Usability Scale (SUS)

One of the methods being used to assess the artefact is the System Usability Scale (SUS). It is described as providing a "quick and dirty, reliable tool for measuring the usability" (Usability.gov, 2022), consisting of a 10-item questionnaire with responses ranging from strongly agree to strongly disagree. It was created by John Brooke in 1986, "it allows you to evaluate a wide variety of products and services, including hardware, software, mobile devices, websites and applications" (Usability.gov, 2022).

Once all the quantitative results are collected, a series of calculations can be completed in order to calculate an average SUS score, detailing which percentile the software falls into, indicating if it is user-friendly.

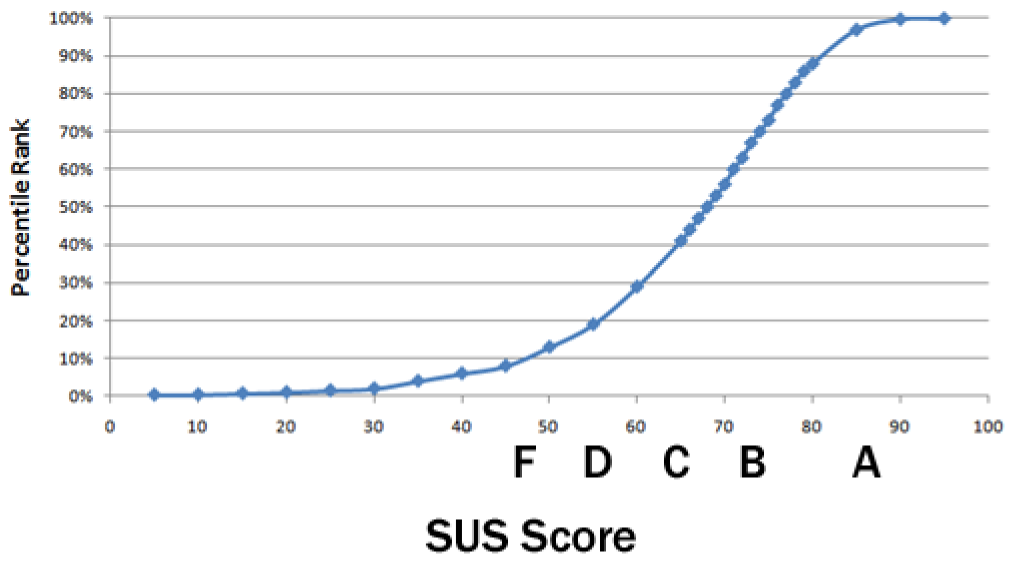

Fig. 6. Line graph with the SUS score interpreted as grades (Sauro, 2019)

These steps include:

- "For each of the odd numbered questions, subtract 1 from the score.
- For each of the even numbered questions, subtract their value from 5.
- Take these new values, add up the total score. Then multiply this by 2.5." (Thomas, 2015)

After doing these calculations, the result should be a number between 0-100. The average score “is around 68. A SUS score above a 68 would be considered above average and anything below 68 is below average.” (Sauro, 2019).

3.4.2 General Feedback

The survey's following part invited respondents to provide any further feedback on the system or their experience. If the experience were transformed into a training device, the comments may reveal which parts the participants liked and which would need to be improved.

This feedback section should provide a more in-depth understanding of how users experienced the artefact and how they interacted with its different elements. The comments that users give would provide qualitative evidence of which components within the system, like weapon weight and audio design, increased their feeling of immersion and sense of presence.

4 Design and Development

4.1 Design

There are four main factors that were considered when designing this artefact to have the highest amount of immersion possible with the hardware currently available, while also mitigating large factors that may induce VR sickness in the user.

4.1.1 Graphical Fidelity

Graphical fidelity is described as any combination of the three elements that contribute to good looking games: detail, resolution, and framerate. The higher the fidelity, the higher the presence.

The two guns used in this simulation are the SA80-A2 (also known as the L85A2) rifle and the Glock-17 handgun which are weapons used by most British Armed Forces personnel. The weapons in the scenario are a key aspect that serves as the foundation for the project. An initial examination was undertaken into a range of gun models in order to determine which would be appropriate for the area. By examining many different models, it was be possible to determine which model would produce a better level of presence, allowing users to be fully immersed.

Fig. 7. The L85A2 model chosen for the simulation (Ulfen, 2015)

The models are of a high poly count and have Physics Based Rendering (PBR) textures which “is an umbrella term for shading and lighting models that accurately represent real world materials and phenomena” (Sairiala, 2015). PBR uses multiple textures to define the look of the final rendered weapon, in the case of the L85A2 rifle it has textures to define the colour, metallic, glossiness and extra detail (normal maps).

Fig. 8. The Glock-17 model chosen for the simulation (MarkkuK, 2020)

This realistic look of the weapons/environment would increase the feeling of presence in the scene when using a VR headset as the ground looks more true-to-life, rather than being a plain colour. However, these graphical improvements may come at a cost to framerate depending on the user's hardware. Having to render multiple instances of the weapons may lower framerate, thus lowering the feeling of presence.

What is viewed is what gives rise to the plausibility illusion (Psi). It is the illusion that what appears to be occurring is actually happening (even though you know for sure that it is not). "Based on evidence over many experiments, it appears that a key component of Psi is that events in the virtual environment over which you have no direct control refer directly to you." (Slater, 2009) Thus, the closer the guns look to real-life; the more likely the user's thoughts will be tricked into assuming that the guns are real.

4.1.2 Interaction Fidelity

Interaction fidelity refers to the precision with which real-world interactions can be recreated. Interaction fidelity aids the transfer of information from the VR user to the real environment. The better the interaction fidelity, similar to graphical fidelity, the greater the user's sensation of presence.

The joysticks on the VR controllers are one method for the user to interact with the scene. Typically, the left joystick is used to move while the right joystick is used to rotate. It has been proposed that interaction fidelity is made up of several separate components, which are detailed in Framework for Interaction Fidelity Analysis (FIFA) (McMahan, 2011). FIFA has been recently updated (McMahan, Lai et al., 2016) to capture the elements of interaction fidelity more accurately.

Biomechanical symmetry, control symmetry, and system appropriateness are the three key characteristics used by FIFA to define interaction fidelity. (Nabiyouni et al., 2015, 3-4) The biomechanical symmetry of our scene/setup is poor fidelity since the user must use their thumbs to tilt the joystick in a direction to move the character in that way. Because the user is directing the avatar differently than they would in real life, this would reduce the sensation of presence and perhaps produce motion sickness. However, this is a less expensive option than incorporating a true walking approach into VR.

The joystick movement nevertheless falls into the low-fidelity category when it comes to the scene/control setup's symmetry. Even though it permits movement in both the X and Y dimensions, the user must release the joystick in order to exit the scene. Because of the sudden deceleration, this reduces the player's immersion and may possibly create VR nausea. Because the joysticks respond accurately and precisely to the user's input, the system appropriateness might be high. Holding physical controllers, on the other hand, may impair the user's sensation of presence because they will constantly be aware that they are in a simulation.

The user's interaction with the firearms comes into this category as well; the user grasping, loading/reloading, pointing, and shooting the guns all need to seem realistic in order for the user to be engaged in the environment and not lose their feeling of presence. To accomplish this, haptic feedback will be implemented for all interactions with the gun, with the strength varying depending on the user's activity. If the user was shooting the gun, the controllers would vibrate more than if the user was reloading the gun.

The movement of the gun itself in the scenario is also shown. Recoil, which attempts to replicate the interaction of a real pistol, would enhance the user's immersion. The amount of recoil depends on the rifle and whether the user is holding the pistol with one or both hands. Because shooting a rifle by itself would result in a large amount of recoil, the gun would become unmanageable. It may be argued that not having this function would immediately disrupt the user's immersion, as a gun with no feedback would not be realistic. Furthermore, unlike other VR shooters, the firearms have a sense of weight to them, forcing the player to move slowly in order to replicate how they would move if they were holding a real gun.

4.1.3 Locomotion

There are many methods of facilitating locomotion in a VR simulation, the three most common being smooth movement with a gamepad (joysticks), teleportation and walking around with 6 degrees-of-freedom (DoF) tracking.

The gamepad is one of the most popular ways to navigate in VR because of its ease of use, familiarity, and effectiveness. Two joysticks are typically used in this interface, one for perspective translation and the other for viewpoint rotation. The user may steer in any direction by moving the joystick in that direction with a percentage-based control. It is designed using sound UXD principles, so even new users can quickly learn how to use it and get the most out of it. Because the input mapping is not accurate to actual walking, this approach might be dubbed a low-fidelity way of locomotion. (Nabiyouni et al., 2015, 30) As a result, the user's experience of presence is diminished. On the other hand, because most VR headsets come with controllers, this would be the simplest technique to include into any VR simulation.

Of all the alternative alternatives already available, teleportation will deliver the most comfortable experience for the broadest audience. It does, however, have benefits and drawbacks, just like any other alternative to true walking. This technique has the advantage of requiring less physical space and reducing the danger of VR sickness if properly implemented. However, it is less realistic than real walking and may be harder to understand for consumers. They may overshoot the target, requiring many attempts to reach the proper location. (Singleton, 2021)

Point-and-teleport is a technique in which the user points at a location they want to move towards, and their virtual viewpoint is instantaneously moved there. To initiate this motion, users often press a controller button while pointing. Despite the popularity of locomotion techniques such as point and teleport in modern VR video games, there has been little prior study on the issue. (Bozgeyikli et al., 2019) However, because the scenario is designed to seem genuine, this strategy may not be suited for this street scene because it may disrupt immersion for the user, diminishing their sensation of presence. The people are all strolling, but the user is teleporting.

Walking organically around the area would be the most fitting mode of locomotion, but it would also be the hardest to accomplish. To prevent walking into barriers or walls, the play area must be exceedingly vast, allowing for maximum immersion and presence in the environment. Redirected walking, which adjusts tracking/graphics geometry such that users appear to be travelling in a straight route while actually walking in a curve, can be used to do this.

Despite all of these extra forms of locomotion, some being more user friendly as they are designed to reduce motion sickness, the one that makes the most sense for this situation and setup would be the simple two joystick method, using smooth movement and snap turning.

4.1.4 VR Sickness

One of the most common reasons of VR sickness is the visual input not matching the sensory input outside of VR, which is caused by the kind of movement impacting the body's senses. Walking in VR with the joystick and then abruptly stopping might trigger VR sickness since there is a strong visual indication of motion change, but the vestibular (balancing) system does not provide a corresponding sensation. The brain might be irritated by these discordant signals, resulting in nausea.

One solution for this, as mentioned previously, is to implement a teleportation locomotion system instead of gradually moving forward. (Vlahovic et al, 2018) compared teleportation to three continuous Virtual Locomotion Techniques (VLTs): joystick, joystick with tunnelling (with a limited field of view), and body tilt. Although there was little change in presence, teleportation provided a substantially better experience, with less symptoms of motion sickness compared to the other methods.

The field of view within the VR headset is another aspect that may influence VR nausea. For experienced users, a large field of vision may be beneficial for a high sense of presence. The expanded FOV, on the other hand, may produce sensory overload in novice users since they can see more of the scene, resulting in more instances of sensory conflict. A dynamic FOV restrictor for when the user is moving may be introduced to fix this problem. This would darken the user's FOV's edges, eliminating unnecessary visual input and directing the user's attention to the display's centre. Because the feeling of self-motion is stronger in peripheral vision, a larger field of view may worsen disease. Due to display technology being less polished in older VR headsets, these issues were more commonplace.

In addition to positional movement locomotion influencing VR sickness, the type of rotational movement locomotion utilised can also influence the severity of the symptoms. Smooth turning with the joystick is the first way; this percentage-based control allows the user to steer in any direction by moving the joystick in that direction. As the user's viewpoint rotates, they may sense sensory conflict, but the vestibular (balance) system does not produce a comparable sensation. These conflicting impulses may irritate the brain, resulting in nausea. As previously stated, decreasing the user's FOV while spinning may help to decrease the impacts of VR sickness.

Instant snap turning is the second type of rotational movement. When the user attempts to turn their character using the joystick, the character will turn by a predetermined amount, preventing motion sickness. This is because in real life, snap turning is how your eyes react to your head motion, making it an excellent comfort choice without sacrificing much in terms of presence. The dynamic FOV approach might be employed with this methodology, but the benefits would be small because the rotation is immediate.

Another way to reduce VR sickness is to have the user sit while using the headset, as this prevents postural instability when standing. In VR, preventing the user from swaying also prevents them from falling over and harming themselves.

4.2 Development

4.2.1 Preparing the 3D Weapon Models

The first step before developing the simulation, is to take the 3D models and convert them into a compatible format Unity. This is done through the free modelling program Blender v2.79 (Community B.O, 2018), the reasons for choosing Blender are outlined in section 3.3.2.

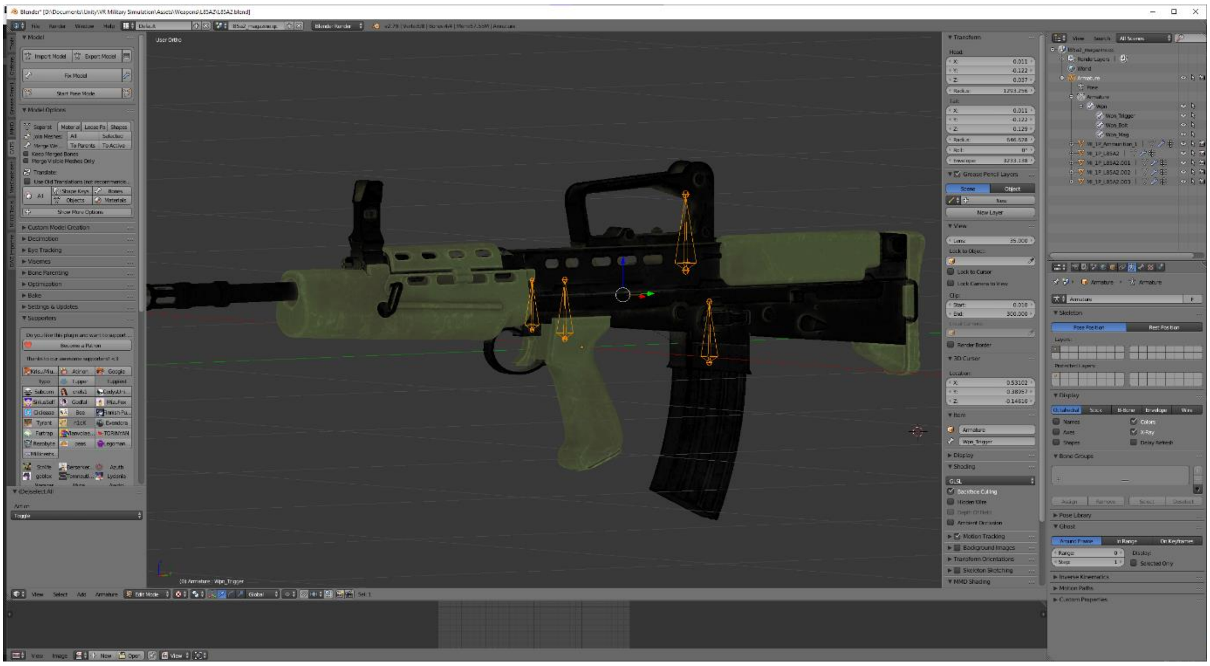

Fig. 9. L85A2 model after rigging in Blender

The focus was on the L85A2 rifle, and the Glock-17 pistol, two weapons used by the UK military as standard. Once downloaded, the models came in an unrigged .obj format, whereas I need them to be in the .fbx format for them to used and animated in Unity which needed to be done in Blender. Here each 3D model was rigged with the trigger, slide, magazine, and main body weight painted to separate bones to be animated in Unity. This is shown in Figures 9 and 10. The orange objects in the window represent the bones of the weapon, when they are moved they manipulate the mesh, moving the parts like a real gun.

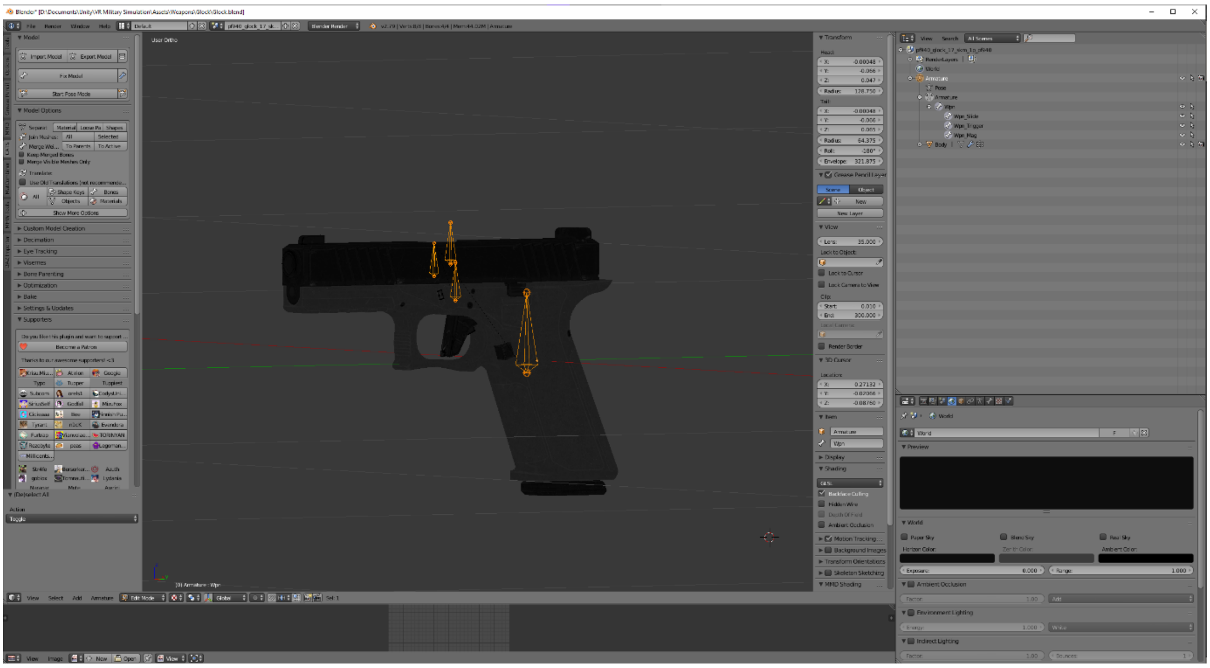

Fig. 10. Glock-17 model after rigging in Blender

Once imported into Unity, PBR textures/materials/shaders could be applied to the models to give them a more realistic look. As shown in Figure 11 below, the PBR textures allow the polygons of the gun to react and reflect the lighting in the scene.

Fig. 11. Both weapons with textures/materials/shaders applied in a blank scene.

4.2.2 First Prototype

The next step in the development was to import all the XR plugins required for integrating any VR headset with Unity. After following a tutorial on how to use XR Framework within Unity, found within Unity documentation “Configuring your Unity Project for XR” (Unity Technologies, 2021b), the development of the artefact could begin. The Unity Asset Store is home to many resources that can be used for any project, in order to aid with development of this artefact the tools and example included in “VR Interaction Framework” (Bearded Ninja Games, 2021) were used as a foundation for the main artefact.

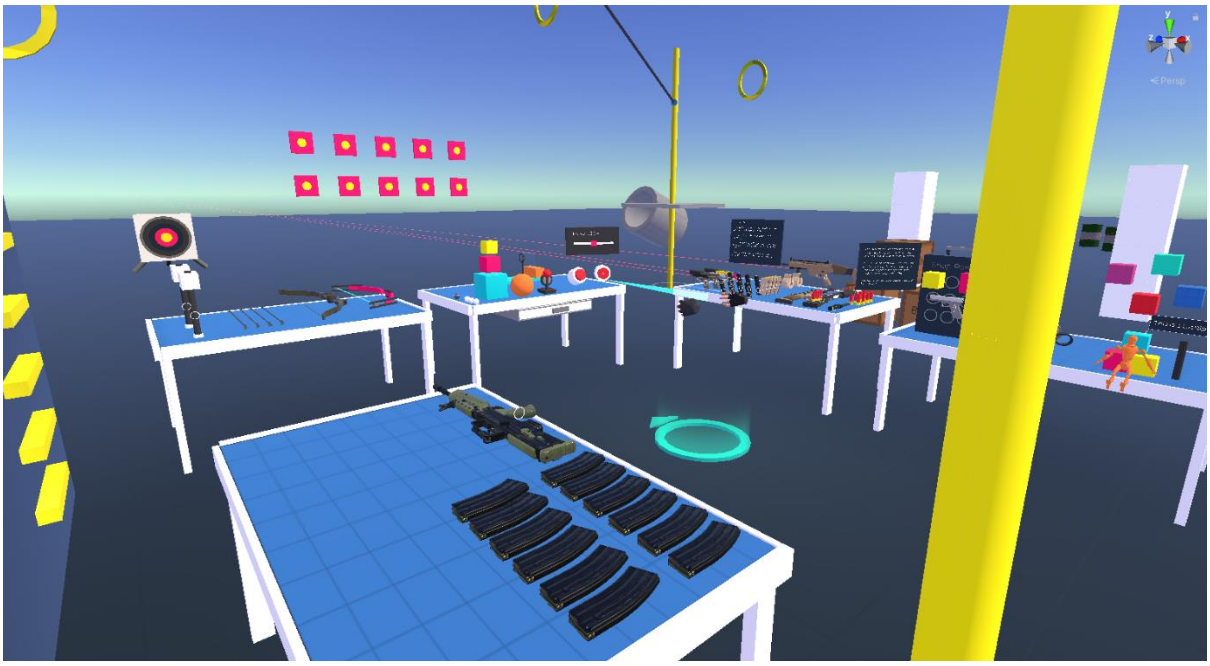

Fig. 12. The example scene included in "VR Interaction Framework" (Bearded Ninja Games, 2021)

To keep the user immersed in the environment and maintain their sense of presence, the user must grab, load/reload, point, and shoot the guns in a realistic manner. To do this, the degree of haptic feedback varies depending on the user's activities. The controllers will vibrate more if the user is shooting the gun than if the user is reloading the pistol. All these basic functions of the gun were first implemented into the first prototype scene of the artefact. However, the gun feels unrealistic to use, there is no recoil, and there are no bullet holes produced at the location where bullets land.

The sound effects heard in the video demonstration (Robinson, 2022a) are basic sound effects provided by the "VR Interaction Framework" (Bearded Ninja Games, 2021). More higher quality sound effects will be implemented in section 4.2.4. A short video clip of the first prototype test is available on YouTube (Robinson, 2022a) containing footage of handling, reloading, and firing the gun at targets.

4.2.3 Firing Range Scene

Due to little prior experience in creating scenery from scratch, and in order to save time for developing additional features of the artefact, a range scene "HQ Shooting Range" (NextLevel3D, 2018) shown in Figure 13 was used as a template to add additional features. This scene was chosen as it has all the requirements needed for this artefact: targets for users to shoot, tables to store weapons, switches on the side to adjust the distance of the target, and PBR textures which the benefits were discussed in Section 4.1.1.

Fig. 13. Base range scene from "HQ Shooting Range" (NextLevel3D, 2018)

The targets that came with the base scene were only a PNG of a generic target, which when fired at, the ray cast sent out by the weapon cannot detect and add the correct number to a score tally. In order to achieve this, the original PNG need to be converted into a Scalable Vector Graphics (SVG) image, which was done using a "Free online image to vector tool" (PngToSvg, 2021). These steps are necessary because Blender has the ability to turn a SVG file into useable polygons. As shown in Figure 14, once the file is imported into Blender, each score area can be divided into separate meshes, which when combined with a mesh collider in Unity can be used to detect which area was shot at by the gun.

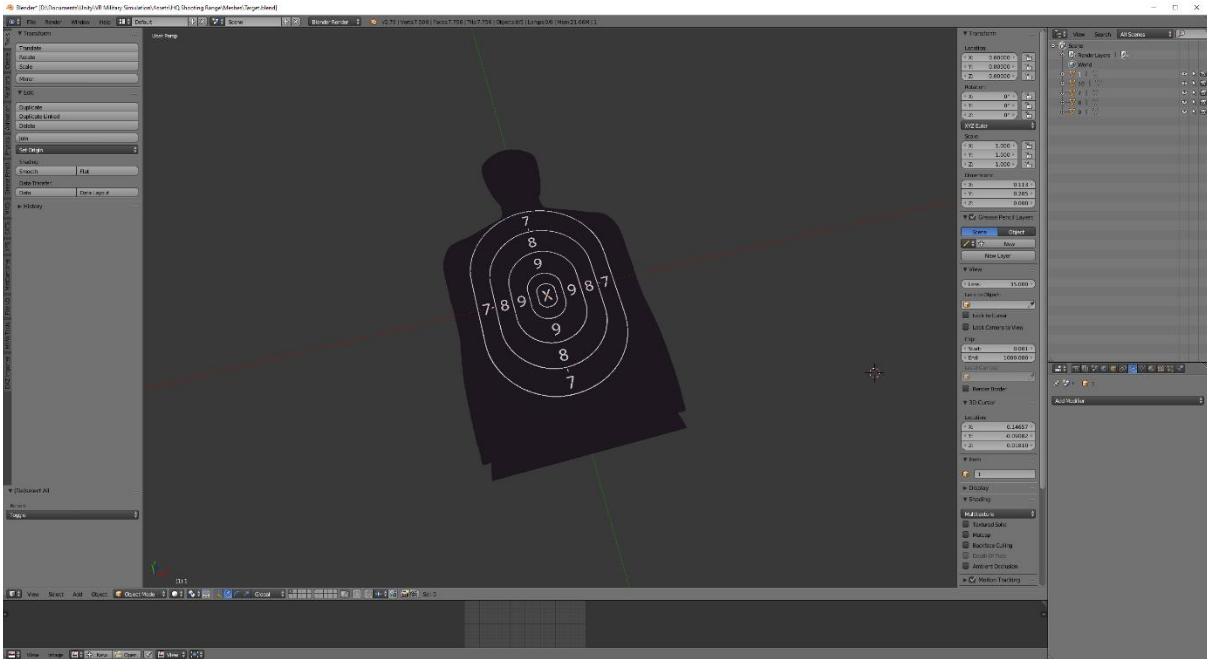

Fig. 14. Each score area as separate meshes in Blender

When the trigger of the gun is pulled, it "Casts a ray, from point origin, in a direction, of length maxDistance, against all colliders in the Scene" (Unity Technologies, 2021c). As shown in Appendix 9.1.1, if the RayCast hits an object with the Scoring component on it, it will then call the AddPoints function in the Scoring code in Appendix 9.1.2. This then adds the correct score to the text object in that shooting range. The main reason for this being added as a feature was so the user gets real-time feedback of their performance, allowing them to improve on the fly, without having to go through the real-life procedure of waiting until the range is clear before checking the target and manually adding the score up.

The next function that was added was the adjustable target distance, which is an important addition to the artefact. As noted in Section 3.2.1, the DCCT training consists of firing the weapon at different distances, something that this feature would replicate. Which would allow the user to adjust the distance of the target in real-time, the code that enables this to be possible is in Appendix 9.1.3.

Both of these functions are combined to calculate the score added to the total, the further away the target is, the higher the score multiplier is, and vice-versa.

Fig. 15. The finalised range environment with the new targets

The final scene is visible in Figure 15, with each range having the previously described features. It could set up a future multiplayer mode, where multiple trainees can use the same instance, with a main trainer observing them and giving feedback similar to how training sessions are conducted in real life.

A short video clip of the second prototype test is available on YouTube (Robinson, 2022b) containing footage of handling, reloading, and firing the gun at these new targets in the new environment.

4.2.4 Gun Developments

It is arguable that "The main purpose of virtual reality (VR) is to enhance realism and the player experience" (Krompiec and Park, 2019). Consequently, the realism of the gun interactivity in the simulation, could be considered the most important element in order to heighten a user's sense of presence. As discussed previously, other implementations of guns in VR games do not include all of the downsides of firing a gun as they are games designed to be fun. In other games, guns can be moved around unrealistically and far too quickly, so the plan was to add a feeling of weight to the guns in this simulation.

Implementing what can only be described as a "fishing rod method" is also used in the fantasy sandbox game "Blade and Sorcery" (Warpfrog, 2019). The way this method works is by taking the users inputs and delaying them depending on the weight specified on the object being picked up. This is shown in Appendix 9.1.4, the object being picked up is checked for the Weight component, it then takes the number and converts it into the resistance applied to the controller's position and rotation. The code that is commented out is the original code that would instantly move the virtual controller to the position/rotation of the physical controller.

It can be hard to demonstrate this method through visual means without actually experiencing the feeling of weight in the simulation. In the "VR Military Sim Short Demonstration" (Robinson, 2022c), at 0:43 the controllers are put together and the gun on the right (which has the weight component applied) moves at a slower rate compared to the unweighted gun on the left. This feature should play an important part in order to produce a sense of immersion in the user, improving the overall experience.

4.2.5 Sound Design

The entertainment industry, which has long acknowledged the significance of sound to lend presence and immersion to cinema and video games, may be used to inspire sound design concepts and ideas for virtual reality simulations. As a result, the cinema industry has invested much in developing strategies for creating sound effects and ambient sounds that elicit emotional reactions and immerse the spectator (Serafin S. et al., 2004). It could be argued that over the years, sound design has become essential in creating new and immersive experiences in any form of media. For VR experiences, the sound effects that the user can hear have to match what it is occurring on screen, as well as adding sounds that recreate what the real-world counterparts sound like. The sound effects heard in the first prototype (Robinson, 2022a) are basic sound effects provided by the "VR Interaction Framework" (Bearded Ninja Games, 2021). More higher quality sound effects were needed, so the basic sounds were replaced by the ones in "Real Recorded Guns & Bullet Sounds" (Sidearm Studios, 2020) from the asset store. Having these new sound effects would enhance the immersion for the user as the guns now sound as close to their real-world counterparts as possible.

Sound is widely known for helping to recreate a feeling of location. However, it is unknown how much information should be added to the environment via sound. Objects that are visible and likely to create a sound, should do so (Serafin S. et al., 2004). Thus, every object in the scene should make sound, when being interacted with. The guns should make sounds when being picked up, handled, reloaded and fired. Something that has never been implemented in a VR shooter before is having the tinnitus (ear-ringing) effect when the user fires a gun, the reason for this being is because it creates an uncomfortable experience for the user. However, for this simulation, the goal is for maximum immersion, that means including all the features of a gun, even the negative ones.

The simple code implementation for this is in Appendix 9.1.5, where when the sound effect for the ear ringing is played, as well as the new higher quality gun firing sound effects, when the trigger of the gun is pulled. These sound effects can also be heard in the "VR Military Sim Short Demonstration" (Robinson, 2022c), both the L85A2 and the Glock-17 have new sound effects and the ear ringing sounds overlaid over them.

4.3 Testing

The testing of the artefact throughout development was conducted by the author

User testing was performed on the application to acquire quantitative findings to assess if the system was usable and qualitative results on user input on the system's immersion. Through university ties, eighteen people were recruited to take part in this study. The experience began with a brief description of what the participant will encounter and an explanation of the testing's aim. The participants were then led to a Participant Information Sheet (Appendix 9.3) to learn more about the study and what they might expect. The participant was then asked to sign a consent form (Appendix 9.2) that detailed the hazards they could face.

Fig. 16. Two tables with two variations of gun on each one

Once the consent form had been signed, individuals were given a brief tutorial explaining how to use the Oculus CV1 Headset and controllers, and how to navigate/interact with the environment/weapons. The testing was structured in such a way that each subject had the same experience, ensuring that the test results were not influenced by irregularities in the testing. The experience began with a brief description of what the participant will encounter and an explanation of the testing's aim. In this case, the user is presented with two tables with weapons on them (Figure 16), the table on the right has the weapons with the added weight and sound design, and the left table does not. In order to keep testing unbiased, the user is not told this detail and is instructed to test the weapons on both tables. After the user had finished testing each gun, the difference of weight and sound design was revealed to them.

Afterwards, the individual was first directed to an introductory questionnaire (Appendix 9.4.1) that included details like age, gender and if they had used VR or even real guns before. If they had experienced this before, they were asked how it compared to these previous experiences. Secondly, they were given a System Usability Scale (Appendix 9.4.2) review to understand if the artefact was a usable system. Then a General Questionnaire (Appendix 9.4.3) on whether the individuals felt as if the artefact was immersive and if the added features such as gun weight and sound design improved this immersion.

5 Evaluation

The male to female ratio for all participants in the artefact testing was presented as the first analytical stage. There were ten men, seven females, and one non-binary in Figure 17. The divide is not particularly significant because the sample is small and there were only 18 users. However, if the dataset was larger, this may have an impact on the outcomes since men and women may perceive the simulation differently.

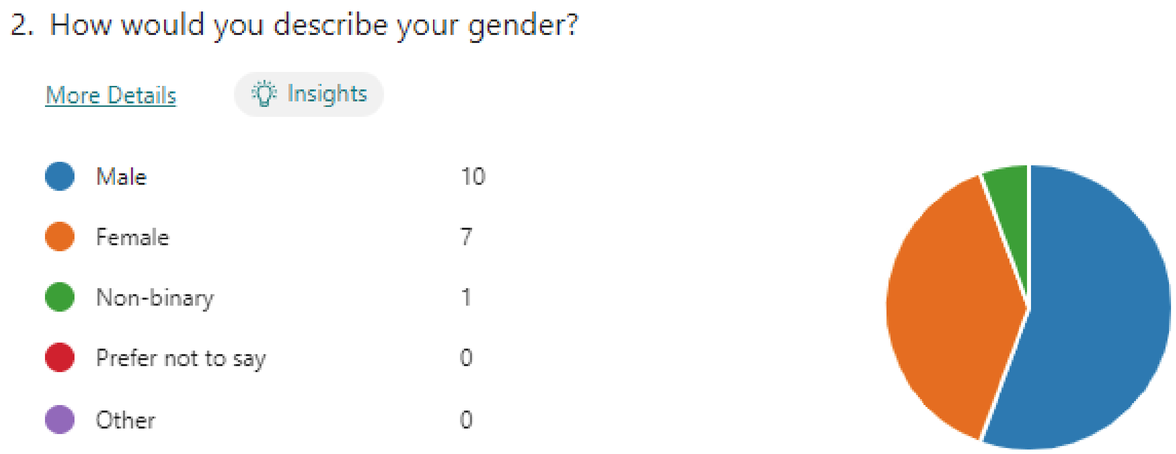

Fig. 17. A pie chart showing the gender ratio

5.1 System Usability Scale (SUS)

As previously stated in Section 3.4.1, the SUS questionnaire is a rapid and accurate way to assess a system's usability. It was created by John Brook and consists of ten questions meant to evaluate a wide range of items. Because of its ease of use, it has become an industry standard. Furthermore, the findings can readily distinguish between usable and non-usable systems.

The reason behind these calculations, is that all odd-numbered questions have a positive tone, thus if the response is "Strongly Agree," the maximum score is awarded. The maximum score is 1 if the response is "Strongly Disagree." After multiplying by 2.5, the minimum is achieved by removing 1 from each odd-numbered question. Even-numbered questions have a negative tone, and the maximum point is 1 if the response is "Strongly Agree." After multiplying by 2.5, the minimum is 1, as determined by removing the points of each question from 5.

	K	L	M	N	O	P	Q	R	S	T	U
1	How would you comp	I think that I would lik	I found the system un	I thought the system	I think that I would ne	I found the various fu	I thought there was to	I would imagine that	I found the system ve	I felt very confident u	I needed to learn a lo
2		4	0	10	2	8	1	10	1	7	2
3		6	1	9	3	8	0	9	4	10	4
4		6	3	8	5	10	1	7	3	9	3
5		2	2	4	6	7	5	3	3	6	4
6		10	1	8	0	9	0	10	0	10	0
7		8	1	8	5	10	5	8	2	9	2
8	very realistic, the additi	8	0	10	2	8	1	8	0	9	2
9	very simular to in real lif	8	3	9	6	9	0	9	3	8	5
10	Only the weight of the v	9	0	9	2	9	0	9	0	9	2
11		8	1	7	0	8	1	9	2	9	1
12	very much the same as I	8	0	10	0	8	0	10	2	10	0
13		10	2	8	6	8	0	7	1	7	1
14		5	5	5	5	5	5	5	5	5	5
15		7	2	8	2	8	1	9	2	7	4
16		8	0	10	0	0	0	10	0	10	0
17		10	0	8	2	10	0	10	1	10	2
18		10	5	8	3	10	0	10	3	10	1
19	although i see there has	6	2	8	1	7	2	7	4	8	2
20	**Total**	**133**	**28**	**147**	**50**	**142**	**22**	**150**	**36**	**153**	**40**
21	Total/2	66.5	14	73.5	25	71	11	75	18	76.5	20
22	Odd=-1, Even=5-score	47.5	81	54.5	70	52	84	56	77	57.5	75
23											
24											
25					Sum of all scores	654.5					
26					Sum * 2.5	1636.25					
27					SUS Score	86.11842105					
28											

Fig. 18. The SUS scores, calculations, and results in a table

Using the steps described Section 3.4.1 and adding an extra step of dividing every value collected by 2, the SUS score was able to be calculated as 86.1. Which marks it as a grade A system, beating the average score of 68, and putting it in the top 5% percentile of systems. It could be argued that this value may be inaccurate as the sample size was small, but as this is a small-scale project such things can be ignored.

Overall, attaining results that place the system in the upper quartile indicates that the system may be effectively deployed to a larger audience. This is due to those who use the system being able to accomplish a task and achieve a goal accurately and completely in a short amount of time. Participants demonstrate that they view the experience to have more pleasure in the process of testing the artefact by performing the tasks of exploring the world and interacting/shooting the weapons in an effective manner.

5.2 General Feedback

The following section of the poll asked respondents for any further feedback about the system or their experience. If the event were turned into a training tool, the feedback may tell which aspects the participants enjoyed, and which needed to be improved. This component of the feedback gave a more in-depth insight of how users engaged with the artefact's various elements. User’s comments give qualitative proof of which aspects of the system, such as weapon weight and sound design, contributed to their sense of immersion and presence. Some examples of these include:

- “The guns on the right table were harder to use and felt larger or more cumbersome. The guns from the left table felt more like using guns from a game whereas I imagine the weighted guns are more like what using a real gun feels like.”
- “The guns on the right felt more realistic to use, when picking them up and shaking them the gun felt more consistent whilst the guns on the left resembled more of a prop and less stable”
- “I can see that there has been much thought into making the weapons feel realistic to use within the game. This can be shown through the existence of recoil, the reloading process of the weapons and the sound design.”
- “While holding them the right table felt probably as realistic as possible without the physical weight of a real gun, left table guns felt light and unrealistic. When not being held the guns seemed a bit too light, especially when interacting with other objects”
- “I thought that the sound design was a good attention to detail due to the tinnitus sound after firing a gun close to the player, although for me personally this sound was very low compared to the rest of the environment.”
- “When I realized that the magazines have shells in them when they're full, and when they're empty, the model actually has no bullets. Also, the switch for making the targets come closer/farther from you was great”

However, one person in the simulation suffered excessive ear ringing, which negatively damaged their experience and caused VR sickness. The audio levels will need to be adjusted so that future experiences for folks are not harmed. Perhaps by including a mechanism to adjust the intensity of ear ringing through using ear mufflers in the simulation.

Some more feedback mentioned that the graphics on the guns seemed realistic, but the environment was fairly limited in complexity. There were many other positive comments on the interactivity/realism of the weapons, which shows that it is an aspect that improves the user experience and increases user presence. However, several people reported experiencing VR sickness because of the way they moved about the environment. Unless teleportation is used, this factor is frequently inevitable in VR. If teleportation is implemented, it will have a detrimental influence on the experience since people will not perceive the world as they would in real life.

Ultimately, input from individuals provided insight into which components people liked and which needed to be improved. The overall response from participants was good, with a few minor criticisms about certain parts that caused VR sickness that may be addressed in future versions of the artefact.

6 Project Conclusion

Before trying to analyse potential future military applications, this research investigated the current status of virtual reality technology and software, as well as its military applications. A virtual reality application was created with the goal of improving on existing training options. This was accomplished by setting up a firing range scene with two different versions of firearms used by the Royal Armed Forces, one with weight and enhanced sound design and the other without. Along with the system's usability, the experience was evaluated for its ability to retain presence, immersion, and overall experience.

The study conducted as part of this project was successful and efficient in terms of gathering findings and obtaining a response to the research question thanks to project management employing the Waterfall technique. It planned out when different components of the project would be finished and how long it would take by utilising a Gantt chart to organise time. By controlling time in this manner, each part of the project was divided into sections, each with sufficient time to complete. The Gantt chart was carefully followed throughout this project, and each step was finished on schedule. Despite this, there was no clear strategy on how to recruit participants to test the software, other than the target demographic being those aged 19 to 30, with a 50/50 male to female ratio. A more effective method might have been implemented to gather a more varied group of volunteers, as well as more persons being evaluated to generate more findings. However, because the testing stage of the artefact was one of the final steps of its production, more volunteers could not be found in the time allotted.

The software could be used to replace traditional training methods. However, because a virtual equivalent can never fully replace its physical counterpart. The quality of the artefact was evaluated in order to establish whether it is a feasible application based on testing findings. The artefact's SUS score was assessed to be 86.1 based on the data obtained from participants. This indicates that the system can be controlled by many people, as only a brief instruction is required for users to engage with it. The entire response was highly favourable, with participants stating that the weapons' interaction and realism further engaged them in the setting. However, constructive feedback was offered on several factors that caused VR sickness, which can be fixed in future versions. The feedback form also verified that the weighted firearms seemed more realistic to wield, and that the sound design improved the overall immersion in the situation. As a result, these enhancements to the status quo of VR shooters were well-received and resulted in a pleasant user experience. Overall, the system could be utilised as a training solution because of its high usability and presence, which allows users to completely immerse themselves in the programme and so imitate real-world events.

This study has opened futures prospects of further developing this virtual reality weapons training programme that may be used to train soldiers. The application might then be modified further with the implementation of training activities as a result of further interviews and cooperation with experts. This might benefit those who don't have a lot of opportunities to train since their roles aren't combat-oriented. Due to its great accessibility, the simulation can be used by anybody, and its strong presence means that users were completely immersed in it, allowing it to be used to imitate real-world situations.

A short video clip of the final artefact demonstration is available on YouTube (Robinson, 2022c) containing footage of handling, reloading, firing both the L85A2 and Glock-17 at the target that has been moved back using the switch, and demonstrating the weight and sound design of the weapons.

7 Reflective Analysis

Conclusively, the project was completed successfully due to the progress made in the construction of the artefact and the findings obtained via testing. Most of the design and development phase went to plan, with multiple features being implemented that increased the user's feeling of immersion and sense of presence. Having the "VR Interaction Framework" (Bearded Ninja Games, 2021) tools and examples played a huge part in the development of this artefact, as they saved a lot of time by providing a basic implementation of gun interactivity to build upon. This programme might theoretically be used to replace traditional training techniques. However, a virtual equivalent will never be able to completely replace its physical counterpart, even with features like gun weight designed to increase immersion.

There would be additional chances to add to the artefact if this study could be conducted again without the restrictions of time and circumstance. Time to research more into more methods of increasing immersion and sense of presence in the simulation, adding more guns for the user to interact with, and additional environments that could be explored and conduct training exercises in. It might pave the way for a future multiplayer option in which numerous trainees can utilise the same instance while a main trainer observes and provides comments, much like how real-life training sessions are performed.

Some improvements to the testing phase of the artefact include inviting a lot more people to participate in order to increase the sample size, which would have resulted in more variety in the data. Furthermore, acquiring a larger sample size would have resulted in more comments from participants, providing deeper insight into areas for development and which features respondents believed enhanced user experience.

From performing a literature analysis on subjects surrounding virtual reality in the military to designing a realistic military simulation in Unity and using the Oculus CV1 headset, the project was a lot of fun. Finally, the application was tested with a range of individuals who were eager to see and experience the scenarios that had been generated. Overall, the experience was highly rewarding, and there are plans to continue working on the project when this report has been submitted.

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9 Appendix

9.1 Development Code

9.1.1 Target Detection Code

```
// Hit something without Raycast. Apply damage, apply FX, etc.
public virtual void OnRaycastHit(RaycastHit hit) {

    ApplyParticleFX(hit.point, Quaternion.FromToRotation(Vector3.forward, hit.normal), hit.collider);

    // push object if rigidbody
    Rigidbody hitRigid = hit.collider.attachedRigidbody;
    if (hitRigid != null) {
        hitRigid.AddForceAtPosition(BulletImpactForce * MuzzlePointTransform.forward, hit.point);
    }

    // Damage if possible
    Damageable d = hit.collider.GetComponent<Damageable>();
    Scoring s = hit.collider.GetComponentInParent<Scoring>();
    if (d) {
        d.DealDamage(Damage, hit.point, hit.normal, true, gameObject, hit.collider.gameObject);

        if (onDealtDamageEvent != null) {
            onDealtDamageEvent.Invoke(Damage);
        }
    }
    else if (s)
    {
        s.AddPoints(hit);
    }

    // Call event
    if (onRaycastHitEvent != null) {
        onRaycastHitEvent.Invoke(hit);
    }
}
```

9.1.2 Scoring Code

```
    public Animator Target;
    public Transform Switch;
    public GameObject SFX;
    float position = 0.0f;

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

    }

    void MoveTarget(string direction)
    {
        if (direction == "Down")
        {
            if (position < 0.0f) { return; }
            else { position -= (Time.deltaTime * 0.2f); }
        }
        else if (direction == "Up")
        {
            if (position >= 1.0f) { return; }
            else { position += (Time.deltaTime * 0.2f); }
        }
        Target.SetFloat("Position", position);
    }

    // Update is called once per frame
    void FixedUpdate()
    {
        float angle = Switch.eulerAngles.x;
        // If the switch is down, move the target forward
        if (20 <= angle && angle <= 50)
        {
            MoveTarget("Down");
            SFX.SetActive(true);
        }
        // If the switch is up, move the target back
        else if (320 <= angle && angle <= 350)
        {
            MoveTarget("Up");
            SFX.SetActive(true);
        }
        else
        {
            SFX.SetActive(false);
        }
    }
```

9.1.3 Target Moving Code

```
    public Animator Target;
    public Transform Switch;
    public GameObject SFX;
    float position = 0.0f;

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

    }

    void MoveTarget(string direction)
    {
        if (direction == "Down")
        {
            if (position < 0.0f) { return; }
            else { position -= (Time.deltaTime * 0.2f); }
        }
        else if (direction == "Up")
        {
            if (position >= 1.0f) { return; }
            else { position += (Time.deltaTime * 0.2f); }
        }
        Target.SetFloat("Position", position);
    }

    // Update is called once per frame
    void FixedUpdate()
    {
        float angle = Switch.eulerAngles.x;
        // If the switch is down, move the target forward
        if (20 <= angle && angle <= 50)
        {
            MoveTarget("Down");
            SFX.SetActive(true);
        }
        // If the switch is up, move the target back
        else if (320 <= angle && angle <= 350)
        {
            MoveTarget("Up");
            SFX.SetActive(true);
        }
        else
        {
            SFX.SetActive(false);
        }
    }
```

9.1.4 Object Weight Code

```
protected virtual void Update() {
    if (GetComponentInChildren<Grabber>() != null)
    {
        grabber = GetComponentInChildren<Grabber>();
        if (grabber.HeldGrabbable != null)
        {
            if (grabber.HeldGrabbable.GetComponent<Weight>() != null)
            {
                resistance = 20 - (grabber.HeldGrabbable.GetComponent<Weight>().Mass * 0.5f);
            }
            else { resistance = 20f; }
        }
        else { resistance = 20f; }
    }

    RefreshDeviceStatus();
    UpdateDevice();
}

protected virtual void FixedUpdate() {
    UpdateDevice();
}

public virtual void RefreshDeviceStatus() {
    if (!deviceToTrack.isValid) {

        if (Device == TrackableDevice.HMD) {
            deviceToTrack = InputBridge.Instance.GetHMD();
        }
        else if (Device == TrackableDevice.LeftController) {
            deviceToTrack = InputBridge.Instance.GetLeftController();
        }
        else if (Device == TrackableDevice.RightController) {
            deviceToTrack = InputBridge.Instance.GetRightController();
        }
    }
}

public virtual void UpdateDevice() {
    float step = resistance * Time.deltaTime;
    // Check and assign our device status
    if (deviceToTrack.isValid) {

        if (Device == TrackableDevice.HMD) {
            transform.localPosition = currentLocalPosition = InputBridge.Instance.GetHMDLocalPosition();
            transform.localRotation = currentLocalRotation = InputBridge.Instance.GetHMDLocalRotation();
        }
        else if (Device == TrackableDevice.LeftController) {
            //transform.localPosition = currentLocalPosition = InputBridge.Instance.GetControllerLocalPosition(ControllerHand.Left);
            //transform.localRotation = currentLocalRotation = InputBridge.Instance.GetControllerLocalRotation(ControllerHand.Left);

            transform.localPosition = currentLocalPosition = Vector3.Lerp(transform.localPosition, InputBridge.Instance.GetControllerLocalPosition(ControllerHand.Left), step);
            transform.localRotation = currentLocalRotation = Quaternion.RotateTowards(transform.localRotation, InputBridge.Instance.GetControllerLocalRotation(ControllerHand.Left), step*40f);
        }
        else if (Device == TrackableDevice.RightController) {
            //transform.localPosition = currentLocalPosition = InputBridge.Instance.GetControllerLocalPosition(ControllerHand.Right);
            //transform.localRotation = currentLocalRotation = InputBridge.Instance.GetControllerLocalRotation(ControllerHand.Right);

            transform.localPosition = currentLocalPosition = Vector3.Lerp(transform.localPosition, InputBridge.Instance.GetControllerLocalPosition(ControllerHand.Right), step);
            transform.localRotation = currentLocalRotation = Quaternion.RotateTowards(transform.localRotation, InputBridge.Instance.GetControllerLocalRotation(ControllerHand.Right), step * 60f);
        }
    }
}
```

9.1.5 Ear Ringing Code

```
public virtual void Shoot() {

    // Has enough time passed between shots
    float shotInterval = Time.timeScale < 1 ? SlowMoRateOfFire : FiringRate;
    if (Time.time - lastShotTime < shotInterval) {
        return;
    }

    // Need to Chamber round into weapon
    if(!BulletInChamber && MustChamberRounds) {
        // Only play empty sound once per trigger down
        if(!playedEmptySound) {
            VRUtils.Instance.PlaySpatialClipAt(EmptySound, transform.position, EmptySoundVolume, 0.5f);
            playedEmptySound = true;
        }

        return;
    }

    // Need to release slide
    if(ws != null && ws.LockedBack) {
        VRUtils.Instance.PlaySpatialClipAt(EmptySound, transform.position, EmptySoundVolume, 0.5f);
        return;
    }

    // Create our own spatial clip
    VRUtils.Instance.PlaySpatialClipAt(GunShotSound, transform.position, GunShotVolume);
    VRUtils.Instance.PlaySpatialClipAt(RingingSound, transform.position, RingingVolume);
```

9.2 Consent Form

UNIVERSITY OF LINCOLN

Ethics reference:

Participant Identification Number for this study:

CONSENT TO PARTICIPATE IN RESEARCH

Title of Project: Creating a Realistic VR Military Simulation

Name of Researcher: Lewis Robinson

Name of Participant:

Please tick box

1. I confirm that I have read the information sheet dated ___________ for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my legal rights being affected. ☐
3. I understand that should I withdraw then the information collected will be kept in line with the Research Participant Privacy Notice and that the information I have provided may still be used in the project analysis. ☐
4. I understand that individuals from the University of Lincoln may look at research data collected during the study, to ensure that the study is conducted appropriately. I give permission for these individuals to have access to my records; I understand that my personal details shall be kept confidential. ☐
5. I understand that by using the VR headset, I may experience forms of nausea, dizziness, and that the headset may cause eye strain. If I am to experience any of these symptoms then I will take a break from the headset and wait for the symptoms to disappear before continuing. ☐
6. I understand that I may be subjugated to loss of balance or may feel claustrophobic when using the headset. However, I should undertake the study while sitting down to avoid damages to myself or the headset. ☐
7. I would like to receive a summary of the results of the study Yes ☐ No ☐
8. I agree to take part in the above study. ☐

____________________	____________________	____________________
Name of Participant	Date	Signature
Lewis Robinson	____________________	____________________
Name of Person taking consent	Date	Signature

2 Copies: 1 for participant; 1 for researcher site file;

9.3 Participant Information Sheet

Participant Information Sheet

Title of Study: Creating a Realistic Military VR Simulation

Name of Researcher: Lewis Robinson

You've been asked to participate in a BSc research project. Before deciding whether or not to complete this study, it is critical that you understand why it is being conducted and what it will entail. Please read the following information carefully and contact us if anything is unclear or if you require further information. Take some time to consider whether or not you want to participate.

What is the purpose of the study?

This project will produce a fully tested and evaluated, realistic and immersive military simulation. Delivering an immersive experience for the user by using all available resources in Virtual reality. The purpose of this study is to investigate the elements/features of a VR simulation that increase the user's immersion.

Am I eligible to take part?

We're looking for about 20 people to participate in our research project, and we'd want you to be one of them. You will be contributing to the project's outcomes, thus there will be no additional reward to you from participating.

Do I have to take part?

This research is fully optional, and you have complete discretion over whether or not to participate. You can withdraw from the study at any time without facing any penalty. If you accept to participate in this study, you will be required to read this information sheet and sign a permission form that will notify you of any potential hazards.

What will I be asked to do?

You will be asked if you have ever used a Virtual Reality headset before, and if you haven't, you will be encouraged to participate in a brief training that will teach you how to navigate the virtual environment. The following stage in the investigation is to enter the environment's initial scene. You'll explore the location and interact with the weapons while assessing if you feel present and immersed in the action.

After you've had a chance to explore the area and interact with the weapons, you'll be asked to fill out the questionnaire, the first part consisting of a System Usability Scale (SUS) review, and the second part consisting of general questions relating to the level of presence and immersion you experienced in the simulation.

Will I be paid expenses for taking part?

No

What are the possible benefits / risks of taking part?

You may experience forms of nausea, dizziness, and that the headset may cause eye strain. If you experience any of these symptoms, it is advised to take a break from the headset and wait for the symptoms to disappear before continuing.

Will anyone know I have taken part?

The information we collect will be handled in confidence. No one will know you have taken part, as your responses are anonymous.

Where will my data be stored?

The data obtained from the study will be stored securely on the university OneDrive in password protected files. Only the researcher/researchers will have access to it. Paper copies will be stored in a secure cabinet/office at the University. The data from this study *may* be put in an Open Access repository for other researchers to use in future research.

What will happen if I don't want to carry on with the study?

As you have completed the study anonymously it will not be possible to remove the data provided, as I will not be able to identify you in any way.

What will happen to the results of the research study?

The results will be used within the final submission of a Computer Science BSc dissertation project, to make a conclusion on whether the virtual environment is a usable system with a high sense of presence and immersion, which could be used as a tool within the military.

Who is organising and funding the research?

This research is being organised and funded by Lewis Robinson at the University of Lincoln.

Who has reviewed the study?

All research conducted by the University of Lincoln is looked at by an independent group of people, called a Research Ethics Committee, to protect your interests. This study has been reviewed and given favourable opinion by a University of Lincoln Research Ethics Committee.

What if there is a problem?

It is very unlikely that this study would cause you any harm. If you have a concern or a complaint about any aspect of this study, you should ask to speak to the researchers who will do their best to answer your questions. The researchers contact details are given at the end of this information sheet.

If you remain unhappy and wish to complain formally, you can make a formal complaint through the University complaints procedure or by contacting ethics@lincoln.ac.uk.

Further information and contact details

Contact details

Lewis Robinson – 15611294@students.lincoln.ac.uk

Dr Patrick Dickinson - pdickinson@lincoln.ac.uk

9.4 Testing Questionnaire

9.4.1 Introduction

1. What is your age? *

Please enter a number greater than 18

2. How would you describe your gender? *

- Male
- Female
- Non-binary
- Prefer not to say
- Other

3. Have you ever used VR before? *

- Yes
- No

4. How would you compare it to previous VR experiences?

Enter your answer

5. Have you ever handled real weapons before? *

- Yes
- No

6. How would you compare it to the real experience of handling weapons?

Enter your answer

9.4.2 System Usability Scale (SUS)

7. I think that I would like to use this system frequently. *

0	1	2	3	4	5	6	7	8	9	10

Strongly disagree Strongly agree

8. I found the system unnecessarily complex. *

0	1	2	3	4	5	6	7	8	9	10

Strongly disagree Strongly agree

9. I thought the system was easy to use. *

0	1	2	3	4	5	6	7	8	9	10

Strongly disagree Strongly agree

10. I think that I would need the support of a technical person to be able to use this system. *

0	1	2	3	4	5	6	7	8	9	10

Strongly disagree Strongly agree

11. I found the various functions in this system were well integrated. *

0	1	2	3	4	5	6	7	8	9	10

Strongly disagree Strongly agree

12. I thought there was too much inconsistency in this system. *

0	1	2	3	4	5	6	7	8	9	10

Strongly disagree Strongly agree

13. I would imagine that most people would learn to use this system very quickly. *

0	1	2	3	4	5	6	7	8	9	10

Strongly disagree Strongly agree

14. I found the system very cumbersome to use. *

0	1	2	3	4	5	6	7	8	9	10

Strongly disagree — Strongly agree

15. I felt very confident using the system. *

0	1	2	3	4	5	6	7	8	9	10

Strongly disagree — Strongly agree

16. I needed to learn a lot of things before I could get going with this system. *

0	1	2	3	4	5	6	7	8	9	10

Strongly disagree — Strongly agree

9.4.3 General Feedback

17. How did you feel when you were using the weighted guns (right table) vs the guns without weight (left table)?

Enter your answer

18. How realistic would you describe the simulation graphics?

Enter your answer

19. How realistic were the gun physics/weight?

Enter your answer

20. What was your opinion on the haptic feedback of the guns?

Enter your answer

21. What did you think about the sound design?

Enter your answer

22. What was the most frustrating moment or aspect of what you just played?

Enter your answer

23. What was your favourite moment or aspect of what you just played?

Enter your answer

24. Which functions didn't work as you expected?

Enter your answer

25. Was there anything you wanted to do that you couldn't?

Enter your answer

26. Initially, the plan was to add a weapon disassembly feature,
Do you think doing weapon disassembly would be useful for training purposes?

Enter your answer

27. What features would you add/improve/remove to better the experience?

Enter your answer