Does Virtual Reality Training Improve Memory Retention of Pilot Flows?

By

Jose Rangel Florez
Master in Science (Computer Science)

Submitted to the College of Science and Engineering in partial fulfilment of the requirements for the degree of Master of Science (Computer Science) at Flinders University – Adelaide Australia.

26/11/2021

DECLARATION OF ORIGINALITY:

"I certify that this work does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text."

Signed

Date 15/10/2021

Jose Rangel Florez

ABSTRACT

The increasing usage Virtual Reality (VR) has seen commercial releases of head mounted display (HMD), and a drive from computer game engines, such as Unity and Unreal Engine, to providing continuous support and tools to develop serious games (SG) and VR environments. A Virtual Reality Flight Training Experience (VRFTE) has been created to train pilots' flows using a SG concept. The cost of accurate simulators is high, making them inaccessible to many trainee pilots, and training is achieved using Paper Tiger (a poster of the cockpit to perform their training).

Learning and retention can be improved using serious videogames that include feedback, decision making, and physical fidelity, compared to traditional training. This research proposes VRFTE, a simulation with the benefits of a serious video game, can improve memory retention. VRFTE implements physical fidelity using VR technology to immerse the user into an aircraft Cessna 172 T41 Mescalero emulating the real size of the plane and cockpit controls. VRFTE uses the sensors of the HMD Oculus Quest 2 to implement hand tracking interaction and provides interactive visual and audio feedback when users are performing pilots flows.

The study has divided the participant sample into two separate groups, Paper Tiger Training (the control group) and VFRTE Training (the experiment group) to compare them. Five simple flows, that pilots perform on the ground, have been extracted from the manufacturer's manual of a Cessna 172 T41 Mescalero and are implemented for both training groups. A flow is a specific task that involves the pilots pulling levers or pressing buttons for a particular purpose.

Fifteen people participated in the study, eight for VRFTE Training and seven for Paper Tiger Training. Each group had two sessions with one week between them, one for training the other for assessment. As participants were not expected to have any experience using and aircraft before, participants had an introductory video explaining the purpose of the study and the training to be performed. The training for Paper Tiger sessions used a poster that identified the cockpit controls with letters that were correlated to the flying instruments in the actual cockpit. In other words, participants were able to match the letters from the manufactures manuals and the cockpit poster to execute the flows.

Whereas, the VRFTE module provide the same training experience but was presented in a VR environment. For both sessions, an evaluation of the correctness and completeness of the established flows was used to determine memory retention.

A memory retention score was created to assess how well the participants performed in the evaluation. The memory retention score was based on one flow called “Engine Failure During Take-Off Roll.” Six steps in a specific sequence needed to be performed to execute the flow correctly. Moreover, the cockpit controls had multiple states. Therefore, six steps and six states were calculated for the memory retention score. Memory retention was assessed one week after the training,

Results have demonstrated that participants that engage in VRFTE perform better than poster training. Therefore, this might be an alternative type of training for students that want to become pilots. Also, expanding this research could be a great opportunity for the aviation industry to consider implementing VR training as an alternative tool compared to simulators.

ACKNOWLEDGEMENTS

This is my first time creating a thesis document and working on developing software for VR. I was excited and scared because balancing my personal life, workload, and university studies were very challenging. My mother tongue is not English, making it difficult to express my ideas and findings in this research. However, I think this journey has been challenging but also rewarding with all the knowledge acquisition.

Thanks to my family Juan Manuel Rangel, Cristina Florez, and Joaquin Rangel, their remote support and wishes keep me motivated.

Ana Maria Casas, my wife and the most important person in my life, I could not finish this thesis without her. Her background in psychology helps me to reduce my anxiety and stress feelings regarding this study.

Luis Morales Trujillo, we have joined forces to create this VR Flight Training experience without his experience as a pilot, technical abilities, and 3D design. The application will not be such a fantastic product. Thank you, mate, for all your supports in this journey.

Finally, Dr Brett Wilkinson, thank you for all your advice and support during my research; your encouragement was valuable and helped me overcome many challenges.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE - INTRODUCTION

Students that want to become pilots before using a real aircraft need to train rigorously in a safe environment. Training programs for pilots can become highly expensive as the cost of accurate simulators (also referred to as physical fidelity) makes them inaccessible (Pope 2019). Typically, to mitigate costs, students in their early phases of training need to learn how to operate an aircraft using a cockpit poster and the aircraft operating manual (Alce et al. 2020). The cockpit poster is referred to as Paper Tiger, which helps them familiarize themselves with the flying instruments located in the aeroplane and learn how they operate it.

Operating an aircraft could be very complex. That is why repetitive training needs to be done, so pilots can memorise a series of patterns, called flows, before they are exposed to costly simulators or the real plane (Alce et al. 2020). A flow is a specific task involving the pilots pulling levers or pressing buttons for a particular purpose, such as turning on the plane's engine or checking the flying instruments (Checa & Bustillo 2020). While Paper Tiger can be a cheap option to train, they lack physical fidelity, and realism is not present. Moreover, Paper Tiger do not provide any feedback or training instructions to follow, which requires the trainee pilot to constantly check the manual for reference and assume that the procedure performed with the cockpit poster is correct (Alce et al. 2020).

Based on these disadvantages, this project sought to build a Virtual Reality Flight Training Experience (VRFTE) with the components of a serious game (SG) to explore the benefits of this technology compared to the Paper Tiger training. Moreover, there is no substantial research comparing traditional poster training to virtual reality (VR) applications, which is interesting to understand the effect of the application aiming to answer the question **Does Virtual Reality Training Improve Memory Retention of Pilot Flows?**

SGs have been used to explore the advantages that they can provide to learning where the game itself is a mediator between education and learning (Ahrens 2015). The increasing usage VR has seen commercial releases of head mounted display (HMD), and a drive from computer game engines, such as Unity and Unreal Engine, to providing continuous support and tools to develop SG and VR environments (Checa & Bustillo 2020).

The project sought to explore VR and SG components and the potential player motivation and learning effects that interactive training can produce (Westera 2019). Previous research has identified features that can enhance learning in games (feedback, decision-making, and physical fidelity) which have been included in the design of VRFTE. Moreover, VR can augment physical fidelity, which is crucial in pilot training, where pilots need to rely on accurate simulators to improve learning outcomes (Checa & Bustillo 2020).

This thesis aims to investigate the educational purpose of VR training for learning pilot flows and assess long term memory retention. Moreover, it will explore the concept of a SG, which features improve learning and memory retention, and how memory can be correlated with training using VR to create physical fidelity. To accomplish this, a VR application was developed using SG components and compared to the traditional training pilots undertake using the Paper Tiger posters.

Five simple flows, that pilots perform on the ground, have been extracted from the manufacturer's manual of a Cessna 172 T41 Mescalero. As a reminder, this aims to evaluate long-term memory retention rather than create a virtual application to replace a flying simulator. Two types of training were developed: the VRFTE application and the Paper Tiger poster. Participants were recruited to train with these approaches in two sessions of Virtual Reality Training VRFTE (experiment group) and Paper Tiger Poster Training (control group).

One session was for training and the second session was for evaluation. Each session was separated by a week to test long-term memory retention in both training methods. Long term memory retention was assessed in the correctness and completeness of steps for a specific flow.

The flow selected for evaluation is named "Engine Failure during Take-Off Roll", which is used to turn off the plane to prevent an accident. The data was extracted from logs generated during the execution of VRFTE and by observing the participants in the Paper Tiger Poster Training. The data was used to draw conclusions and attempt to answer the question Does Virtual Reality Training Improve Memory Retention of Pilot Flows?

Chapter two discusses the literature review, the importance of memory retention, SG components that affect learning, as well as applications and research into VR. Chapter three discusses the software design and development process and the challenges faced. Chapter four outlines how the experiment was conducted in detail: The recruitment process, how the training sessions were designed and how the evaluation was conducted. Chapter five provides an analysis of the memory retention scores of VRFTE and Paper Tiger Poster Training. This is followed by Chapter six that summarises and concludes the thesis, outlining key discoveries and contributions as well as presenting the future work that can be done in this field.

CHAPTER TWO – LITERATURE REVIEW

SG, memory retention and VR are explored in this chapter. The research will aim to understand the concept of learning and memory retention, the different types of memory, and what the researcher has found to be used in serious video games to train memory effectively. Moreover, the research will search for the link between memory retention and learning in Serious Video Games and how memory retention has been assessed in these types of games. Furthermore, it explores VR interaction in training and which components of games have been used in learning to improve memory retention using VR as a tool.

2.1 The Importance of Memory and Knowledge Retention.

As the main focus of the research is related to knowledge retention and how it relates to the VR environment, it is essential to understand the concept of memory and how memory works. As Bechtold et al. (2018) suggest, memory is described as a cognitive process that responds to a series of life events. Memory is not a single function that recalls information in the brain. Instead, memory involves multiple memory modules of a complex nature. There are two specific types of memory explained in the literature: short term memory and long term memory. Short term memory recalls as a cognitive process that can last seconds or a couple of hours; then, it is discarded. Long term memory includes the memory that is resistant to interference and provides consistent information. The project aims to evaluate long term memory using VR as a tool.

As Brem, Ran and Pascual-Leone (2013) suggest, different types of memory are classified in short and long term memory, such as declarative memory, semantic episodic, non-declarative, and procedural, which are shown in Figure 1.

Removed Due To Copyright Restriction

Figure 1 Describes the types of Memory in Correlation to Learning(Brem, Ran & Pascual-Leone 2013).

The research presented in this thesis focuses on a particular type of memory: procedural memory. Procedural memory can be defined as the memory that is exercised using motor skills through repetitive processes or practice (Brem, Ran & Pascual-Leone 2013). Procedural memory is acquired implicitly, which means that repeated physical movements can be performed and learned without complete awareness of the ultimate goal of the task (Bo, Jennett & Seidler 2012).

Moreover, procedural memory is more related to long-term memory as it is described as implicit memory, which refers to mechanic procedures such as riding a bike or getting dressed. The VRFTE was designed to pay strict attention to this type of memory and concentrate efforts to improve learning and memory retention using motor skills for pilots' flows in VR.

Another important term related to procedural memory is working memory. Working memory can be defined as the process to store limited information to execute cognitive tasks (Morrison & Chein 2011). Working memory has been found a strong predictor of peoples' capabilities such as mathematical skills, reading comprehension, problem-solving and language acquisition (Morrison & Chein 2011).

Pilot flows require detailed motor skills and series to be performed in a specific order. Seidler, Bo and Anguera (2012) suggest the learning process in motor skills is a combination of two-components buffer loading and dual processing. Buffer loading is when participants can split the sequences into chunks and are strongly related to working memory. Dual-process is more associated with the cognitive-motor process, which helps the participants select the required interaction. Dual-process will be presented in the research when the player uses a control panel in an aircraft, such as moving a lever or pushing a switch. The research aims to evaluate the knowledge retention of the sequences performed associated with a flow. The memory retention test evaluates explicit and procedural memory as participants are asked to identify flying instruments in the cockpit and interact with them to achieve the state of that instrument in the flow (Shapiro & Krishnan 2001).

A survey conducted by Seidler, Bo and Anguera (2012) has found that participants learning complex sequences need to chunk the content into minor procedures, not more than 3 or 4 sequences per procedure, suggesting that there is a capacity in the visual memory of no more than four sequences. Furthermore, as (Chun 2011) mentioned, understanding the capacity of visual working memory can be crucial for learning this concept. Therefore, while designing this research, an approach for training pilot flows was to separate the flow sequence into chunks, limiting the steps of a flow to four actions while training.

This research will not explore in detail the concept of working memory. Still, it is essential to acknowledge that this type of memory is necessary for the learning process for procedural memory.

2.2 How Serious Games Components Affect Education and Knowledge Retention.

The SG term has been introduced as a game developed pursuing a goal in which the primary focus is not entertainment (Ahrens 2015). Numerous SG for training may differ in their format but mostly are presented as quizzes, puzzles, a virtual world with interactive training, or motor rehabilitation, each with a specific goal, without ignoring the action to play itself (Westera 2019). In a game, play involves an act that is a leisure activity that is inherently for fun, a state to relax the body, a voluntary action that expresses freedom (Ruckenstein 1991). However, a SG concept challenges the play component in the game where it needs to balance how a SG can be created? That is enjoyable, pleasant, attractive to many players and still leads the player to their serious goal. A serious goal can be learning in a topic or training, motor rehabilitation, enhancing an ability such as memory and numeracy skills (Laamarti, Eid & El Saddik 2014). As Susi, Johannesson and Backlund (2007) suggested serious video games have been widely used in multiple sectors such as government, education, corporate, healthcare. Some clear advantages of SG are that they can provide instruction in a dangerous environment. Whether the player could be in real danger or a mistake could be life-threatening

However, to understand a SG first, it is essential to know which are the primary components of the game and how they interact with the player. According to Schell (2008) the four primary components of a game are Mechanics, Story, Aesthetics and Technology. These are represented in Figure 2.

Removed due to
Copy Right
Restrictions

Figure 2 The Primary Components of a Game (Schell 2008).

As Schell (2008) suggested, mechanics can be described as how the player interacts with the game. Do they have controllers? How the game receives the input of the player. The story involves the play in a sequence of events and the process of emergent narrative. While the game progresses, it is the way the mechanics affect the game and how the characters and environment are related that helps unfold the story. Technology can refer to the interactions that the game and the player can perform, the use of goggles, controllers, and platforms, and is strongly associated with aesthetics. Last but not least, aesthetics refers to *"how the game looks, sounds, smells and feels" (Schell 2008)*.

Numerous studies have analysed the entertainment elements of games to be applied in SG and how games can affect education. The research will focus on the aspects that can improve learning and knowledge retention. How SG can affect learning, and which components of the game can enhance knowledge retention? The research aims to investigate these learning elements and apply them to the VR experience for pilot training flows VRFTE.

A study conducted by Hobo et al. (2017) compared the differences between computer simulated training that provides feedback and decision making in dentistry learning materials with another that does not. Their study indicated that the decision-making and feedback incorporated in the computer simulated environment, improved the participants' knowledge retention and reduced anxiety levels. To achieve that, they have compared knowledge and anxiety levels on two different groups, those that received computer simulation training (Feedback and decision-making) versus traditional training. This study provides motivation for the benefits that computer simulations may provide and the development of the VRFTE system.

Another important discovery found in the research was how feelings could affect learning. An example of those feelings could be happiness, which creates enjoyable experiences essential for the players' individual state of mind. Therefore, serious gaming also generates positive or negative emotions within the player, leading to maintaining or improving their level of engagement, which is a crucial factor that can determine if the player will achieve the game's goal (Perttula et al. 2017).

From the basics elements of the game, Kiili et al. (2012) suggested that SG should have flow state in their games. Flow state can be defined as a person's state when it is entirely immersed in its activity (Kiili et al. 2012). It is a state where the player can focus on the task at hand, forgetting unpleasant feelings (Kiili et al. 2012). Engagement is a crucial part of educational games and obtaining the state of flow improves play time and motivation. Engagement maintains players attention to the point that if the task is complex, the player will keep their interest to beat the game's challenge (Kiili et al. 2012). Playing a game should not be effortless; overcoming difficulty in games and the ability to demonstrate skill or mastery, will maintain players interaction.

When games become very challenging, players can experience anxiety instead of pleasure. Moreover, as Ninaus et al. (2015) suggested, the flow state is associated with the loss of awareness in a specific place, the maximum concentration on a task to be executed, lack self-awareness, and unaware of the passage of time. Their study had an important discovery related to the research presented in this thesis, where gaming elements such as a progress bar (shows the progress of the player during their learning), player scores and difficulty levels improve learning performance in working memory tasks. This discovery motivated the research to evaluate if these type of gaming elements could be implemented in VFRTE.

Training related to working memory is critical to the research. It is strongly related to procedural memory, as the tasks evaluated by the study are pilot flows that need working memory to be performed (Seidler, Bo & Anguera 2012). Therefore, this enforces the concept of a SG to be developed in the research as gaming elements can improve performance in learning (Ninaus et al. 2015). In addition, Morrison and Chein (2011) have suggested that working memory can be trained and can potentially improve cognitive skills. This statement keeps enforcing the concept of a game to train and develop pilots' flow training.

Kiili et al. (2012) and Ninaus et al. (2015) have identified essential concepts that can be included in the VRFTE simulation to obtain flow.

- SG require clear goals to direct and focus the interest of the player to progress within the game.
- Feedback incorporated in games allows players to understand their mistakes and track their performance, which helps challenge them.
- Playability: interaction with the game needs to be effortless, without compromising the difficulty level, as difficulty challenges the player to improve their ability or skills.
- Sense of Control: players need to believe and experience an improved performance while playing the game repeatedly.

Chittaro and Buttussi (2015) evaluated an interesting comparison of a SG developed in VR for aviation safety compared to the safety manual usually provided by aviation companies that explain the aviation safety procedures. Aviation safety is a complex topic as passengers are not engaged to learn the material. Chittaro and Buttussi demonstratedthat emotional states can also improve memory retention. Elements such as harming the player's avatar are ways to communicate to the player and provide feedback about an incorrect decision. Moreover, the study concluded that the aviation safety VR game was more engaging and fearful, producing intense emotional arousing experiences, leading to better performance in the knowledge retention tests. The inclusion of game mechanics to generate an emotional response in the player was something explored in the design of the VRFTE prototype .

2.3 Virtual reality and Serious Games

VR has been defined as an interaction with a virtual world itself controlled by a set of hardware (Steuer 1992), as a simulated environment where there is a human presence and their perception of their surroundings. Another definition of VR is "***a computer simulation environment that can imitate a physical presence in real or imagined worlds" (Howard 2017)***. VR can imitate the real world, which is one of the main reasons that have captured the research interest to develop the study in VR. The idea is to build a purposeful experience involving senses and spatial reconnaissance (Dale 1969). Figure 3 represents the cone of learning where Dale has suggested that Learners retain more information by what they "do" as opposed to what is "heard", "read", or "observed" (Dale 1969). The experiences that provide more exposure to senses are directly related to knowledge retention from top to bottom. The cone of learning has been enhanced, suggesting percentages for learning and knowledge retention that can be misleading as no substantial empirical evidence supports these percentages (Dwyer 2010). Education can also be affected by multiple factors such as gender, intellectual ability, reading comprehension (Dwyer 2010). Even though the study is interested in what Dale (1969) has suggested as long term memory retention is principally affected by our repetitive actions.

Removed due to Copy Right Restrictions

Figure 3 Edgard, Dale Cone of Experience (Dale 1969).

However, the usage of VR, particularly in education, has been delayed because the hardware and cost to use the system were expensive, as such was initially limited to military and research application (Youngblut 1998). As more affordable head mount displays were developed, multiple applications emerged for VR applications in various fields such as health, mathematics, computer science, project management, science, and language (Checa & Bustillo

2020). During initial investigation and development, a clear advantage of VR was identified: realism was provided in training and education in dangerous situations or hazardous environments such as oil, gas, and electricity industries without compromising the health and safety of employees (Wang et al. 2018). This advantage provided motivation to the researcher and justification for how VR could be important to make an accessible training program for pilot flows.

Other vital advances in health care are the practicability of VR in exercising the muscle memory for healthcare personnel manipulating medical instruments and how the human body will be treated, such as surgery or medical procedures emulating a person's body (Desselle et al. 2020).

As Checa and Bustillo (2020) suggested, it wasn't until head mount displays improved and developed to be accessible for people, reducing their prices, and particularly with the launch of Oculus Rift, that VR started to get more attention from the general public. In addition, computer games engines such as Unity and Unreal Engine have been providing continuous support and tools for the development of games and have facilitated the tools to create VR environments for both traditional entertainment and SG (Checa & Bustillo 2020). These facts posed a question for the researcher on why training simulators have not been migrated to VR and why there is a lack of research in memory and training using VR for pilots flows.

Traditional, oral-based education lacks the spark of interaction compared to the advantage attributed to VR and its realism. The concept of serious gaming and VR can expand the learning to another level where users can become active participants in the virtual world and learn differently (Checa & Bustillo 2020). Therefore, VR is considered an excellent tool to improve immersion in learning. A large amount of research in VR has been focused on physical rehabilitation and motor rehabilitation. Howard (2017) has suggested that virtual reality can be far more effective in rehabilitation programs than traditional ones. VR can increase excitement, physical fidelity, and cognitive fidelity in rehabilitation programs (Brem, Ran & Pascual-Leone 2013). These qualities exposed in VR are fascinating in the research, as procedural and implicit memory can be trained using repetitive movements (Brem, Ran & Pascual-Leone 2013). Therefore, as VRFTE and rehabilitation programs require repetitive movements, following specified procedures to assess improvements, the study will explore if the identified qualities in the rehabilitation programs can be applied to the training in VRFTE.

Cognitive fidelity can be achieved if particular tasks are included during the training program developed in VRFTE. A clear example of this is to have some status of switches or levers in a specific flow that the player will need to check or change regarding different scenarios. The cognitive fidelity in flying simulators has been found to improve the learning of the association on flying instruments in the cockpit (Koglbauer 2016).

Physical fidelity is achieved by providing realism to the actions executed in a rehabilitation program (Howard 2017). The research will provide physical fidelity, as the environment created in VR is carefully measured to be the same size as the actual plane cockpit of the Cessna T41D Mescalero. Hence, the player will reach levers, buttons, throttle, yokes, and flying instruments in the exact position in the cockpit.

VR can improve excitement, boosting participation in rehabilitation programs making repetitive movements more interesting (Ludlow 2015). Excitement is a desirable feeling for VRFTE as it is one of the components to achieve the state of "flow" in games (Kiili et al. 2012). VRFTE will combine the elements of a game and VR photo-realism for training pilot flows which have been proven to increase knowledge retention (Ninaus et al. 2015). To train pilots, the players need to execute repetitive movements in the aeroplane cockpit using flying instruments.

VR can be a different tool to provide an exciting environment for learning. As Noble (2002) suggested learning outcomes in flying simulators were better than in the actual planes for students starting their careers. The research wants the improve the attention, interest and participation of players in the training program. That is why VR is used as a tool to increase players' interest and engagement, as suggested by Ludlow (2015) and Howard (2017) during their studies in rehabilitation programs. The study presented in this thesis argues that excitement, physical fidelity, and cognitive fidelity in the training program will be critical features of the VRFTE to increase the chance of the state of flow, which can improve the outcomes of the memory retention tests.

2.4 Learned Concepts to Apply to the VR Prototype.

Flying simulators that emulate the precise details of a plane’s cockpit, need very complex hardware and cost multimillions of dollars (Koonce & Bramble Jr 1998). Therefore, the cost of accessing accurate simulators can be prohibitive, making them inaccessible to pilots (Pope 2019).

Research has shown that VR can improve daily activities and reduce performance error for people who have experienced mild cognitive impairment due to the realistic environment (Coyle, Traynor & Solowij 2015). This real environment can be applied to VRFTE, exploring the possibility to design a cockpit where a pilot can train as if they were in an aeroplane. Game features can improve knowledge and memory retention, such as difficulty levels, identifying the player, progress bars, high scores, or achievement badges. Also, Perttula et al. (2017) suggest that developing a game that promotes a state of flow in the player will positively affect their perception of learning and performance. However, VR has some disadvantages which the research will seek to address, such as lack of feedback, inaccuracies of user input, VR motion sickness, usability, insufficient realism, all of which can make the learning process complex (Kavanagh et al. 2017).

Gamification and flow can improve players' memory retention levels as they are motivated to engage and progress in their training (Ninaus et al. 2015). Moreover, VR can enhance teaching methods, providing more exposure and engagement for specific materials, such as learning pilot flows, which can become repetitive and boring (Chittaro & Buttussi 2015). Another critical related discovery is that VR can increase participation, motivation and interaction for education and training at a low cost (Wang et al. 2018).

VRFTE is also an interesting approach to finding relationships between working memory and procedural memory and understanding any relationship between both. Existing research explains that working memory is a temporary memory to execute procedures, but it is highly important for knowledge retention and cognition processes (Morrison & Chein 2011).

Developing a serious video game in VR also need some considerations, that the research aimed to follow, starting with an idea and project to develop the game. Creating a SG in VR requires essential components that cannot be omitted: target audience and application domain (Checa & Bustillo 2020).

Based on the literature reviewed, VRFTE will implement a SG concept in VR and the notion of the state of flow, to evaluate memory retention. Critical facts such as feedback and decision-making are some of the main topics of the prototype to be developed for this research. Moreover, how procedural memory can be used in VR as an effective tool for long-term memory.

Finally a critical feature in the literature identified is that the participant's emotional state can also improve performance and knowledge retention, such as engagement. People tend to think that negative emotions such as sadness, boredom, and hopelessness can generate bad learning outcomes and positive emotions good learning outcomes. On the contrary, Cheng, Huang and Hsu (2020) suggest that negative emotions can have an essential role in learning and retention. Moreover, emotions are linked to human learning and development where perception, attention, memory and decision making can be affected (Pekrun 2011).

2.5 A Future Perspective of VR

Before concluding this chapter, an essential reflection of the future of VR ahead. As Lanier (2020) suggested, VR will become as expressive and engaging as a child's imagination. Communication has language constraints where people use their vocal cords and writing symbols to express or transfer information which is a limitation. VR and technology can transcend when software development creates things as fast as we think or feel them in a virtual world. The cultural context of technology has changed from survival to ***"make things of such a seductive beauty that they distract us from mass suicide"*** (Lanier 2020).

CHAPTER THREE – SOFTWARE DEVELOPMENT

VRFTE has been developed in Unreal Engine 4.26. Unreal Engine is a game development environment created by Epic Games and its founder Tim Sweeney. Unreal Engine was designed to provide a tool for games, architecture, automotive and transportation, film television, simulation, and VR development tools (Epic Games 2021). Some of the Unreal Engine functionalities are world building, animation, gameplay, simulation, rendering effects, lightning, virtual production, content management, and a complete development tool that suits the need of the research presented in this thesis (Games 2004-2021).

This tool was chosen because of the researcher's experience. Furthermore, the broad development community, tutorials, and wide support of game creation and VR have been exceptional to achieve this virtual experience.

VRFTE has the following aspirations, which have been defined as part of the design workflow described by Checa and Bustillo (2020), see Figure 4:

- VRFTE has followed design procedures to establish the requirements and goals of the application.
- VRFTE is intended for pilot training in basic procedures to establish the relationship and benefit of a virtual environment compared to a traditional training program.
- VRFTE is intended for students or people with experience or no previous experience using an elemental plane such as Cessna 172 T41D Mescalero.
- VRFTE has five designed flows that will be measured in a memory retention test.
- VRFTE aims to provide basic training on how to perform the flows and the flying instruments that the player should manipulate to achieve the desired outcome to perform a flow in the correct order.
- VRFTE has been developed using Blueprints and C++ programming code to control the functionality of the application.

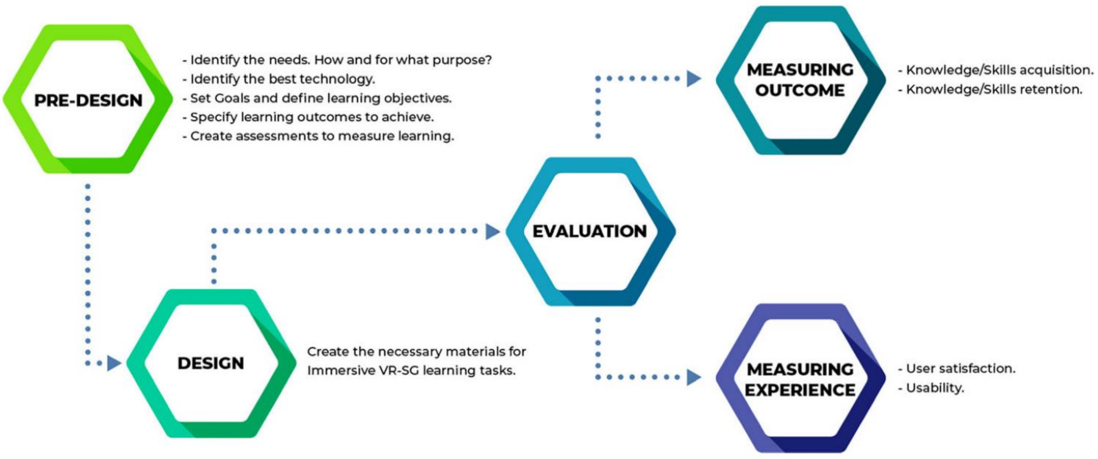

Figure 4 A Design Approach of a Serious Video Game (Checa & Bustillo 2020).

The software development chapter is divided into four sections to explain the features developed and challenges faced during this phase of the project. Implementing hand tracking, designing and developing the behaviour of the cockpit and flying instruments, granularity in bone Collisions and Grabbing functionality.

3.1 Implementing Hand Tracking

The first challenge presented was to configure and utilise the functionality of the Oculus Rift HMD to use their sensors and track hand movement with the Unreal Engine. Following multiple tutorials and using Facebook for developers and Unreal Engine documentation, hand tracking was implemented.

Removed due to Copy Right Restrictions

Figure 5 Hand Tracking Architecture In Unreal Engine Oculus Quest 2.0 (Facebook Technologies 2021)

In Figure 5, there is a representation of the architecture of hand tracking and Unreal Engine. The configuration of hand tracking with Oculus components in Unreal Engine needs to be performed, including the controllers. The application will not recognize the hands as a part of the virtual experience if the controllers are not added to the configuration. As seen in Figure 5, the Hand controller component has been designed as a part of the motion controller component (Facebook Technologies 2021).

To represent the player in the world using hand tracking, VFRTE has been divided into different classes to parametrize the code in a structured manner. **`VR_Character`** as the VR character, **`VRHand`** (left hand of the character), **`VRHandRight`** (right hand), and **`BPCOculusHand`**.

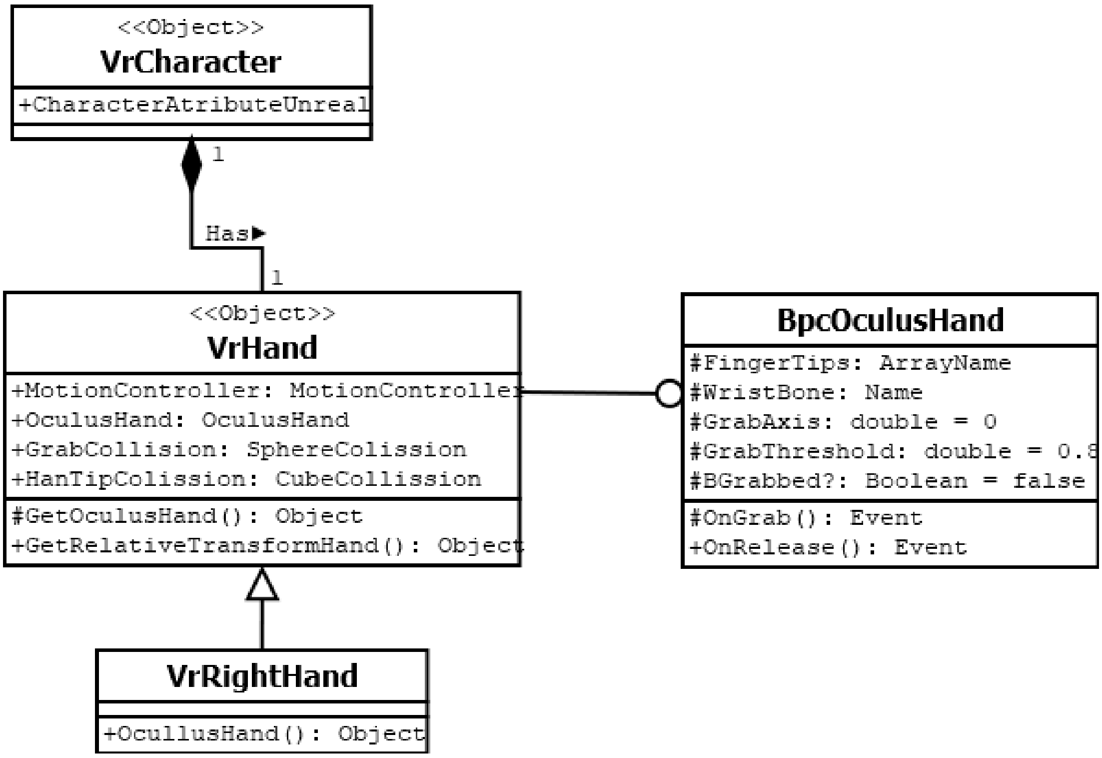

Figure 6 Spawning Hands-on Character.

Figure 6 shows a small UML diagram and the methods implemented in VRFTE. The **`VRCharacter`** class is a class direct from Unreal Engine, which creates a character in Unreal Engine. **`BPCOculusHand`** is a class that inherits from the default Oculus Quest 2 support classes to perform hand tracking. This class, **`BPCOculusHand`**, has been modified to include created events to grab objects in the cockpit and track the grabbing functionality. **`VRHand`** is where Oculus Quest 2 configurations have been made to spawn the hands and use all the functions of the Oculus in the VR environment. Moreover, **`VRHand`** is the primary class that has the collisions defined to interact in the VR world. The research aims to provide an authentic experience similar to the interaction achieved in a physical flying simulator for specific pilot flows, as Socha et al. (2016) have suggested, simulators can improve pilot confidence and flying habits and improve performance handling errors in flight procedures.

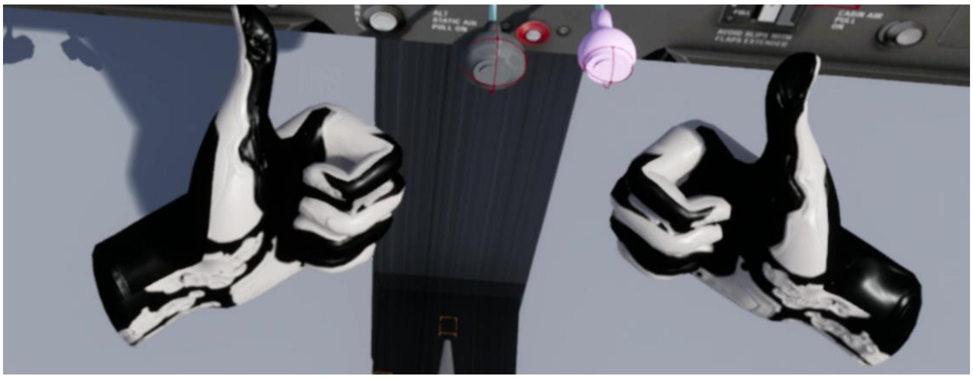

Figure 7 VRFTE Preview of Hand Interaction Implemented.

Figure 7 shows a preview of the hands spawning on VRFTE software using the Oculus hand skeletal mesh that maps the bones of the hands to perform hand gestures.

3.2 Designing and Developing the Behaviour of the Cockpit and Flying Instruments.

In this part of the development process, the study has developed the interaction of the control panel and the cockpit.

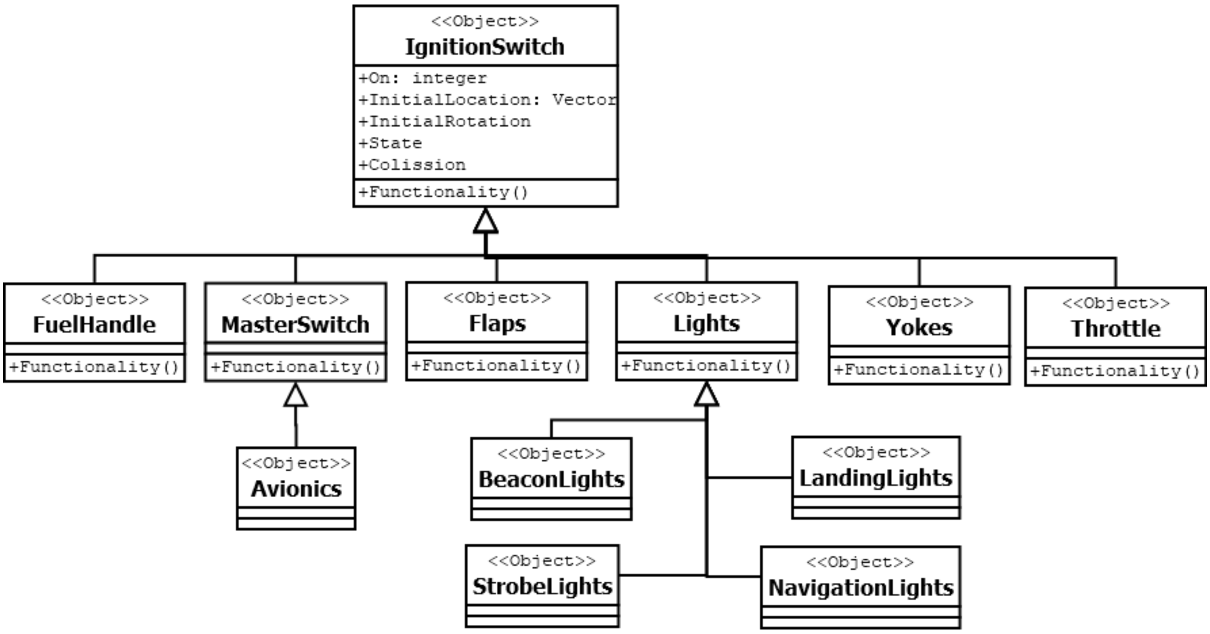

Figure 8 Control Panel Behaviour.

Figure 8 shows a general perspective of each element implemented in the cockpit. As a general rule, each flying instrument has a state, initial position, and rotation in the world. Depending on the switch, their functionality defers, but in this case, it gives a general overview of the structure used to implement the cockpit's functionality. Furthermore, it is crucial to note that each flying instrument has a collision that will be triggered as there is an interaction with the hands in VRFTE. Communication was achieved using casting and collision events between the hands and the cockpit controls. This casting helped connect hand tracking functionally with the world and interaction with levers, buttons, yokes, and throttles, among the other cockpit controls.

3.3 Granularity in Collisions

A significant challenge in the software development process for VRFTE were the granularity of the collisions. The problem was that the hands had an internal sphere collision that triggered multiple levers simultaneously destroying the precision in their hand tracking functionality required for the experience. The solution was to create a new collision in the fingertip of the index finger of each hand and reduce the size of the sphere collision located in the palm.

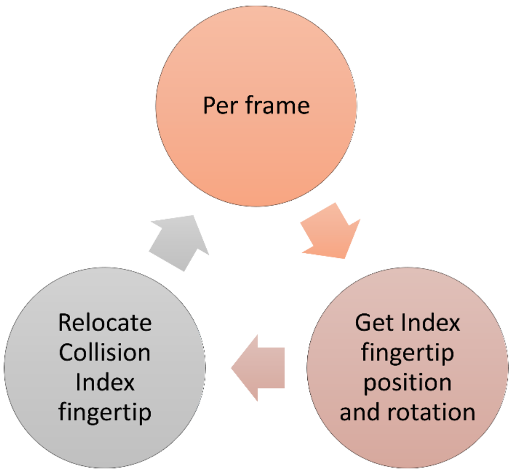

Figure 9 Improving Collisions.

Figure 9 shows the cycle executed per frame in VRTFE that was the solution implemented to improve collisions in the hand tracking functionality. Every static mesh (flyings instrument in the cockpit) can be activated based on the object’s collision meshes and the index finger interaction in VRFTE. In other words, each object contained a specific spheric or box collision; when the index finger interacts with this a collision generates an event that triggers the desired movement or animation, displaying the feedback to the user.

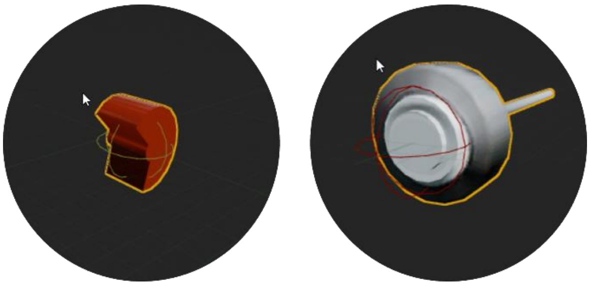

Figure 10 VRFTE Handling Collisions Master Switch, Throttle.

Figure 10 shows how items created in Unreal Engine editor and the collision are located in two different types of cockpit controls, such as a master switch on the left and a throttle on the right. The objects have been created using the actual names of the elements of the aeroplane. The red wireframe represents a collision zone that the user cannot see, but the cockpit control will perform an action on the plane system once the user interacts with that collision zone.

Important features added to VRFTE in SG development are decision making and feedback. Research has shown that feedback plays an essential role in improving memory retention and knowledge, as is suggested by the study conducted on flight safety training by Chittaro and Buttussi (2015). Decision making also improved performance in knowledge retention in the dentistry study (Hobo et al. (2017). Therefore, constant feedback is seen In VRFTE when the player interacts with any button, lever, switch, yokes, throttle in the aeroplane, indicating the state of the interaction. As some switches turn off or on, and others have different conditions, VRFTE shows the state of the interaction to the player.

Figure 11 Displaying Feedback.

Figure 11 shows the feedback showed by VRFTE when a user has interacted with the master switch (identified in red colour). Decision making will be assessed when the player will need to perform a specific pilot flow in the simulation. The study will evaluate the correct interaction of touching switches, pulling levers, the correct end state of a cockpit control, and executing the correct order of the flow.

3.4 Grabbing Functionality.

The study aims to provide a better interaction with some levers and the yoke in the cockpit using a grabbing functionality.

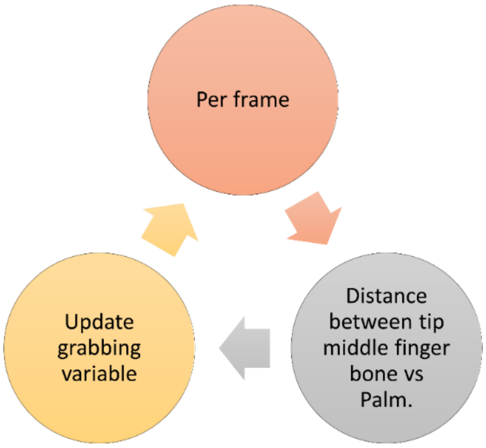

Figure 12 Grabbing Functionality.

Figure 12 shows the cycle that was performed in the grabbing functionality. This idea is to understand when the user closes their hand and triggers an alert to VRFTE. Therefore, the cycle that runs per frame can provide the distance between the fingertip and the palm. In other words, when the palm and the fingertip's distance reaches a fixed variable, the software will understand that the user has closed their hand.

3.5 VRFTE Training and Evaluation Methodology Software Implementation

The training and evaluation methodology was one of the most challenging processes in VRFTE to implement. Figure 13 shows the loop conducted to perform the training of each flow.

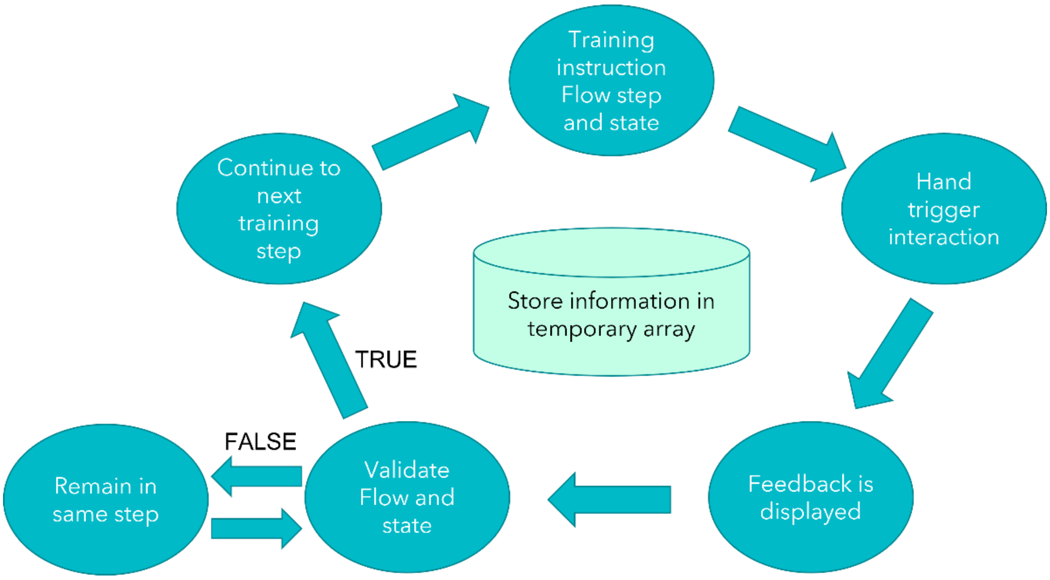

Figure 13 Training Module Workflow.

VRFTE displayed the training instruction to the participants and validated the input of the hands when there was an interaction. This interaction initiated feedback and validated the flow and state of the training instruction. Depending on the validation, the training program would continue with another flow step or remain on the same step, allowing the participant to attempt the correct process to complete the step. Logs were stored in an array for each interaction. Table 1 shows an example of the data recorded in the system; the data is recorded in a text document where each field is separated with a comma to facilitate future analysis and export in an Excel spreadsheet.

Table 1 VRFTE Data recorded from Participants Interaction.

Participants ID	Cockpit interaction	State	TimeStamp	Training activated?	Number Flow
A012	Throttle	Idle	61.5	1	Flow1
A012	Parking Brake	Activated-Applied	65.4	1	Flow1
A012	Wing Flaps	Retract	69.3	1	Flow1
A012	Mixture	Cut Off	75.2	1	Flow1
A012	Ignition Switch	Off	78.9	1	Flow1
A012	Master Switch	Off	85.2	1	Flow1

The data is stored in a temporary array; after the user progresses to the next flow, the system will dump all the information saved to the text file and reset the collection. The training methodology will show how a participant can change to different flows in their training tutorial for further reference.

CHAPTER FOUR – METHODOLOGY

VRFTE has been developed in Unreal Engine. The interface between the computer game and the participant will be the Oculus Quest 2, a VR Head Mounted Display (HMD). The prototype will be focused on a stationary seated interaction. The trainee will not need to move their entire body, just their hands interacting with the control panel of a Cessna T41Mescalero. It is expected that this seated interaction will mitigate some of the issues associated with VR sickness. Figure 14 shows the cockpit view presented to users when interacting with VRFTE.

Figure 14 VRFTE Cockpit Preview.

An ethics application was submitted to the Human Research Ethics Committee at Flinders University and approval for Project ID 4450 was provided. Participants were recruited using a bulk email from Flinders University College of Science and Engineering. The email sent to students in the College of Science and Engineering at Flinders University provided an outline of the research and captured the participants' interest. The email was sent through the teaching program learning management system portals and was not connected to any specific topic. The email contained information about the VRFTE, the aims of the experiment and project, the requirements for their time, the experience they would be engaging in, and where the study was to be held. During the investigation participants would have two sessions to evaluate memory retention.

The email also contained instructions on replying to the email to indicate their willingness to participate. Once the volunteer had shown they were interested in being part of the evaluation and confirmed, they were provided with the Participation Information Sheet and Consent Form along with a time and location for the assessment.

After the participant's registration, sessions were conducted in the Interaction Research Lab in the Tonsley building. The recruitment process started one month before the date of the experiments. Participants were students from Flinders University who may have or may not have had experience in a flying simulator or VR itself.

To evaluate the research question "Does virtual reality Improve memory retention in Pilots flows," the VRFTE research conducted two sessions, the first session for training memory retention and the second session for evaluation.

Participants that had been recruited for the study were divided into two different groups, Poster Training (control) and VR Training (experiment). The study aimed to compare learning outcomes from VR training compared to traditional paper based training. This methodological approach was based on previous research where studies confirmed that memory retention outcomes could be enhanced using interactive training with a SG concept (Chittaro & Buttussi 2015) (Hobo et al. 2017). As the first step of the training, both groups (VR Training and Poster Training) were be asked to watch an introductory video. The introductory video provided essential concepts of a flow, why pilots need to know those flows and a general overview of the cockpit explaining the flying instruments and how they work.

As the introductory video advanced and provided a general overview of the aeroplane and the cockpit, each flow was described in a simulator. The study did not expect that participants would have any experience with an aircraft before. This introductory video helped participants familiarise themselves with the concept of this study and what type of training they could expect in the training sessions. Moreover, it was essential that participants understood that as the study involved memory retention, they would be assessed in the correct completion of steps and the flow sequence to evaluate memory retention.

The second session was conducted one week after the first to evaluate long term memory retention with an assessment exercise. VR Training and Poster Training groups had completely separate sessions to avoid exposure to a different activity for each group.

Poster Training and VR Training groups were exposed to the same model plane's cockpit and asked to perform the five flows designed. Figure 15 shows is the experiment schedule for each group in the first session of interaction with the participants.

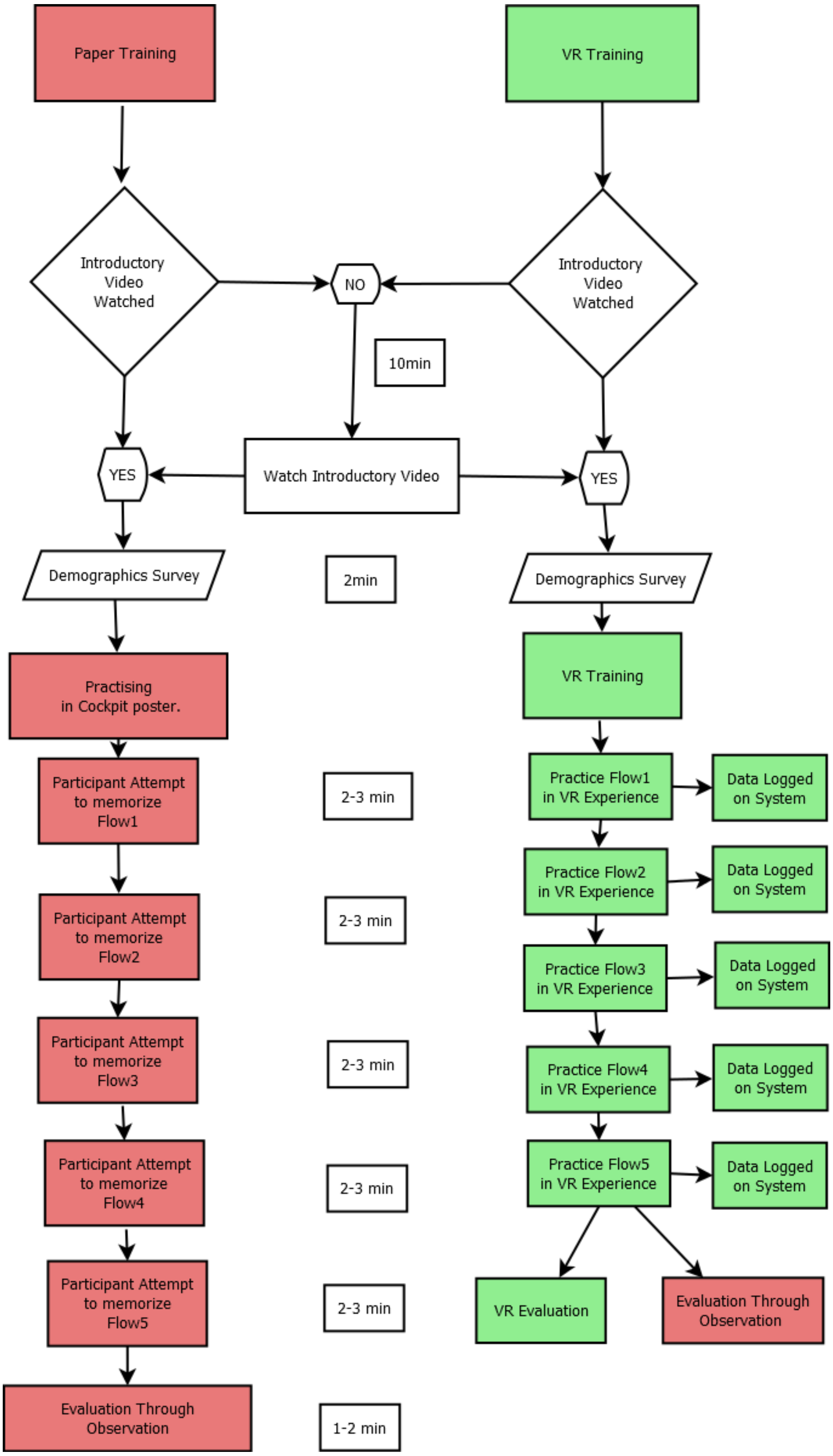

Figure 15 First Session VRFTE Memory Retention Training.

4.1 Poster Training

Discussion of the Poster Training process is divided into three sections to be explained in detail: Poster Introduction, Poster Training, and Poster Assessment.

4.1.1 Poster Introduction

In the introduction stage of the Poster Training, participants were welcomed to the Interaction Research Lab of Flinders University, or the place designated to conduct the study.

In this introduction stage, the participants are asked whether they have watched the introductory video. As explained in Figure 14, the participants had to watch the video to continue the process. After the participants had watched the recording of the explanation of the flows, a demographics survey was conducted to obtain information about the participants.

The demographics survey contained basic information including participants age, if they have had any experience in flying simulators and if they had used headsets before in a virtual experience. In a separate document, the study maintained the participant's name, email, mobile number if there was any need to contact them during the research. With this information saved separate to any research data, an ID was generated to maintain the participants’ anonymity.

4.1.2 Poster Training

Before being challenged by a simulator, pilots in their early stage of training commonly train with the aircraft operating manual and posters that emulate a cockpit, referred to as a Paper Tiger (Alce et al. 2020). The idea of having a Paper Tiger printed with the plane's size is that students who aim to be pilots can familiarise themselves with the flying instruments of the panel and locate these instruments of an aeroplane (Alce et al. 2020).

VRFTE poster training is based on this principle trying to provide the same type of training that a student will perform at their first stage of learning, providing a cockpit poster of a Cessna C172SP. The Paper Tiger C172SP has the same flying instruments as the VRFTE application. The participants were provided with five flows, which were drawn from the aeroplane manufacturer’s manuals, that were intended to be executed while the plane was on the ground.

Figure 16 Tiger Paper Training Poster Cessna172.

Figure 16 shows the poster that the control group participants used for their training. On this poster, each flying instrument was represented with a letter. The letters were for the participants, who had a sheet instructing them the flow steps to follow extracted from the aeroplane manual. The idea of the poster was that the participant touched the location in the control panel and simulate interaction in the cockpit. Depending on the cockpit interaction, each flying instrument has different states, such as the lights (H, I, J, K, M) have an ON and OFF state, the mixture (O) has three states: Cut Off, which means pulled all the way out, Lean, in the middle, and Rich, pushed all the way in.

Ref Letter	Cockpit Interaction	State	Comments
Flow1 Initial Cockpit Check			
Q	Parking Brake	Activated	Out, pulled Back
F	Master Switch	Off	Switched Off Press in the bottom of the switch
C	Battery Voltage Check	Check	
I	Landing Lights	On	lever facing up
J	Taxi Lights	On	lever facing up
K	Navigation Lights	On	lever facing up
H	Beacon Lights	On	lever facing up
L	Strobes Lights	On	lever facing up
P	Flaps	Extended	Flaps all the way down
Flow3 Engine Start			
N	Throttle	Middle	1/2 forward or pulled back in Middle position
F	Master Switch	On	Switched Off Press in the top of the switch
G	Fuel Pump	On	
O	Mixture	Lean	1/2 forward or pulled back in Middle position
H	Beacon Lights	On	lever facing up
E	Ignition Switch	Start	Rotate to Star Position
O	Mixture	Rich	Full Forward
B	Oil Pressure	Check	
AV	Avionics	On	Switched Off Press in the top of the switch
D	Transponder	On	On

Ref Letter	Cockpit Interaction	State	Comments
Flow2 Before Starting Engines			
S	Fuel Selector	Both	Rotation is facing North
Q	Parking Brake	Activated	Out, pulled Back
I,J,K,H,L	Lights	Off	All lights must be in an off state
F	Master Switch	On	Switched Off Press in the top of the switch
A	Fuel Quantity Check		
N	Throttle	Iddle	Out, pulled Back
O	Mixture	Rich	Full Forward
AV	Avionics		Switched Off Press in the bottom of the switch
Flow4 Emergency Engine Shutdown on Ground.			
O	Mixture	Full Lean	Out, pulled Back
R	Fuel ShutOffKnob	Off	Out, pulled Back
E	Ignition Switch	Off	Rotate to Off position
F	Master Switch	Off	Switched Off Press in the bottom of the switch
Flow5 Engine Failure during Take-Off Roll			
N	Throttle	Idle	Out, pulled Back
Q	Parking Brake	Activated	Out, pulled Back
P	Wing Flaps	Retract	All the way up
O	Mixture	Cut-Off	Out, pulled Back
E	Ignition Switch	Off	Rotate to Off position
F	Master Switch	Off	Switched Off Press in the bottom of the switch

Figure 17 Extracted Manufacturers Flows from Manual (Aircraft & Company 1988) .

The training started after the demographics survey was completed. Each participant had up to three minutes to memorise the steps of the flows. Each participant received a checklist showing the steps of the flows to be performed. The list provided the actions of the flows and the same letters that are shown in Figure 16 of the poster. This checklist helped participants understand the cockpit controls and where they needed to interact with the poster. Figure 17 shows the different flows extracted from the manual that the participants were asked to complete. The letters in the Ref Letter column correspond to the annotated letters on the cockpit poster seen in Figure 16. It was expected that the introductory video and the checklist would provide enough information on the flows to allow participants to memorise them. However, during the Poster Training, the researcher was present to answer any additional questions regarding the interaction of the control panels of the cockpit.

In Figure 15, shows the expected time for each participant at each stage of the training. The study had allocated 30 minutes to conduct the entire first session. It is essential to highlight that the introductory video was a crucial piece of the study as it provided details of how the cockpit panel operates and the definitions of the flows. However, if the participant had not watched the video, the research allocated an extra 10 minutes per session to have the same condition for each person doing the Poster Training.

4.1.3 Poster Assessment

After the participants completed the training from flow one to flow five, the researcher took the participant to the secondary room, where the evaluation poster was prepared. Figure 18 shows the poster that participants used during their evaluation. The evaluation poster was the same dimensions as the training poster but it was printed without letters.

Figure 18 Cessna172 Cockpit Paper Tiger Evaluation Poster.

The Fifth Flow was given to the participant to be evaluated. This flow contained a checklist of steps to follow. The participant was to attempt to simulate the flow in the cockpit while out loud describing their thoughts and the steps that they were taking. Through observation, the researcher was able to evaluate the participant's interaction with the poster. It is was explained to the participant that they were expected to explain their interaction with the cockpit and the flow through each stage.

Table 2 Engine Failure During Take-Off Roll Flow#5.

Reference letter	Cockpit interaction	State	Comments
N	Throttle	Idle	Out pulled Back
Q	Parking Brake	Activated-Applied	Out, pulled Back
P	Wing Flaps	Retract	Wing Flaps to the top
O	Mixture	Cut Off	Out, pulled Back
E	Ignition Switch	Off	Rotate Left In Off Position
F	Master Switch	Off	Switched Off Press in the bottom of the switch.

In Table 2 Engine Failure During Take-Off Roll Flow#5., there is an example of a successful explanation of the flow where the participants interacted with the poster with the referenced letter and touch the control panel in order N, Q, P, O, E, F. Also, Table 2 shows, in the Comments column, a description of the final stage of the interaction.

During the evaluation, the researcher had the flow checklist in a spreadsheet. Through observation and the storytelling role of the participants, the researcher recorded the flying instrument that the participants interacted with, the instrument's final stage, and a timestamp of the action for each step of the flow.

The checklist and the storytelling role aimed to understand the participant's thoughts regarding the interaction of each step in the control panel. During the evaluation, the researcher timed the responses (using a stop watch app) and recorded that information for each step of the flow.

4.2 VR Training

VR Training has been divided into three sections, VR Introduction, VR Training, and VR Assessment.

4.2.1 VR Introduction

For the VR Training procedure the same introductory steps as the Poster Training were undertaken. This included welcoming the participants into the research lab, they were asked if they had viewed the introductory video, and if not they were directed to watch the video. They were then asked to complete the demographics survey and subsequently provided with their unique ID. At this stage, the researcher provided the participants with directions for the wearing and use of the VR system explaining the system's controls and helping them to familiarise themselves with the system.

There was a possibility that some participants could experience slight nausea similar to motion sickness from the use of VR. Motion sickness was considered to be a rare side effect due to the nature of this particular VR experience as the participants would be seated and not moving around a defined space.

Participants were told before they started the experiment to cease the training module if they experienced any nausea during the module. In addition, as Oculus Quest 2 was the HMD hardware chosen for this project, specific considerations, as outlined by Facebook (Facebook 2021b) in the Oculus Quest manual were made known to participants that approximately 1 in 4000 people might have seizures.

“Motion sickness is a consequence of light flashes/patterns and could be presented while watching TV, playing video games, or experiencing VR. Therefore, anyone who has had a seizure, loss of awareness, or other symptoms linked to an epileptic condition should consult their general practitioner before using this technology” (Facebook 2021a). Due to this, the Participant Consent Form highlighted this matter for the awareness of the participants.

4.2.2 VR Training.

Based on Figure 17, flows were created for the VRFTE to provide an interactive VR experience where participants used their hands to interact with the control panel of the Cessna 172. The Oculus Quest 2’s sensors were used to track the hand's movements that were displayed in VRFTE. The VRFTE application did not use the controllers of Oculus Quest 2, just the sensors to show the hands in the application.

VRFTE application started with the first flow named Initial Cockpit Check as the first part of the training. Figure 19 below shows a preview of what the participant saw in the cockpit once the application is started.

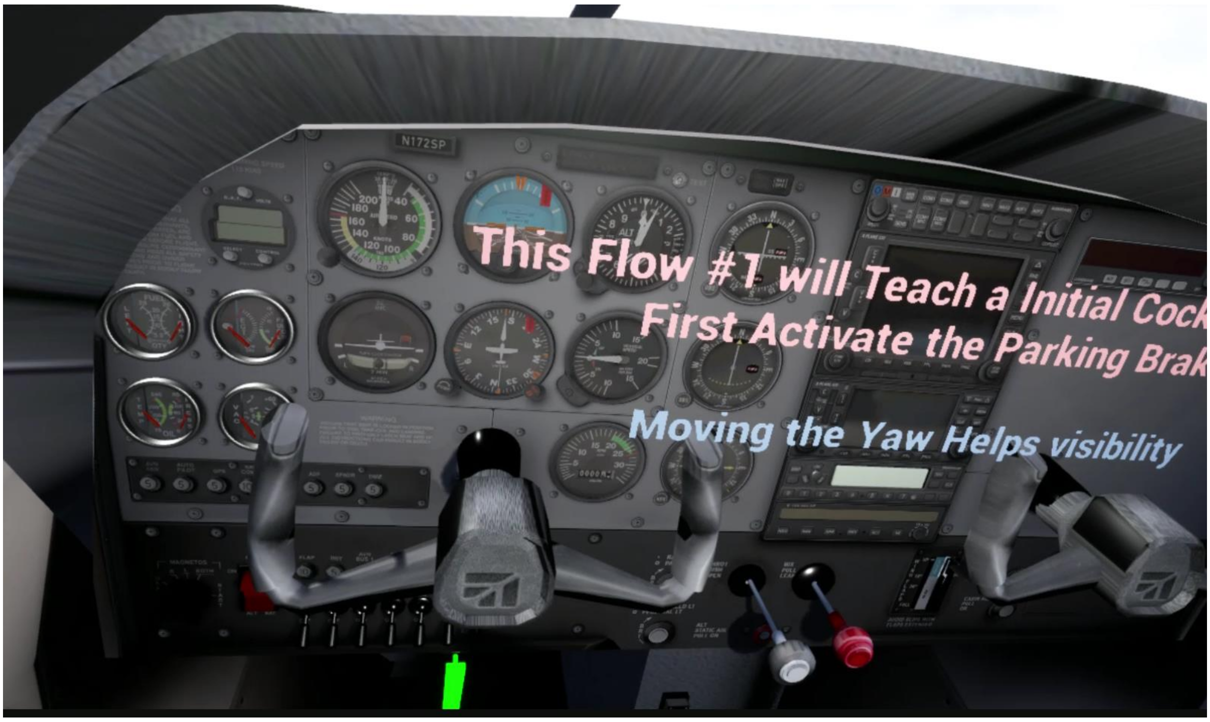

Figure 19 VFRTE Preview Cesnna Cockpit is Displaying Flow Step, Visual Feedback.

All participants started in Flow#1 (Initial Cockpit Check) when they put the headset and initialize the application. Participants were presented with a view of the inside of a cockpit of a Cessna172 as though they were seated on the pilots' chair. As VRFTE provided guided training, the first element that participants noticed was the text displayed in a red font that included information regarding which flow they were performing and the initial step a participant needed to progress with the training.

The study did not expect that participants had interacted with a plane before. Therefore, it was essential to highlight additional visual feedback in the green colour in each step of the flow indicating to the participant what should be interacted with during the training.

In each flow step, the participant used their hands to reach the highlighted cockpit instrument. Figure 20 shows a sequence from one to seven of a complex interaction beginning with activating the parking brake and concluding with turning on the master switch. The steps represented in the figure are as follows:

- Image 1: displays a red instruction text showing the number of the flow and the first action that is pending for the participant to perform.
- Image 2: after the participant has moved their head and therefore field of view, they can identify the parking brake, highlighted in green.

- Image 3: to improve visibility the participant has gripped the yoke and moved it out of the way. It can be seen that the yoke have been moved full-forward, and the participant has better visibility of the parking brake highlighted in green. Moreover, it is crucial to mention each interaction of the participant is displayed with text on the screen in a blue colour.

Figure 20 VFRTE Guiding the participant in Flow#1 Initial cockpit check.

- Image 4: shows the participant moving their hands to interact with the parking brake, reaching toward it.
- Image 5: after the participant has interacted with the parking brake, the blue text displayed shows the state of the parking brake.
- Image 6: after a delay, the instruction displayed asks the participant to turn on the Master Switch
- Image 7: participant can be seen reaching for the master switch, highlighted in green. The parking brake colour changed to standard colour after the participant interacted with it in the previous steps. Moreover, for some other flow steps where the flying instrument has numerous states, such as the mixture (Idle, Lean, Rich) the green colour will not fade away until the desired state has been achieved in their training.

There are multiple essential features to highlight that will help improve the training experience in VR that have been explained in detail in the software development chapter. However, in this training, we can identify the following:

- Hand tracking functionality,
- Guided training,
- Animated Objects interaction, and
- Visual and Audio Feedback.

After the flow training, a final message of completion will inform the participants that the flow has been completed. Once completed the participant can choose the next flow to work with. Multiple buttons have been created so the participants can change the flow to be trained. The controls are located at the top of the cockpit.

Figure 21 VFRTE Changing Flow Pressing Button Top of the Cockpit.

In Figure 21, the participants' hand shows that the second button is being touched from left to right, the participant is activating flow number two. The interaction with the buttons resets the states of the cockpit and the flying instruments so the participants can perform the flow selected.

From left to right, participants can chose flow 1 to 5. However, the training is intended to be in order from flow number one to flow number five. A preview of VRFTE flow five for training can be found below in Figure 22, this is a captured video of the application, a link to the hosted video is also included in case of display issues.

Figure 22 Training Preview If video did not play, click here

4.2.3 VR Assessment

After the participants have completed the training from flow one to flow five, the participants will be instructed to finish the sessions and start the evaluation. VRFTE has a designated button to start the evaluation in the system. It is essential to mention that VRFTE records logs of all the hand-tracking interactions of the participants in the training module and the assessment.

The Fifth Flow was given to the participant to be assessed. As with all other training flows, this flow contained a checklist of steps to follow. The participant attempted to complete the flow in VRFTE, explaining to the researcher their interaction with the system with a think out loud approach. The assessment mode in VRFTE deactivates all notification prompts (green highlights on instruments), and displays the complete flow sequence to the participant. The evaluation intends to put into practice the information that the participants can recall from the VRFTE experience.

As well as the logs of the VRFTE system, to be consistent in the way participants were evaluated during the Poster Training, the same spreadsheet was used to store the session information. The spreadsheet contained the flying instrument that the participants were to interact with, the instrument's final stage, and a timestamp of the action for each step of the flow, which is linked to the participant ID.

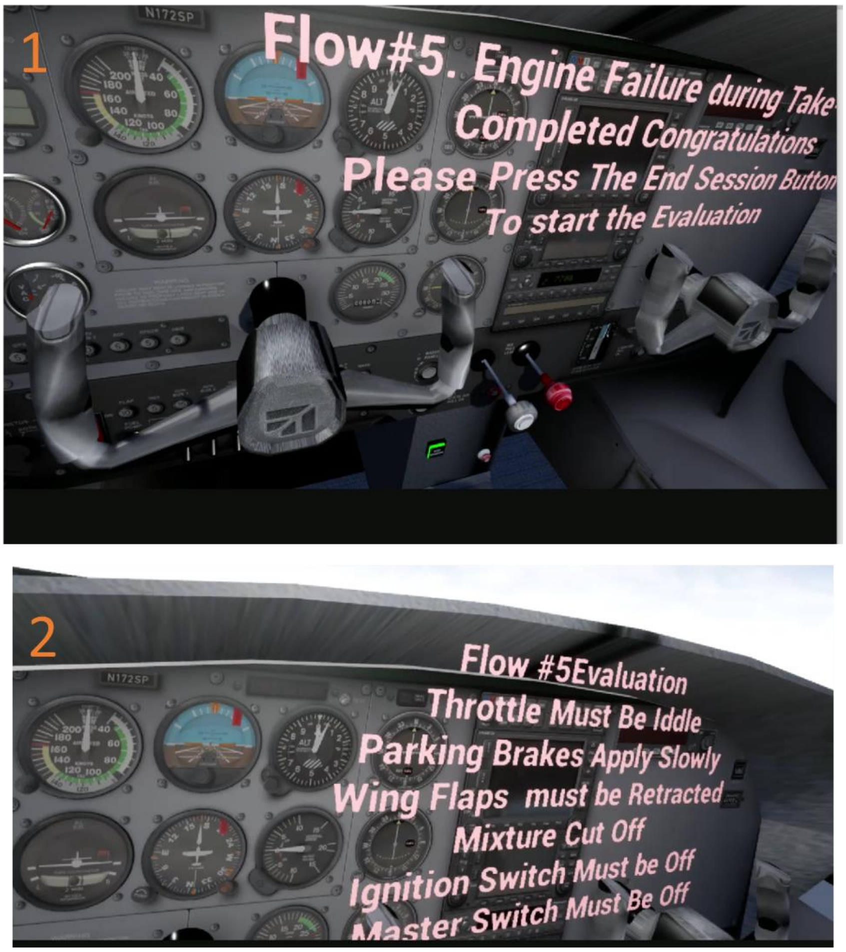

Figure 23 VFRTE Training Sessions Completion and Evaluation Displaying Checklist.

Figure 23 shows the VRFTE module when the last flow has been completed in the training section and when the evaluation button has been pressed. The evaluation button can be seen in Figure 23, in Image 1 toward the bottom of the image, highlighted with green Figure 23, Image 2 displays the checklist of the evaluation to be performed.

4.2.4 Poster Training and VR Training

The research was also interested in understanding how participants felt using the system and how confident they were with their answers. This would be used to provide a perspective of the systems logs compared to the users' perception of their success. The Likert scale (strongly disagree to strongly agree) questions presented to the participants were:

- I was confident in my selection during the evaluation.
- I was confident with the sequence of the steps during my evaluation.

Participants were also asked to provide a response to the following question, indicating the amount of times they had watched the introductory video.

- How many times did I watch the introductory video?

One week after the first session had been completed, a second session with the participants was scheduled to perform the follow-up evaluation of long term memory retention. The participants were instructed to watch the introductory video to practice and recall the information learned at least once per day.

4.3 Second Session

The second session contained the long-term memory evaluation to build up the datasets to finalise the study. The results obtained in the assessments were analysed to provide conclusions regarding whether a VR interactive experience can be more effective than a traditional poster training for pilot flows.

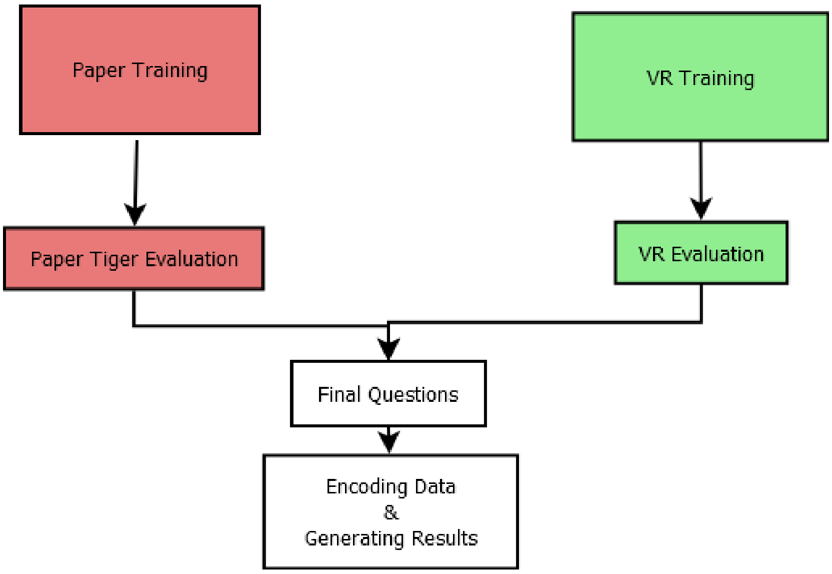

Figure 24 Second Session Long-Term Memory Retention.

The two groups divided at the start of the study completed their evaluation in their second session and were assessed using the evaluation procedure outlined in sections 4.1.3 and 4.2.3 for their knowledge retention. Once completed the participants were asked to answer a survey asking the same questions as previously discussed. Figure 24 shows a flow diagram of the activities for session 2, where the evaluation was conducted and the data was encoded for further analysis.

CHAPTER FIVE – ANALYSIS OF RESULTS

This chapter will explain how the data was encoded and analysed. It is essential to highlight that a memory retention score was created based on the fifth flow, which was the one evaluated.

Returning to the thesis statement **Does Virtual Reality Training Improve Memory Retention In Pilots flows?** The study sought to answer this question by comparing VRFTE and Paper Tiger Training. A single flow was selected from the five developed in VRFTE (Engine Failure during Take-Off Roll) to compare memory retention scores. As the methodology has explained, two types of training have been implemented in this research Paper Tiger Poster and VRFTE. The score of the memory retention evaluation from both sessions will inform which training obtained the best results aiming to answer the initial thesis statement.

Table 3 Evaluated Flow Engine Failure During Take off Roll

Sequence	Cockpit interaction	State
1-N	Throttle	Idle
2-Q	Parking Brake	Activated-Applied
3-P	Wing Flaps	Retract
4-O	Mixture	Cut Off
5-E	Ignition Switch	Off
6-F	Master Switch	Off

Table 3 shows Engine Failure During Take Off Roll; this flow indicates the sequence of events that the participants needed to complete. As it is shown in Table 3, Engine Failure during Take Off Roll has six steps and six states. The memory retention score was created based on this: the evaluation assesses the proper cockpit interaction and the state of the cockpit instrument.

Table 4 Retention Score Evaluation of a Participant

Participant ID	Time Stamp	Flow Step	Step Correct?	Flow State	State Correct?	Step Score	State Score	Memory Score
VRYC1	3	Throttle	No	Idle	No	0	0	0
VRYC1	7.82	Parking Brake	Yes	Activated-Applied	Yes	1	1	2
VRYC1	30	Wing Flaps	Yes	Retract	No	1	0	1
VRYC1	21	Mixture	Yes	Cut Off	Yes	1	1	2
VRYC1	8	Ignition Switch	Yes	Off	Yes	1	1	2
VRYC1	6	Master Switch	Yes	Off	Yes	1	1	2

Table 4 shows a participant evaluation identified with participant ID VRYC1. It is essential to note that if the participant has not interacted with the correct flying instrument of the flow sequence automatically for that step, the participant will score 0. An example of this interaction can be seen in Table 4 in the first row, where the incorrect flow step was chosen.

A total of fifteen participants were evaluated, eight for the VRFTE session and seven for the Paper Tiger session. The research aimed to obtain ten participants for each training. However, due to some difficulties, some participants could not participate in both sessions, which is why the research sample size was reduced to fifteen participants.

Figure 25 shows the memory retention score by type of training, and it is seen that VRFTE application has a higher result than Paper Tiger Sessions. Long term memory retention was assessed in the second session after one week of training. In general, the study suggests that VRFTE application can positively affect memory retention scores; this might be because VRFTE had SG components, including decision-making, physical fidelity, and feedback.

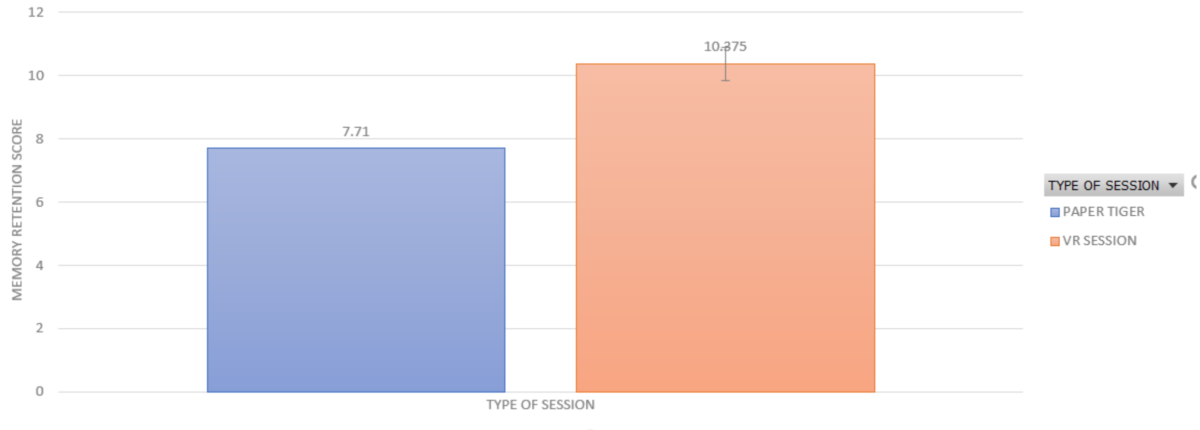

Figure 25 Long-Term Memory Retention Score

Figure 26 shows memory retention score per University and type of Training VRFTE and Paper Tiger Training. An interesting finding was that Participants from the University of South Australia had better average scores in long term memory retention. However, analysis of this result should be cautious as those participating from the University of South Australia may have exposure to the basics of flight training as part of the courses offered at the University of South Australia, which offers courses related to aviation. Moreover, participant ID VRSY2 from the University of South Australia was the only person in the sample with previous plane experience, which may have produced a positive shift in the University of South Australia memory retention score.

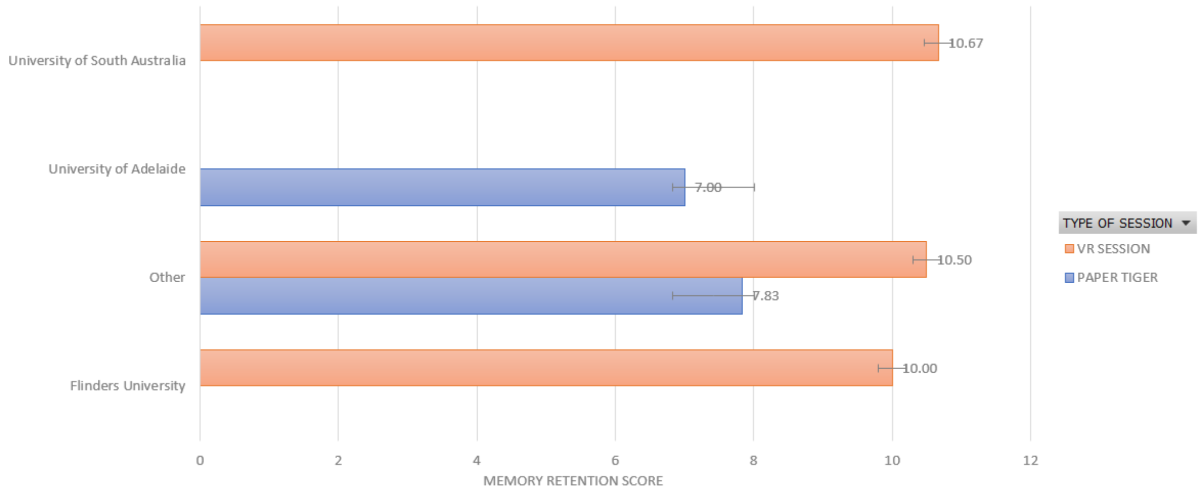

Figure 26 Long-Term Memory Retention Score By University and Session.

It is also essential to mention that participants were limited. As shown in Figure 26, indicates that there were no participants from the University of South Australia for the Paper Tiger sessions. Every participant that volunteered for the study was randomly allocated.

Figure 27 shows memory retention scores of people who have and do not have any experience in VR. This is further categorised by how confident participants felt performing the sequence of the flow steps during the evaluation. As shown in the graph, the research suggests that confidence was not a specific factor that affected scores. Participants with less confidence in their assessment had similar memory retention scores to those that were confident.

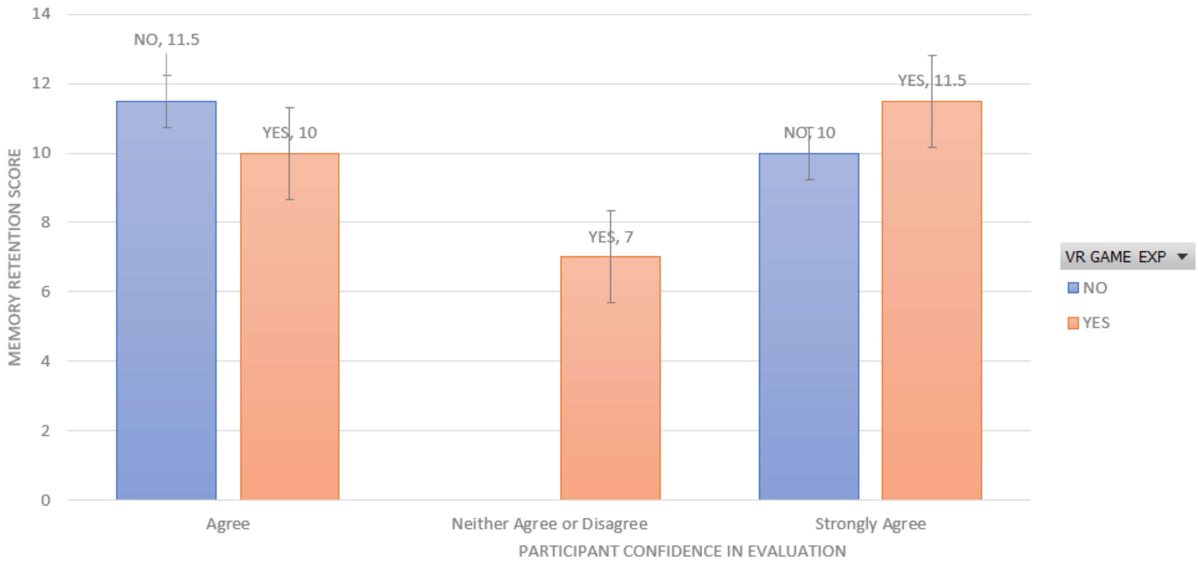

Figure 27 Memory Retention Score Vs Participant Confidence and Previous VR experience

Figure 27 might indicate that previous VR experience may not affect memory retention scores in the VR application VRFTE. Literature investigations have demonstrated that memory is affected by many factors such as age, motivation, cognitive abilities, amount of training and effort. It is also essential to acknowledge that the graph is just an analysis of VRFTE training sessions. There is no point in comparing previous experiences in VR for a comparison to the Paper Tiger Sessions.

Participants invited to join the VRFTE training session were interested in being immersed in the VR environment, trying the application, and using the hand tracking interaction. Furthermore, participants asked how the application was developed, expressing interest in the hand tracking functionality. In other words, this might indicate that their interest in the application might be a factor for future exploration if this can affect memory retention scores as Wade (1992) suggest that interest in a related topic may improve memory retention and learning.

Figure 28, Figure 29 shows gender memory retention scores by type of session and in total, from the demographics also an interesting finding is that men had better retention scores than women. According to research, spatial memory can be affected by gender, where spatial memory is how people identify objects located in an environment (Fernandez-Baizan, Arias & Mendez 2019). The research may suggest that also spatial memory and physical fidelity can be correlated. Spatial memory terms have not been used in this research before. However, spatial memory could be an exciting topic to further explore and evaluate in the future. Therefore, this research might indicate another field that needs further development as gender can affect how people identify objects in a location.

Figure 28 Long-Term Memory Retention Score Vs Gender and Training Session.

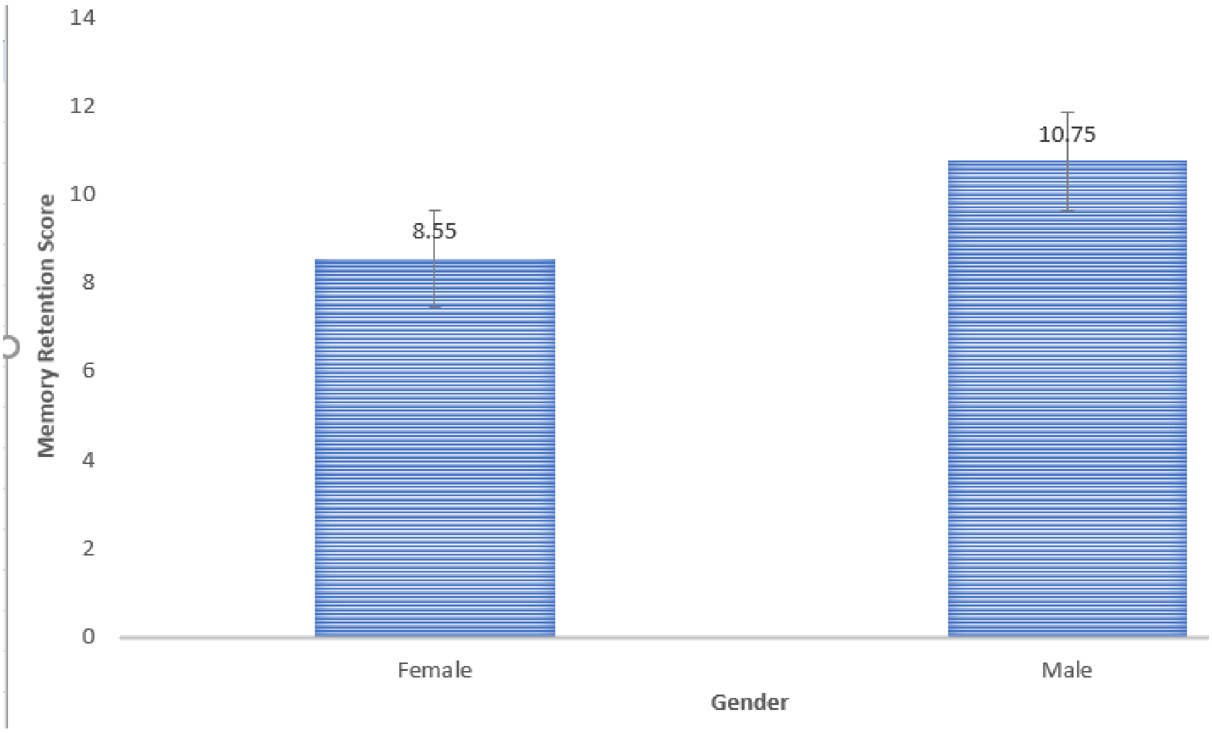

Figure 29 Long-Term Memory Retention Score Vs Gender.

CHAPTER SIX – CONCLUSION

The goal of the thesis has been to answer the question **Does Virtual Reality Training Improve Memory Retention in Pilot Flows?** The results suggest that potentially yes. VRFTE application has better scores in memory retention than the Paper Tiger Poster Training. To achieve this, the researcher needed to understand how memory retention works and understand the aviation sector. The research has found that the pathway to connect games VR and knowledge retention was a SG concept. Furthermore, the concept suggested by Dale (1969) that learners retain more information by what they "do" as opposed to what is "heard", "read", or "observed" the research aims to be achieved in VRFTE using audio feedback and visual feedback through the VR Experience.

6.1 Limitation of the study.

- Some limitations are affecting the results and the scope of the project of the VRFTE application. The experiment was with a small population taken from different universities in Adelaide without previous experience in pilots flows. 15 in total participated in training and evaluation sessions.
- Training sessions and evaluations were designed for one day; participants interacted with the training methods for half an hour. As memory is affected by training, this can limit that exposure to the amount of training and affect memory retention scores in the study.
- One headset was provided to conduct the research. Therefore the amount of training for participants was limited to the training sessions, i.e., the participants did not have the ability to take the HMD home with them to continue practicing between sessions.
- Learning and memory can be complex topics and need further research from experts in Education and Psychology. Education experts or psychologists were not present in this study which affects the scope of the project.

6.2 Serious Game Findings

The game aspects of the VRFTE are not completed and could be improved according to the research performed in this thesis. The concept of emotions and feelings has been demonstrated to be influential in memory retention; VRFTE does not use this concept due to the time limit and development of the application. Positive and negative emotions could lead to greater memory retention. The study conducted by Chittaro and Buttussi (2015) suggested that a VR game in aviation safety improved memory retention when the game harms the player's avatar and produces a fearful feeling compared to traditional training.

Another critical factor that was not included in the VRFTE application is the game functionality itself. Unfortunately, VRFTE was limited to a simulation rather than a game due to the project's complexity. As it is explained in this thesis, difficulty levels can boost motivation and maintain player engagement. Difficulty levels can affect training as the player keeps trying to beat the game. Therefore, if a difficulty level was implemented in VRFTE, it could lead the player to keep practising pilot flows in the game, which can lead to training memory and improve memory retention

Further research on a new topic has not been explored, as mentioned in gender comparisons in Chapter Five. Spatial memory is a new term that was not fully explored in the literature. The researcher was curious why male subjects perform better in memory retention than females. A potential gap was identified to further explore and analyze in the future.

6.3 Training Methodology

The literature review explains that breaking complex sequences into chunks of four steps can improve memory retention. Due to the limitations that visual memory has, they have found people can process complex sequences better smaller numbers of steps. Reviewing the operation of VRFTE it could be argued that the application and training methodology are not breaking flows sufficiently. This was evident in the training environment, some flows can be long and challenging to learn. The training methodology could be improved using buffer loading in pilot flows.

6.4 Improving VRFTE prototype

Physical fidelity was achieved in VRFTE, creating a completed cockpit of a small plane with all its flying instruments. Also, the interaction of the player with levers and yokes had an incomplete grabbing functionality. The system does not snap the hand to the flying devices and moves the object following the hand interaction. In this case, the hand tracking functionality can feel peculiar in the training environment as the yokes and levers move by themselves rather than using the movement of the hand.

Player interactions could be improved using more complex collision systems including all the fingers of the hand. At this stage, VRFTE was implemented with two types of collision in the index finger and the palm.

The simulation of VRFTE was limited to five flows on the ground for a small plane. Therefore, there are many functionalities of the Cessna 172 T41 Mescalero aeroplane which were not implemented. The complete functionality of the aircraft can be considered to be developed for future investigations.

6.5 Concluding Remarks

An interesting idea was found, which is, that SG and procedural memory are correlated. In other words, learning in a SG and procedural memory is implicit without the user's awareness.

Essential facts to mention that are detailed in this research are the comparison of a non interactive training process with a VR application. It was found that feedback, decision making, and physical fidelity were essential factors that improved memory retention scores. Feedback, decision making, and physical fidelity were implemented in VRFTE in the following ways:

- Feedback: VRFTE implemented feedback whenever there was an interaction with a lever or a switch,
- Decision Making: Users needed to touch the right levers and buttons to progress their training, and
- Physical fidelity: A realistic environment in VRFTE had been designed to emulate the cockpit of a Cessna T41 Mescalero to emulate the position and dimension of all the flying instruments of the aeroplane.

The analysis of the results suggests that physical fidelity, decision-making, and feedback have affected and improved the memory retention scores of the people who use the VRFTE application. However, given the sample size further investigation, with a larger sample, is required to verify these initial results.

REFERENCES

Ahrens, D 2015, 'Serious games–A new perspective on workbased learning', *Procedia-Social and Behavioral Sciences*, vol. 204, pp. 277-81.

Aircraft & Company, C 1988, *Pilot's Operating Handbook and FAA Approved Airplane Flight Manual*, Wichita, KN: The Cessna Aircraft Company, 8/06/1988.

Alce, G, Klang, K-J, Andersson, D, Nyström, S, Wallergård, M & Niehorster, DC 2020, 'Using augmented reality to train flow patterns for pilot students-An explorative study', in *International Conference on Augmented Reality, Virtual Reality and Computer Graphics*, pp. 215-31.

Bechtold, D, Hoffman, DL, Brodersen, A & Tung, K-H 2018, 'Assurance of Learning and Knowledge Retention: Do AOL Practices Measure Long-Term Knowledge Retention or Short-Term Memory Recall?', *Journal of Higher Education Theory and Practice*, vol. 18, no. 6, p. 10.

Bo, J, Jennett, S & Seidler, R 2012, 'Differential working memory correlates for implicit sequence performance in young and older adults', *Experimental brain research*, vol. 221, no. 4, pp. 467-77.

Brem, A-K, Ran, K & Pascual-Leone, A 2013, 'Learning and memory', *Handbook of clinical neurology*, vol. 116, pp. 693-737.

Checa, D & Bustillo, A 2020, 'A review of immersive virtual reality serious games to enhance learning and training', *Multimedia Tools and Applications*, vol. 79, no. 9, pp. 5501-27.

Cheng, MT, Huang, WY & Hsu, ME 2020, 'Does emotion matter? An investigation into the relationship between emotions and science learning outcomes in a game-based learning environment', *British Journal of Educational Technology*, vol. 51, no. 6, pp. 2233-51.

Chittaro, L & Buttussi, F 2015, 'Assessing knowledge retention of an immersive serious game vs. a traditional education method in aviation safety', *IEEE transactions on visualization and computer graphics*, vol. 21, no. 4, pp. 529-38.

Chun, MM 2011, 'Visual working memory as visual attention sustained internally over time', *Neuropsychologia*, vol. 49, no. 6, pp. 1407-9.

Coyle, H, Traynor, V & Solowij, N 2015, 'Computerized and virtual reality cognitive training for individuals at high risk of cognitive decline: systematic review of the literature', *The American Journal of Geriatric Psychiatry*, vol. 23, no. 4, pp. 335-59.

Dale, E 1969, *Audiovisual methods in teaching*, The Dryden Press, N.Y.

Desselle, MR, Brown, RA, James, AR, Midwinter, MJ, Powell, SK & Woodruff, MA 2020, 'Augmented and virtual reality in surgery', *Computing in Science & Engineering*, vol. 22, no. 3, pp. 18-26.

Dwyer, F 2010, 'Edgar Dale's cone of experience: A quasi-experimental analysis', *International Journal of Instructional Media*, vol. 37, no. 4, pp. 431-8.

Epic Games, E 2021, *Epic Games*, viewed 16/01/2021 2021, <https://www.epicgames.com/site/en-US/about>.

Facebook 2021a, *Oculus-Quest-Warnings-English-052119*, viewed 06/06/2021 2021, <https://www.oculus.com/legal/health-and-safety-warnings/>.

—— 2021b, *Oculus Health and Safety Warnings* viewed 10/06/2021, <https://www.oculus.com/safety-center/>.

Facebook Technologies, L 2021, *Oculus for Developers -Hand Tracking in Unreal Engine*, <https://developer.oculus.com/documentation/unreal/unreal-hand-tracking/>.

Fernandez-Baizan, C, Arias, J & Mendez, M 2019, 'Spatial memory in young adults: Gender differences in egocentric and allocentric performance', *Behavioural brain research*, vol. 359, pp. 694-700.

Games, E 2004-2021, *Unreal Engine*, viewed 16/07/2021 2021, <https://www.unrealengine.com/en-US/unreal>.

Hobo, K, Noritake, K, Sunaga, M, Miyoshi, T, Cao, R, Nitta, H, Kabasawa, Y & Kinoshita, A 2017, 'Effects of an interactive simulation material for clinical dentistry on knowledge acquisition and memory retention in dental residents', *Journal of medical and dental sciences*, vol. 64, no. 4, pp. 43-52.

Howard, MC 2017, 'A meta-analysis and systematic literature review of virtual reality rehabilitation programs', *Computers in Human Behavior*, vol. 70, pp. 317-27.

Kavanagh, S, Luxton-Reilly, A, Wuensche, B & Plimmer, B 2017, 'A systematic review of Virtual Reality in education', *Themes in Science and Technology Education*, vol. 10, no. 2, pp. 85-119.

Kiili, K, De Freitas, S, Arnab, S & Lainema, T 2012, 'The design principles for flow experience in educational games', *Procedia Computer Science*, vol. 15, pp. 78-91.

Koglbauer, I 2016, 'Simualtor Training Improves Pilot's Procedural Memory and Generalization of Behaviour in Critical Flight Situations', *Cognitie, Creier, Comportament/Cognition, Brain, Behavior*, vol. 20, no. 5.

Koonce, JM & Bramble Jr, WJ 1998, 'Personal computer-based flight training devices', *The international journal of aviation psychology*, vol. 8, no. 3, pp. 277-92.

Laamarti, F, Eid, M & El Saddik, A 2014, 'An overview of serious games', *International Journal of Computer Games Technology*, vol. 2014.

Lanier, J 2020, *Reality And Fantasy In Terms Of Software Design And The Virtual World*, Ideacity, You tube, 21/04/2020, <https://www.youtube.com/watch?v=AGBmuXCh2Vw>.

Ludlow, BL 2015, 'Virtual reality: Emerging applications and future directions', *Rural Special Education Quarterly*, vol. 34, no. 3, pp. 3-10.

Morrison, AB & Chein, JM 2011, 'Does working memory training work? The promise and challenges of enhancing cognition by training working memory', *Psychonomic bulletin & review*, vol. 18, no. 1, pp. 46-60.

Ninaus, M, Pereira, G, Stefitz, R, Prada, R, Paiva, A, Neuper, C & Wood, G 2015, 'Game elements improve performance in a working memory training task', *International Journal of Serious Games*, vol. 2, no. 1, pp. 3-16.

Noble, C 2002, 'The relationship between fidelity and learning in aviation training and assessment', *Journal of Air Transportation*, vol. 7, no. 3, pp. 33-54.

Pekrun, R 2011, 'Emotions as drivers of learning and cognitive development', in *New perspectives on affect and learning technologies*, Springer, pp. 23-39.

Perttula, A, Kiili, K, Lindstedt, A & Tuomi, P 2017, 'Flow experience in game based learning–a systematic literature review', *International Journal of Serious Games*, vol. 4, no. 1, pp. 57-72.

Pope, TM 2019, 'A cost-benefit analysis of pilot training next', Student Graduate 2314 thesis, Air Force Institute of Technology AFIT Scholar.

Ruckenstein, M 1991, 'Homo ludens: a study of the play element in culture', *Leisure and Ethics*, vol. 237.

Schell, J 2008, *The Art of Game Design: A book of lenses*, CRC press.

Seidler, RD, Bo, J & Anguera, JA 2012, 'Neurocognitive contributions to motor skill learning: the role of working memory', *Journal of motor behavior*, vol. 44, no. 6, pp. 445-53.

Shapiro, S & Krishnan, HS 2001, 'Memory-based measures for assessing advertising effects: A comparison of explicit and implicit memory effects', *Journal of advertising*, vol. 30, no. 3, pp. 1-13.

Socha, V, Socha, L, Szabo, S, Hána, K, Gazda, J, Kimlickova, M, Vajdová, I, Madoran, A, Hanakova, L & Nemec, V 2016, 'Training of pilots using flight simulator and its impact on piloting precision', *Transport Means. Juodkrante: Kansas University of Technology*, pp. 374-9.

Steuer, J 1992, 'Defining virtual reality: Dimensions determining telepresence', *Journal of communication*, vol. 42, no. 4, pp. 73-93.

Susi, T, Johannesson, M & Backlund, P 2007, 'Serious games–an overview [Technical Report HS-IKI-TR-07–001]', *Skövde, Sweden: University of Skövde School of Humanities and Informatics*.

Wade, SE 1992, 'How interest affects learning from text', *The role of interest in learning and development*, pp. 255-77.

Wang, P, Wu, P, Wang, J, Chi, H-L & Wang, X 2018, 'A critical review of the use of virtual reality in construction engineering education and training', *International journal of environmental research and public health*, vol. 15, no. 6, p. 1204.

Westera, W 2019, 'Why and how serious games can become far more effective: Accommodating productive learning experiences, learner motivation and the monitoring of learning gains', *Journal of Educational Technology & Society*, vol. 22, no. 1, pp. 59-69.

Youngblut, C 1998, 'Educational uses of virtual reality technology (No. IDA-D-2128)', *Institute for defense analyses alexandria va*.

APPENDIX A

Questionnaire 1

Demographics Survey

The following survey aims to understand the participant's previous experience, in order to position the project Virtual Reality Flight Training Experience in the current state of VR. In addition, this project has been approved by Flinders University's Human Research Ethics Committee to comply with the privacy and safety of the participants.

' Required

1. Unique ID *

2. Age *

18-24

25-30

31-40

>40

3. What is your experience playing/interacting with a Flight Simulator? *

	1	2	3	4	5	
Without Experience	☐	☐	☐	☐	☐	Experience

4. Have you used or played any VR game/application? *

- ◯ Yes
- ◯ No

5. If you have experienced VR, How comfortable you feel with the use of this technology? *

	1	2	3	4	5	
Strongly uncomfortable	◯	◯	◯	◯	◯	Strongly comfortable

6. Degree *

7. Educational Institution *

- ◯ Flinders University
- ◯ University of South Australia
- ◯ Torrens University
- ◯ Other

8. Do you have any flight experience? If Yes, in which Aircraft and how many months/years of experience? *

APPENDIX B

Questionnaire 2

VRFTE Usability Questionnaire Session1
Participant ID:

Usability testing evaluation form of participants perception by the end test session.

1. I was confident in my selection during my evaluation.

Strongly Disagree ◯ ◯ ◯ ◯ ◯ ◯ ◯ ◯ ◯ ◯ Strongly Agree

2. I was confident in the sequence of steps during my evaluation.

	1	2	3	4	5	6	7	8	9	10	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

VRFTE Usability Questionnaire Session1
Participant ID:

Usability testing evaluation form of participants perception by the end test session.

1. I was confident in my selection during my evaluation.

Strongly Disagree ◯ ◯ ◯ ◯ ◯ ◯ ◯ ◯ ◯ ◯ Strongly Agree

2. I was confident in the sequence of steps during my evaluation.

	1	2	3	4	5	6	7	8	9	10	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

VRFTE Usability Questionnaire Session1
Participant ID:

Usability testing evaluation form of participants perception by the end test session.

1. I was confident in my selection during my evaluation.

Strongly Disagree ◯ ◯ ◯ ◯ ◯ ◯ ◯ ◯ ◯ ◯ Strongly Agree

2. I was confident in the sequence of steps during my evaluation.

	1	2	3	4	5	6	7	8	9	10	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

APPENDIX C

Memory Retention Evaluation Paper Tiger Training Session

Participant ID	Flow Step	Step Correct?	Flow State	State Correct?	Step Score	State Score	Memory Score	Type Of Session
PTAK1	Throttle	YES	Idle	NO	1	0	1	PAPER TIGER
PTAK1	Parking Brake	YES	Activated-Applied	YES	1	1	2	PAPER TIGER
PTAK1	Wing Flaps	YES	Retract	NO	1	0	1	PAPER TIGER
PTAK1	Mixture	NO	Cut Off	NO	0	0	0	PAPER TIGER
PTAK1	Ignition Switch	YES	Off	YES	1	1	2	PAPER TIGER
PTAK1	Master Switch	YES	Off	NO	1	0	1	PAPER TIGER
PTAK2	Throttle	YES	Idle	NO	1	0	1	PAPER TIGER
PTAK2	Parking Brake	YES	Activated-Applied	YES	1	1	2	PAPER TIGER
PTAK2	Wing Flaps	NO	Retract	NO	0	0	0	PAPER TIGER
PTAK2	Mixture	YES	Cut Off	NO	1	0	1	PAPER TIGER
PTAK2	Ignition Switch	YES	Off	NO	1	0	1	PAPER TIGER

PTAK2	Master Switch	NO	Off	NO	0	0	0	PAPER TIGER
PTAB3	Throttle	NO	Idle	NO	0	0	0	PAPER TIGER
PTAB3	Parking Brake	YES	Activated-Applied	NO	1	0	1	PAPER TIGER
PTAB3	Wing Flaps	YES	Retract	YES	1	1	2	PAPER TIGER
PTAB3	Mixture	YES	Cut Off	NO	1	0	1	PAPER TIGER
PTAB3	Ignition Switch	YES	Off	YES	1	1	2	PAPER TIGER
PTAB3	Master Switch	YES	Off	YES	1	1	2	PAPER TIGER
PTNN4	Throttle	YES	Idle	NO	1	0	1	PAPER TIGER
PTNN4	Parking Brake	YES	Activated-Applied	YES	1	1	2	PAPER TIGER
PTNN4	Wing Flaps	YES	Retract	NO	1	0	1	PAPER TIGER
PTNN4	Mixture	YES	Cut Off	NO	1	0	1	PAPER TIGER
PTNN4	Ignition Switch	NO	Off	NO	0	0	0	PAPER TIGER
PTNN4	Master Switch	YES	Off	NO	1	0	1	PAPER TIGER
PTKC5	Throttle	YES	Idle	YES	1	1	2	PAPER TIGER

PTKC5	Parking Brake	YES	Activated-Applied	YES	1	1	2	PAPER TIGER
PTKC5	Wing Flaps	YES	Retract	YES	1	1	2	PAPER TIGER
PTKC5	Mixture	NO	Cut Off	NO	0	0	0	PAPER TIGER
PTKC5	Ignition Switch	YES	Off	YES	1	1	2	PAPER TIGER
PTKC5	Master Switch	NO	Off	NO	0	0	0	PAPER TIGER
PTKO6	Throttle	YES	Idle	YES	1	1	2	PAPER TIGER
PTKO6	Parking Brake	YES	Activated-Applied	NO	1	0	1	PAPER TIGER
PTKO6	Wing Flaps	YES	Retract	NO	1	0	1	PAPER TIGER
PTKO6	Mixture	YES	Cut Off	YES	1	1	2	PAPER TIGER
PTKO6	Ignition Switch	YES	Off	YES	1	1	2	PAPER TIGER
PTKO6	Master Switch	YES	Off	YES	1	1	2	PAPER TIGER
PTAC7	Throttle	YES	Idle	NO	1	0	1	PAPER TIGER
PTAC7	Parking Brake	YES	Activated-Applied	YES	1	1	2	PAPER TIGER
PTAC7	Wing Flaps	YES	Retract	NO	1	0	1	PAPER TIGER

PTAC7	Mixture	YES	Cut Off	YES	1	1	2	PAPER TIGER
PTAC7	Ignition Switch	YES	Off	YES	1	1	2	PAPER TIGER
PTAC7	Master Switch	YES	Off	YES	1	1	2	PAPER TIGER

APPENDIX D

Memory Retention Evaluation VRFTE Training Session

Participant ID	Flow Step	Step Correct?	Flow State	State Correct?	Step Score	State Score	Memory Score	Type Of Session
VRYc1	Throttle	NO	Idle	NO	0	0	0	VR SESSION
VRYc1	Parking Brake	YES	Activated-Applied	YES	1	1	2	VR SESSION
VRYc1	Wing Flaps	YES	Retract	NO	1	0	1	VR SESSION
VRYc1	Mixture	YES	Cut Off	YES	1	1	2	VR SESSION
VRYc1	Ignition Switch	YES	Off	YES	1	1	2	VR SESSION
VRYc1	Master Switch	YES	Off	YES	1	1	2	VR SESSION
VRSY2	Throttle	YES	Idle	YES	1	1	2	VR SESSION
VRSY2	Parking Brake	YES	Activated-Applied	YES	1	1	2	VR SESSION
VRSY2	Wing Flaps	YES	Retract	YES	1	1	2	VR SESSION
VRSY2	Mixture	YES	Cut Off	YES	1	1	2	VR SESSION
VRSY2	Ignition Switch	YES	Off	YES	1	1	2	VR SESSION

VRSY2	Master Switch	YES	Off	YES	1	1	2	VR SESSION
VRTU3	Throttle	YES	Idle	NO	1	0	1	VR SESSION
VRTU3	Parking Brake	YES	Activated-Applied	YES	1	1	2	VR SESSION
VRTU3	Wing Flaps	YES	Retract	YES	1	1	2	VR SESSION
VRTU3	Mixture	YES	Cut Off	YES	1	1	2	VR SESSION
VRTU3	Ignition Switch	YES	Off	YES	1	1	2	VR SESSION
VRTU3	Master Switch	YES	Off	YES	1	1	2	VR SESSION
VRTU4	Throttle	YES	Idle	YES	1	1	2	VR SESSION
VRTU4	Parking Brake	YES	Activated-Applied	YES	1	1	2	VR SESSION
VRTU4	Wing Flaps	YES	Retract	NO	1	0	1	VR SESSION
VRTU4	Mixture	YES	Cut Off	YES	1	1	2	VR SESSION
VRTU4	Ignition Switch	YES	Off	YES	1	1	2	VR SESSION
VRTU4	Master Switch	YES	Off	YES	1	1	2	VR SESSION
VRAI6	Throttle	YES	Idle	NO	1	0	1	VR SESSION

VRAI6	Parking Brake	YES	Activated-Applied	YES	1	1	2	VR SESSION
VRAI6	Wing Flaps	NO	Retract	NO	0	0	0	VR SESSION
VRAI6	Mixture	NO	Cut Off	NO	0	0	0	VR SESSION
VRAI6	Ignition Switch	YES	Off	YES	1	1	2	VR SESSION
VRAI6	Master Switch	YES	Off	YES	1	1	2	VR SESSION
VREC7	Throttle	YES	Idle	YES	1	1	2	VR SESSION
VREC7	Parking Brake	YES	Activated-Applied	YES	1	1	2	VR SESSION
VREC7	Wing Flaps	YES	Retract	YES	1	1	2	VR SESSION
VREC7	Mixture	YES	Cut Off	YES	1	1	2	VR SESSION
VREC7	Ignition Switch	YES	Off	YES	1	1	2	VR SESSION
VREC7	Master Switch	YES	Off	YES	1	1	2	VR SESSION
VRAW8	Throttle	YES	Idle	YES	1	1	2	VR SESSION
VRAW8	Parking Brake	YES	Activated-Applied	YES	1	1	2	VR SESSION
VRAW8	Wing Flaps	NO	Retract	NO	0	0	0	VR SESSION

VRAW8	Mixture	YES	Cut Off	YES	1	1	2	VR SESSION
VRAW8	Ignition Switch	YES	Off	YES	1	1	2	VR SESSION
VRAW8	Master Switch	YES	Off	YES	1	1	2	VR SESSION
VRCD9	Throttle	YES	Idle	YES	1	1	2	VR SESSION
VRCD9	Parking Brake	YES	Activated-Applied	YES	1	1	2	VR SESSION
VRCD9	Wing Flaps	YES	Retract	NO	1	0	1	VR SESSION
VRCD9	Mixture	YES	Cut Off	YES	1	1	2	VR SESSION
VRCD9	Ignition Switch	YES	Off	YES	1	1	2	VR SESSION
VRCD9	Master Switch	YES	Off	YES	1	1	2	VR SESSION