Exploring Immersive Technology in Flight Training: Trainee Pilots' Perceptions of Learning and Behavioural Outcomes.

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Declaration

A research report submitted to the Faculty of Humanities, University of the Witwatersrand. In partial fulfilment of the requirements for the degree of Masters of Arts by coursework and research report in Organisational Psychology. Submitted for examination: March 2024.

I declare that this research report is my own, unaided work. It has not been submitted for any degree at any other academic institution or published in any form.

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Abstract

The primary aim of this research was to examine the effectiveness of immersive technology on trainee pilots' learning and behavioural outcomes. The first phase of the research included building a survey to measure trainees' learning and behavioural outcomes. An initial sample of fifteen subject-matter experts assisted in creating the final survey. The second phase of the research involved distributing the survey to trainee pilots and consisted of twenty-seven participants. Spearman's Rank Correlation and Kendall's tau-b Correlation were run on the data. A Regularized Exploratory Factor Analysis (REFA) method was used to ensure the constructed survey measured trainee pilots' perceptions of their learning and behavioural outcomes. The main results showed a significant relationship between the use of immersive flight simulation training and trainee pilots' learning and behavioural outcomes. On the other hand, age, level of experience as a pilot, total flying time, and total flying time in modern flight decks had no significant association with trainee pilots' perceptions of their learning and behavioural outcomes. The small sample size affected the findings of the research and should be considered a limitation of the study. The findings of the research have implications for the design of flight simulations.

Key words: immersive technology, training, trainee pilots, flight simulation

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Table of Contents

Chapter 1: Introduction 7
Chapter 2: Literature Review 8
2.1 Introduction 8
2.2 Key Definitions 8
2.3 Evolution of Flight Simulation 11
2.4 Immersive Technology 13
2.4.1 Learning Outcomes – Cognitive Abilities 18
2.4.2. Behavioural Outcomes – Interpersonal Skills 20
2.5 Rationale 24
2.5 Research Aims 26
Chapter 3: Methodology 27
3.1 Research Paradigm 27
3.2 Research Design 27
3.3 Sample and Sampling 29
3.4 Procedure 35
3.5 Instrument 37
3.6 Data Analysis 42
Chapter 4: Results 46
4.1 Ethical Considerations 55
Chapter 5: Discussion and Implications 57
5.1 Overview of Findings 58
5.2 Factors Influencing Learning and Behavioural Outcomes 59
5.2.1 Learning Outcomes – Cognitive Effort 59
5.2.2 Behavioural Outcomes – Flying Competence 63
5.3 Lack of Association with Demographic and Experience Variables 64
5.4 Theoretical and Practical Implications 65
5.4.1 Cognitive Abilities in Pilot Training 65
5.4.2 Interpersonal Skills and Decision-Making 65
5.4.3 Transferability of Skills 65
5.5 Practical Implications 66
5.5.1 Curriculum Design and Integration 66
5.5.2 Training Programme Standardisation 67
5.3 Limitations and Recommendations for Future Research 68

5.4 Conclusion ... 69
References... 70
Appendices ... 92
Appendix A: Initial Pilots' Perceptions Scale... 92
Appendix B: Participant Information Sheet... 97
Appendix C: Consent Form ... 99
Appendix E: Final Perception Questionnaire ... 103
Trainee Pilots' Perceptions of the Impact of Aircraft Simulation... 103
Participant Information Sheet ... 103
Appendix E (continued): ... 104
Appendix E (continued): ... 105
Appendix E (continued): ... 106
Appendix E (continued): ... 107
Appendix E (continued): ... 109
Appendix E (continued): ... 110
Appendix E (continued): ... 111
Appendix E (continued): ... 112
Appendix F: Flight School Permission Letter... 113
Appendix F (continued):... 114
Appendix G(a) – G(e): Outlier Boxplots for each Question... 115
Appendix G Continued (b):... 116
Appendix G Continued (c): ... 117
Appendix G Continued (d):... 118
Appendix G Continued (e): ... 119
Appendix H: Official Consent from Flight School ... 120
Appendix H (continued):... 121
Appendix I: Ethics Certification... 122
Appendix J: Ethics Clearance... 123

List of Tables

Table 1: Key Term Definitions 9

Table 2: Additional Key Term Definitions 10

Table 3: Demographic Data of the Final Sample (N=26) 33

Table 4: Lawshe's (1975) Minimum Values of CVR 38

Table 5: Items Retained After Applying Lawshe's (1975) Method 40

Table 6: Test Assumptions for Factorability: 43

Table 7: Rotated Loadings Matrix 48

Table 8: Reliability and Item Statistics for Factor 1: Cognitive Effort (N= 26) 49

Table 9: Reliability and Item Statistics for Factor 2: Flying Competence (N= 26) 50

Table 10: Spearman's rho Correlations 52

Table 11: Kendall's tau-b Correlations 53

Table 12: Correlations for Demographic Variables 54

Table 13: Items Included in Final Trainee Pilots' Simulator Perception Questionnaire . 58

Table 14: IATA Core Competencies and the Related Items in the TPSP-Q 60

List of Figures

Figure 1: Penguin System Approach 11
Figure 2: Timeline Illustrating the Evolution of Flight Simulation 13
Figure 3: Reality-Virtuality Continuum 15
Figure 4: Differences between AR and VR 16
Figure 5:Overall Research Design 29
Figure 6: Scree Plot for Factorability 51

Chapter 1: Introduction

The advancement of technology has led to the development of many new and innovative technologies that have the potential to significantly improve human performance. Increasing attention has been paid to the advantages afforded by immersive technology as it can simulate a desired realistic or abstract environment using visual, auditory, and tactile displays (Pratisto et al., 2022; Rubio-Tamayo et al., 2017; Wickens, 1992; Handa et al., 2012). Immersive technology can be understood as technologies “that enable a more intuitive human-computer interface through devices and sensors that interact with up to the 5 human senses” (Fernandes et al., 2023, p. 1). Virtual reality (VR) and augmented reality (AR) are two technologies that are useful in creating an immersive environment as they can integrate both the real and virtual worlds (Boyles, 2017; Gandolfi, 2019; Yin et al., 2021; Milgram & Kishino, 1994). Immersive technology has been successfully applied to various fields such as entertainment (Christodoulou et al., 2018; Doumanis et al., 2015; Ji, 2020), education (Georgiou et al., 2020; Hernández-Lara et al., 2019; Pears et al., 2020; Liu et al., 2020), medicine (Wiehagen, 2008; Ovunc et al., 2021; Taekman & Shelley, 2010; Costell et al., 2012), and training in other fields such as emergency rescue (Li & Zuo, 2021), forklift safety (Abbas et al., 2023), and mining (Bednarz et al., 2010). The research available on the use of immersive technology in the aviation industry is limited to areas such as air traffic control and management (Cordeil et al., 2016), the fidelity of the flight simulator (Oberhauser et al., 2018), and the role of flight simulators in pilot training (Caro, 1973; Cross et al., 2022; Macchiarella et al., 2006; Taylor & Clayton, 2021; Fussell & Truong, 2020). Of particular interest to the current research, is the use of immersive technology, such as aircraft simulators, in training pilots. Specifically considering the effectiveness of immersive technology on pilots’ perceptions of their learning and behavioural outcomes.

With its potential to improve human functioning through simulating various scenarios and environments, immersive technology has a great influence on how learning occurs and how behaviour can be shaped to suite the requirements of specific environments. Despite the growing interest in studying the impact of immersive technology in various industries, there appears to be a lack of research exploring the impact of immersive technologies on trainees’ perceptions of learning and behavioural outcomes. Therefore, this research seeks to examine trainee pilots’ perceptions of learning and behavioural outcomes using immersive technology in flight training. Specifically, the research sought to investigate the impact of using immersive technology, such as an aircraft simulator, on trainee pilots' learning outcomes such as knowledge acquisition, skills, values, and attitudes. The behavioural outcomes of using immersive technology in trainee pilots' training was examined using data from a survey instrument and explored constructs such as cognitive response to training, stress and anxiety levels, confidence, and decision-making abilities. By exploring the evolution of immersive technology in flight training and reviewing the current literature available on the topic, final results from the present research uncovered gaps in the literature regarding the impact of immersive technology on trainee pilots' perceived learning and behavioural outcomes.

Chapter 2: Literature Review

2.1 Introduction

When conducting a research study, it is essential for existing literature to be reviewed and critically examined. This is because the literature review provides the researcher and readers with an overview of the topic at hand, an idea of gaps in existing research, and how the research being conducted contributes to the greater context (Knopf, 2006). A successful literature review involves the consultation of various sources on the topic being explored, providing a foundation of knowledge and thorough understanding (Rowley & Slack, 2004). Research examining the effectiveness of immersive technology on trainee pilots' perceptions of their learning and behavioural outcomes is lacking when approached from an organisational psychology perspective. For this reason, there is limited literature available on the topic. One of the purposes of this research study, then, was to add further discourse to the existing knowledge on the topic.

In the current chapter, the evolution of flight training is examined; specifically focusing on the evolution of flight simulation. Thereafter, the chapter introduces the concept of immersive technology and its use as a method of training within various industries. Included in this discussion are the concepts of learning and behavioural outcomes and the constructs used to measure these outcomes.

2.2 Key Definitions

Definitions of four key terms used throughout the research paper are provided in Table 1. These definitions are crucial for the discussion and literature review and assist in developing a thorough understanding of key concepts. These final definitions were informed by differing definitions from other scholars presented in Table 2.

Table 1: Key Term Definitions

Term	Definition
Flight Simulation	"…the object of flight simulation is to reproduce on the ground behaviour of an actual aircraft in flight" (Rolfe & Staples, 1988, p. 1). "The flight simulation of an aircraft provides a virtual scenario on the ground itself (in the simulation laboratory/facility) of the flight conditions in air, and this helps in understanding the flight dynamics, and the behaviour of the aircraft during the take-off and the landing conditions" (Raol & Singh, 2023, p. 3).
Immersive Technology	Immersive technology refers to a group of technologies that work together to simulate an environment that appeals to several senses and makes it difficult to tell the difference between reality and virtual reality. This is made possible by utilizing cutting-edge technology like surround sound, haptic feedback, and high-resolution 3D graphics, which provide users a more realistic and immersive virtual experience (Lee et al., 2013; Slater, 2009). "Immersive technology imitates a physical world using computer-generated simulation and creates a sense of immersion in the form of Virtual Reality (VR), Augmented Reality (AR) or Mixed Reality (MR)" (Wang et al., 2023, p. 2).
Learning Outcomes	"Learning outcomes are statements of what a learner is expected to know, understand and/or be able to demonstrate at the end of a period of learning" (Adam, 2004, p. 2). "…learning outcomes describe how students will apply the material both in and outside the classroom" (Rafiq et al., 2023, p. 667).
Behavioural Outcomes	Behavioural outcomes refer to the visible and quantifiable acts or behaviours that follow an intervention, program, or educational experience. They are described in terms of particular behaviours, abilities, or information that participants should possess following an intervention, program, or educational experience (Brown, 2019; Caro, 1973; Macchiarella et al., 2006; Oberhauser et al., 2018). "Improved technology has changed the behavior and attitudes of students and has changed the way they learn and communicate in and outside the classroom" (Rafiola et al., 2020, p. 75).

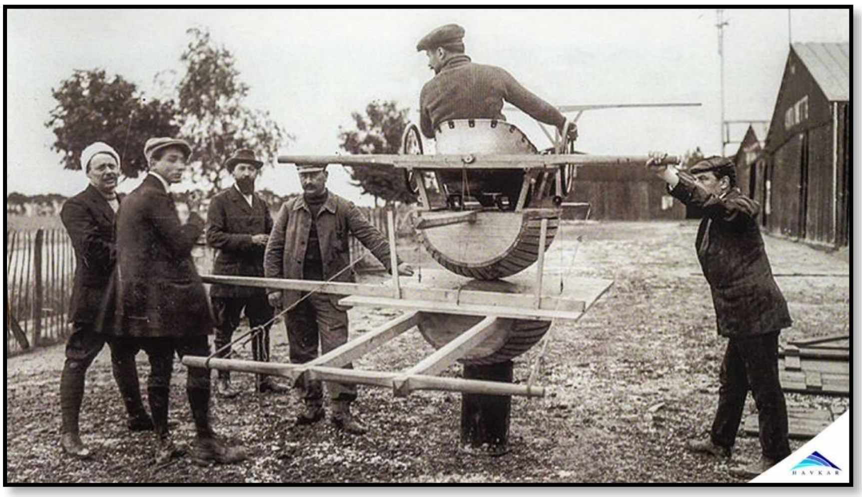
Table 2: Additional Key Term Definitions

Term	Definition
Flight Simulation	"…is the flight simulator, in which the pilot can practice many flying tasks while sitting safely on the ground. He or she can even practice responses to unlikely events, particularly those that might lead to disaster" (Haber, 1986, p. 96). "Flight simulators are devices in which air crews and pilots can train without the use of an actual aircraft" (Zhou & Fang, 2018, p. 1).
Immersive Technology	"Immersive 360◦ environments allow participants to feel as though they are inside the environment while non-immersive environments only allow participants to see the contents based on how the device in use- PC, smartphone, or tablet- is held and moved" (Ventura et al., 2019, p. 1). "Immersive technologies are defined as any form of technology that allows the blurring of virtual and real worlds while providing a sense of immersion" (Tom Dieck & Han, 2022, p. 110).
Learning Outcomes	"A learning outcome is a statement of what a learner is expected to know, understand, and/or be able to do at the end of a period of learning" (Donnelly & Fitzmaurice, 2005, p. 16). "Stated differently, a learning outcome demonstrates knowledge that learners acquire through learning experiences proposed by the educator during the enactment process" (Makumane & Khoza, 2020, p. 2).
Behavioural Outcomes	"…behavioral change intentions account for an individual's intentions to be and act more climate consciously" (Petersen et al., 2020, p. 13). "…the use of VR training may contribute to sustained safety behavior change by providing unique experiences that would be only available in a controlled interactive VR environment such as immediate feedback, empathy building, experiencing consequences due to unsafe behavior, future projection, and emotional self-regulation" (Abbas et al., 2023, p. 1).

2.3 Evolution of Flight Simulation

Continuous developments and advancements in technology have allowed for the introduction of new, creative, and innovative methods of learning and training. This is especially true in the training of pilots which makes use of immersive technology, such as virtual reality, in training pilots (Oberhauser et al., 2018). Before these developments, however, initial training methods of pilots involved performing sequences on a real aircraft (Page, 2000). By using the 'penguin system' approach (Figure 1), grounded pilots could practice simulating aerodynamic forces and becoming acquainted with aircraft controls (US Department of Aviation, 2016; Page, 2000). Using real aircraft parts, early flight aids such as the Sanders Teacher (Bolton, 2018) gave aspiring pilots a risk-free way to experience flying. These devices were limited in erratic wind conditions, though, as they relied on 10 mph winds. With the development of mechanical or electrical actuators, flight simulators have become more advanced, doing away with the necessity for manual manipulation. In order to facilitate the transfer of skills to actual aircraft operation, the Link Trainer (1927–1929) imitated cockpit conditions (Jeon, 2015). By the late 1930s, developments had included radio signals for navigation and visual systems for pitch and roll in electrical and electronic simulation techniques. The introduction of these technologies contributed to pilots' learning as it positively simulated radio navigation aids encountered in the actual aircraft, allowing them to acclimatise to the conditions of the aircraft quicker (Page, 2000).

Figure 1: Penguin System Approach

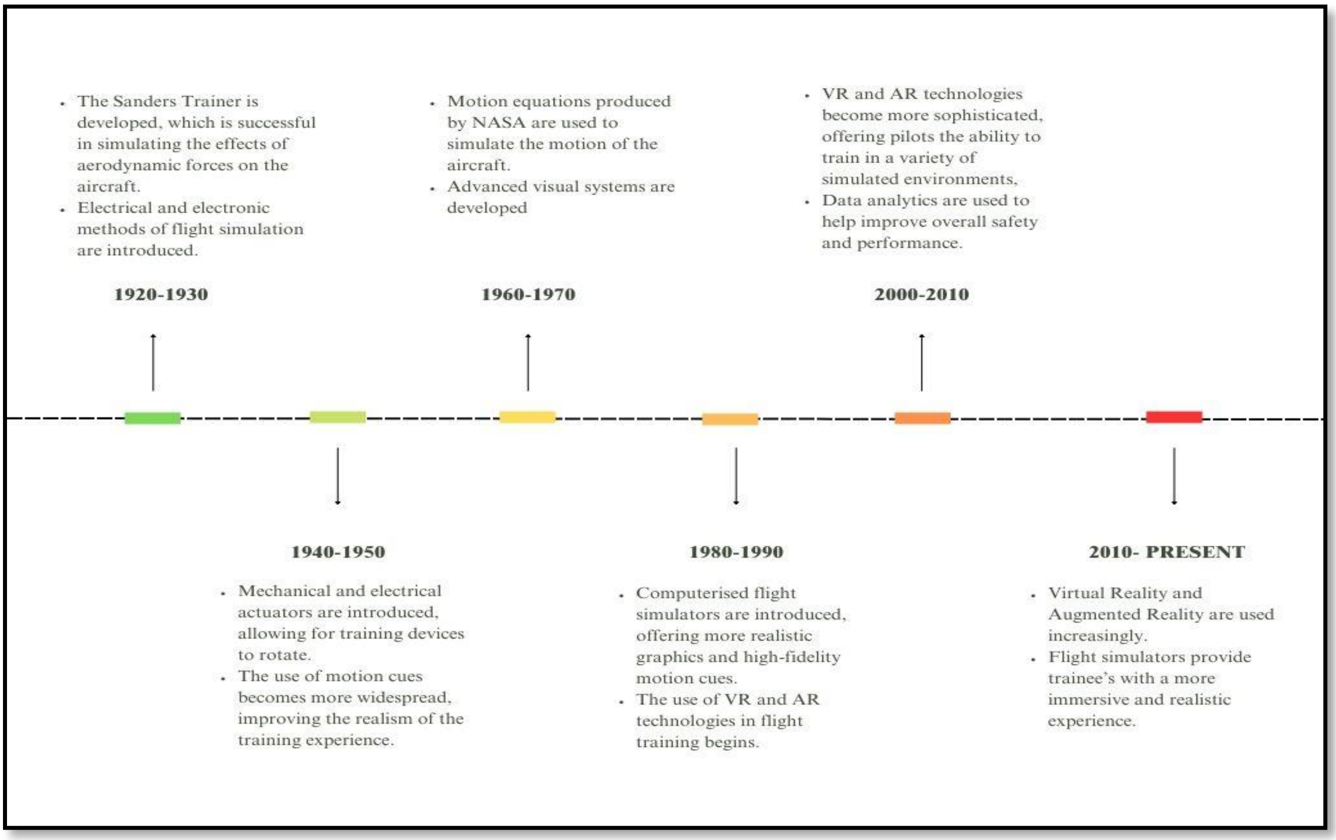


Source: Havkar, n.d. (https://havkar.com/en/blog/view/first-aircraft-simulator/90).

What these early designs lacked, however, was the simulation of the motion of the aircraft (Page, 2000). The motion equations produced by the National Aeronautics and Space Administration (NASA) used in the simulation of the Lunar Landing assisted designers in resolving this issue, thus improving the quality of the flight training devices. The continued advancement of visual systems led to the creation of systems that remain relevant today, such as the continuous projection of an image on a curved screen. The improvements in simulated flight training devices were successful in guaranteeing cost savings and in reducing training-related accidents using an actual aircraft. Furthermore, these devices were able to ensure the transfer of skills from the simulator to the aircraft by establishing a connection between the representations of different failures or emergencies in the actual aircraft and the actions required to resolve such issues (Jeon, 2005; Page, 2000). The integration of technological advancements in aviation training has been successful in heightening learner engagement and ensuring more effective knowledge retention (Rupasinghe et al., 2011), accelerating skill development through the sense of presence/immersion (Jentsch et al., 2011), and improving pilots' decision-making skills when under pressure (Lee, 2016). What is evident is that flight training simulators evolve with the advancements made in technology. As the Fourth Industrial Revolution involves increasing collaboration between humans and automated technology, it is only natural that flight training simulators have evolved to include immersive technology in the successful training of pilots. As such, one of the main research questions of this paper is to explore the use of immersive technology in flight training by understanding trainee pilots' perceptions of their learning and behavioural outcomes.

Presented in Figure 2 below, is a timeline illustrating the evolution of flight simulation. This provides a visual representation of the progress of flight simulation and indicates how technological advancements influenced the development.

Figure 2: Timeline Illustrating the Evolution of Flight Simulation



Source: Author

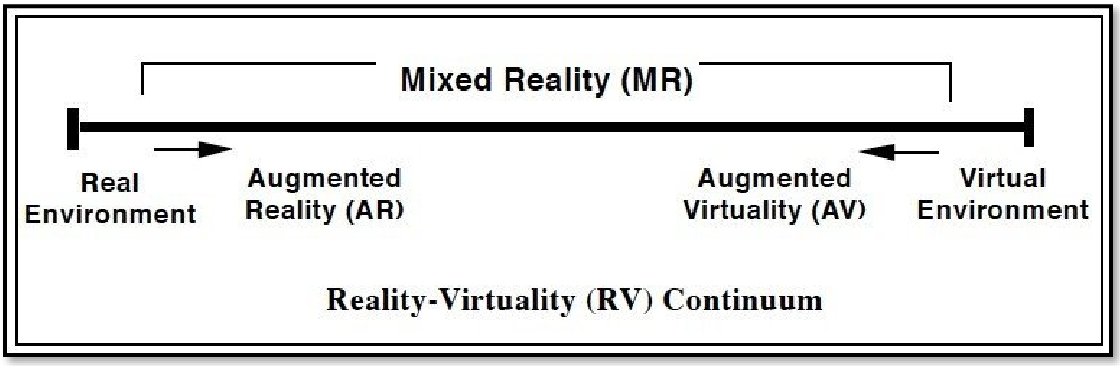
2.4 Immersive Technology

The increasing popularity of immersive technology has resulted in various definitions of the term. According to Slater (2009), immersive technology is used to simulate an environment using high-quality sensory information. It is viewed as a technology that blurs the line between reality and the virtual environment by creating a sense of immersion (Lee et al., 2013). Immersive technology utilises factors such as haptic technology, 3D graphics, and surround sound (Pavithra et al., 2020), to emulate reality in a virtual environment, thereby immersing users in virtual scenarios (Liu et al., 2020; Makransky & Lilleholt, 2018; Suh & Prophet, 2018; Handa et al., 2012). In this research, the following definition of immersive technology is used: Immersive technology refers to a group of technologies that work together to simulate an environment that appeals to several senses and makes it difficult to tell the difference between reality and virtual reality. This is made possible by utilising cutting-edge technology like surround sound, haptic feedback, and high-resolution 3D graphics, which provide users a more realistic and immersive virtual experience (Slater, 2009; Lee et al., 2013).

The successful replication of reality using immersive technologies allows users to be immersed in the virtual environment by creating a sense of presence or "being there" (Cummings & Bailenson, 2016; Steuer et al., 1995; Ruscella & Obeid, 2021; Neo et al., 2021; Makransky et al., 2019). This state of presence or immersion can be achieved through immersive technology such as virtual reality (VR) which falls on the reality-virtuality continuum proposed by Milgram and Kishino (1994). The reality-virtuality continuum (Figure 3) suggests that different levels of immersion can be achieved along the continuum depending on the degree of augmented virtuality applied to real-world environments (Milgram & Kishino, 1994; Suh & Prophet, 2018). Virtual reality can be understood as technologies that enable users to interact with and engage in a virtual environment that simulates reality or real-world scenarios (Zeng & Richardson, 2016). As virtual reality merges the real world and the virtual world through visual, auditory, and tactile displays, it utilises augmented reality technologies to create mixed reality (Milgram & Kishino, 1994; Suh & Prophet, 2018; Oberhauser et al., 2018; Zeng & Richardson, 2016). By creating a mixed reality environment using augmented reality, the user can experience immersion in the virtual world as there is a blurring of the boundaries between the virtual, real, and simulated worlds thus creating a sense of presence or ‘being there’ (Cummings & Bailenson, 2018; Lee et al, 2013; Steuer et al., 1995).

Immersion is developed and enhanced in these virtual reality systems when they can stimulate the users’ senses via surround sound, vivid visual displays, and haptic feedback (Cummings & Bailenson, 2018; Slater, 2009). The inclusion of these factors allows for the development of an “interactive digital learning [environment] that [imitates] a real-life process or situation” (Merchant et al., 2014, p. 30). These simulations allow users to understand the outcomes of certain actions/ inputs thus assisting in the learning and training of students or pilots (Liu et al., 2020; Merchant et al., 2014; Parong & Mayer, 2018; Bailey et al., 2017). For instance, Al-Zyoud et al., (2023) conducted a study aimed at reducing smoking amongst university students through a virtual reality smartphone application. The findings of the study indicate the efficacy of immersive technology in influencing behaviour. Preceding the VR intervention, 63.6% of the sample indicated intent to quit smoking however, after the VR intervention, this number increased to 81.8% (Al-Zyoud et al., 2023, p. 114). Furthermore, a study conducted by Adertino et al., (2023), examined the efficacy of VR-based rehabilitation in stroke patients. The authors found VR-based rehabilitation as offering an immersive and interactive platform that motivates and engages patients in their rehabilitation process as opposed to traditional rehabilitation methods which tend to be monotonous and cause disinterest (Adertino et al., 2023).

Figure 3: Reality-Virtuality Continuum



Source: Milgram & Kishino (1994).

Augmented reality creates an immersive environment through wearable technologies such as head-mounted displays which project computer-generated graphics onto real-world environments allowing the user to manually interact with virtual objects (Milgram & Kishino, 1994; Rolland & Hua, 2005). This is advantageous for the learning process as AR-supported training programmes allow students to comprehend important components such as "spatial structure and function, long-term memory retention, improved physical task performance, and increased student motivation" (Schaffernak et al., 2020, p. 3). Applied to the aviation industry, augmented reality can assist in the checklist and manual training, as well as interactive training for understanding the components and systems of the aircraft (Brown, 2017). Additionally, augmented reality has been introduced into pilot training programmes to assist in collision avoidance training by simulating various problems pilots may encounter and allowing them to develop strategies to avoid potential accidents (Moesl et al., 2021). Virtual reality technologies create immersive experiences by simulating environments through graphic displays, and audio and tactile components (Milgram & Kishino, 1994). Imitating the cockpit both virtually and realistically allows the pilot to comprehend the workings of the actual aircraft (Fussell & Hight, 2021). Furthermore, using virtual reality to create an immersive environment for pilot training can ensure the successful transfer of training to the actual aircraft as pilots experience procedural and task training required in the actual aircraft (Brown, 2017; Fussell & Hight, 2021). Haptic technology is often used in conjunction with the above-mentioned immersive technologies to enhance user experience. A haptic device provides users with touch sensations that respond to the input of the user (Clapan & Hamza-Lup, 2008). Flight training simulators include haptic technology such as the many control buttons and switches characteristic of the cockpit panel, the vibrations of turbulence, and the tiller of the aircraft (Girdler & Georgiou, 2020). This is effective in simulating the real-life conditions that the pilot may encounter in an actual aircraft, further contributing to the successful transfer of training. Figure 4 below shows the differences between augmented reality and virtual reality.

Figure 4: Differences between AR and VR

Augmented Reality (AR)	Virtual Reality (VR)
The system adds to reality, it augments the real-world.	The system completely replaces reality by simulating a virtual environment.
Users experience partial immersion.	Users experience complete immersion.
Real world is enhanced by virtual technologies.	Real world is replicated by haptic, visual, and audio technologies.
Makes use of wearable technologies such as head-mounted displays.	Makes use of wearable technologies as well as motion detecting technologies.

Source: Author

Immersive virtual reality technology has been applied to various fields such as education (Liu et al., 2020; Merchant et al., 2014; Pribeanu et al., 2017), healthcare (Taekman & Shelley, 2010; Costell et al., 2012; Pears et al., 2020), manufacturing (Govindarajan et al., 2018; Ramalho et al., 2020), entertainment (Bian et al., 2016; Bodzin et al., 2021; Brondi et al., 2015), safety and maintenance training (Bailey et al., 2017; Buttussi & Chittaro, 2017), and aviation (Brown, 2019; Caro, 1973; Fussell & Truong, 2020; Taylor & Clayton, 2021; Oberhauser et al., 2018). Research conducted in these fields provides evidence for the usefulness of immersive technology in improving the learning outcomes of students (Makransky et al., 2019; Liu et al., 2020) which is also replicated in studies using immersive technology in the training of pilots (Brown, 2019; Caro, 1973; Fussell & Truong, 2020; Macchiarella et al., 2006; Taylor & Clayton, 2021). This is also known as Synthetic Flight Training Systems (SFTS) which utilises “automated training features and manual features” (Caro, 1973, p. 5). This technology, like flight simulators, generate environments and flight dynamics through computers to create a realistic experience of flying. The influence of immersive technology on the learning and behavioural outcomes of trainee pilots has pertinence to the current paper.

As the use of automation and complex technology in aircraft increases, so does the need for trainee pilots' training to mirror this change to ensure an effective and seamless transfer of skills from flight simulation to the actual aircraft (Brown, 2019). According to Brown (2019, p. 164), using advanced technology, such as immersive technology, is effective in accelerating students' learning and "[enables] students to master knowledge, skills, and ability (KSA) with increased situational awareness". This is relevant to trainee pilots' learning experience as they are crucial skills which assist pilots' ability to respond to environments and emerging situations. By providing a simulation of the flight deck, trainee pilots can acclimatise to the instruments, equipment, controls, and panels of the actual aircraft seamlessly and efficiently (Macchiarella et al., 2006). The incorporation of such factors in the flight simulator training device establishes a sense of presence in the trainee pilot, allowing trainee pilots to feel as though they are flying an actual aircraft (Zhang et al., 2006). Additionally, immersive technology encourages engagement in the content, develops decision-making skills, and is an ideal method for scenario-based training which is characteristic of the training pilots require (Fussell & Truong, 2020). The engagement encouraged using immersive technology results in the trainee pilot experiencing the psychological state of flow (Georgiou & Kyza, 2017). According to Csikszentmihalyi (1997), flow is the mental state of the user in which they experience intense focus, engagement, and commitment to the performance of a task. When experiencing a state of flow, the cognitive and physiological processes of the user are evoked which produce positive emotions, deep absorption, acquisition of necessary skills, and instinctual functioning (Alhalabi, 2016; Bian et al., 2016; Passig et al., 2016; Webster, 2016). Once users are engaged in a state of flow, they begin to experience enjoyment in the task they are fulfilling, making learning, or training an enjoyable experience (Brondi et al., 2015). Furthermore, when immersive technology is used in the training of pilots, the detailed and well-developed visual graphics simulating the experience of flying leads to higher levels of skills transfer from the simulator to the actual aircraft (Macchiarella et al., 2006; Sitzmann, 2011). Additionally, high fidelity of the physical, control, and cognitive tasks, the simulations of visual scanning and response tasks, and the ability to simulate various scenarios the pilot may encounter whilst flying, all contribute to the successful transfer of skills and knowledge to the actual aircraft (Macchiarella et al., 2006; Sitzmann, 2011; Vogel et al., 2006). The successful simulation of the conditions a pilot may encounter in the actual airplane promotes the creation of accurate mental models of both procedural tasks and critical skills, allowing the trainee to easily access the information required for adaptive decision-making and problem-solving (Bailey et al., 2017; Buttussi & Chittaro, 2017). These immersive technologies also prove effective in developing and improving the user's situation awareness by acclimatising them to the multiple displays and controls that exist in the real world (Roldan et al., 2017). The development of situation awareness is especially important in trainee pilots as they are required to remain aware of the multiple sources of information provided to them to ensure safety and the prevention of possible incidents or accidents (Roldán et al., 2017; Wickens et al., 2013).

2.4.1 Learning Outcomes – Cognitive Abilities

An individual's capacity to learn is strongly determined by the cognitive abilities they possess (Snow, 1994). Knowledge acquisition, decision-making, problem-solving, processing speed, and situation awareness are key cognitive abilities that contribute to one's learning. This discussion focuses on the relationship between these cognitive abilities and learning outcomes, specifically examining how flight simulation can positively influence and enhance these abilities in trainee pilots.

Knowledge acquisition is a key cognitive ability in the learning process and influences learning outcomes as it affects how individuals acquire, process, and retain information (Kuhn et al., 1995). Often, the learning process begins by building foundational knowledge through theoretical knowledge which then is then strengthened through practical experience (Gomez-Arizaga et al., 2016). However, possessing theoretical knowledge does not guarantee that performance of a related, practical task will be successful as the individual may understand what is happening but is incapable of responding effectively (Schunk, 2012). Applied to the aviation industry, trainee pilots need to acquire an in-depth understanding of aircraft systems, standard operating procedures (SOP's), and emergency responses (Beköz & Akteke, 2022; Lee, 2017). The flight simulation provides trainee pilots with an opportunity to expand upon this knowledge and understand the practical applications in a safe and cost-effective manner (Lee, 2016; Ng, 2022; Ng & Chu, 2021). Decision-making skills are crucial in the aviation industry, as such it is essential to create a learning environment that develops trainee pilots' decision-making skills. Pilots need to possess the ability to make high quality and optimal aeronautical decisions, assess risk, and identify solutions to a problem an decide on a course of action (Bruskiewicz et al., 2007; Thomas et al., 2023).

Flight simulation provides a learning environment for trainee pilots to experience challenging scenarios and emergencies, developing their ability to make quick and effective decisions when under pressure (Risukhin, 2015; Thomas et al., 2023; Whitehurst et al., 2019). A connected skill is problem-solving, pilots must be able to approach any unforeseen circumstances in an analytical and critical manner to ensure they can adapt to any situation they may encounter (Barnes et al., 2000; Warner & Knapp, 2000). Flight simulation is effective in developing this skill as it can simulate a variety of complex situations that challenges the trainees' deductive and inductive reasoning skills (Fleishman et al., 1984), contributing to their problem-solving capabilities. Processing speed is a cognitive ability that plays an important role in how quickly and effectively pilots can make decisions and problem solve. Pilots need to be able to compare letters, numbers, objects, or patterns quickly and accurately to be able to respond to a situation timeously (Barnes et al., 2000). Flight simulation training has the potential to expose trainee pilots to real-time data, requiring quick processing and decision-making, simulating the speed at which information needs to be processed. Pilots must also develop the ability to respond effectively to unpredictable challenges they may face in the aircraft. For instance, in 2022 South African Airways pilots faced a fuel contamination issue during a flight from Accra to Johannesburg (Ginindza, 2022). The pilots successfully responded to the situation due to their rigorous training which included extensive simulations of emergency situations. This situation illustrates the effectiveness of simulation training as the pilots were able to engage in well-informed problem-solving techniques. The pilots' ability to analyse and navigate through such a challenging situation can be credited to the simulation-based training they underwent. Tying the above-mentioned cognitive abilities together is situation awareness. According to Endsley (1999, p. 257), "Situational awareness (SA) can be thought of as an internalised mental model of the current state of the flight environment". Possessing situation awareness allows pilots to operate in a safe manner, monitor many instruments, and adapt to changing conditions (Wickens, 2002). The immersive nature of flight simulation develops trainee pilots' ability to anticipate events, multitask, remain aware of their environment, and make informed decisions thus developing their ability to remain situation ly aware (Bailey et al., 2017; Liu et al., 2020; Merchant et al., 2014; Parong & Mayer, 2018). By simulating real-world conditions, flight simulation offers trainee pilots a realistic and immersive experience that resembles real-world flight scenarios. Repeated practice through simulations strengthens cognitive abilities and develops muscle memory, allowing for the seamless transfer of skills to the actual aircraft. As a result, flight simulation can significantly enhance learning outcomes by positively developing key cognitive abilities. Therefore, the paper uses the above-mentioned cognitive abilities to measure trainee pilots' perceptions of their learning outcomes.

2.4.2. Behavioural Outcomes – Interpersonal Skills

Interpersonal skills are crucial for effective interaction and collaboration, this is especially important in the aviation industry as it is a high-risk environment. Communication, awareness, pattern recognition, adherence to standard operating procedures, motivation, and adaptability are some of the key interpersonal skills that contribute to one's behavioural outcomes. This discussion focuses on the relationship between these core interpersonal skills and how training in flight simulators can enhance these skills and lead to positive behavioural outcomes for trainee pilots.

In aviation, clear and concise communication is essential for ensuring safe operations (Crumley & Bailey, 1979). Flight simulation provides a learning environment for trainee pilots to practice and enhance their communication skills, by engaging in realistic scenarios that require precise information exchange with other aviation professionals- such as cabin crew or ground personnel (Barnes et al., 2000; Bruskiewicz et al., 2007; Fleishman et al., 1984; Risukhin, 2015; Warner & Knapp, 2000; Ziccardi et al., 2020; Zuluaga-Gomez et al., 2023). Behavioural outcomes in the aviation industry are closely linked to situation awareness, the ability of pilots to understand the aircraft in relation to the environment (Bruskiewicz et al., 2007). Flight simulation can heighten trainee pilots' situation awareness by encouraging collaboration with other aviation professionals, interpreting communication cues, and responding to everchanging environments (Yu et al., 2014; Zhou et al., 2022). The American Airlines Flight 965 is a useful example to understand the importance of clear and effective communication and situation awareness in aviation (Idowu et al., 2022). The Boeing 757 crashed into a mountainous area in Colombia which killed all but four on the flight. After a detailed investigation, communication issue and a loss of situation awareness were identified as the key factors in the crash. As the crew did not speak fluent Spanish, they could not effectively communicate with Colombian Air Traffic Control resulting in some key information being omitted during communication with the air traffic control (Idowu et al., 2022). The crew also deviated from the planned approach and misinterpreted navigational information as they were fatigued. Consequently, the lack of effective communication and the loss of situation awareness placed the crew in an unfamiliar situation to which they could not respond effectively. Pilots need to be able to recognise patterns as this helps them identify and respond to similar situations in an effective and efficient manner (Warner & Knapp, 2000). Flight simulators expose trainees to a range of scenarios which helps them develop this key skill which contributes to their overall performance, decision-making and problem-solving capabilities (Kaukoranta et al., 2003). To maintain safety and consistency, it is crucial for pilots to know and adhere to standard operating procedures (Palla et al., 2018; Patankar, 2003). Flight simulation plays an important role in ensuring positive behavioural outcomes and establishing a disciplined approach to handling the aircraft and interacting with other professionals (Balcerzak & Kostur, 2018). Being adaptable is an essential behaviour for pilots as they operate in a dynamic and ever-changing environment and are required to quickly adapt and change priorities when needed (Bruskiewicz et al., 2007). Flight simulators provide trainee pilots with exposure to diverse and unpredictable scenarios which encourages them to adapt and cultivate a flexible mindset (Cross et al., 2022). Motivation is a key interpersonal skill that plays a role in trainees' performance and success when using the flight simulations (Ng, 2022). By presenting engaging and challenging scenarios, trainee pilots are motivated to learn, excel, and improve their interpersonal skills which leads to positive behavioural outcomes.

Immersive technology also can influence and encourage behavioural changes in users through what is known as the Proteus effect (Yee et al., 2009). The Proteus effect proposes that behaviour in virtual reality can influence behaviour in real-life situations as the behaviours that are perceived to be rewarded or likeable in the environment are expected to evoke similar reactions in real-life (Yee et al., 2009). This can be applied to the use of flight simulators where trainee pilots can observe which behaviours, skills, and operations result in a favourable outcome and thus which to replicate in the actual aircraft. The positive feedback provided in the flight simulation will encourage trainee pilots to replicate that feeling when actually flying due to the intrinsic reward associated with the positive feedback, therefore the trainee will internalise critical skills and knowledge to transfer to the actual aircraft (Brown, 2019; Caro, 1973; Macchiarella et al., 2006; Oberhauser et al., 2018). Replication of the flight deck in the simulator is useful in acclimatising the trainee pilot to the environment they will encounter in the actual aircraft (Buttussi & Chittaro, 2018). While there are many studies available discussing the positives of immersive technology on learning and training, the negative consequences of using these technologies should be addressed.

Some research conducted on the effects of immersive technology have found that some users experience negative emotions such as anxiety and fear (Buttussi & Chittaro, 2017), cognitive overload which results in a negative effect on learning (Makransky et al., 2019), motion sickness from using head-mounted displays (Liu et al., 2020), and negative transfer of skills whereby the skills learnt in the simulator do not transfer to actual experiences of flying an aircraft (Caro, 1973; Macchiarella et al., 2006). The importance placed on using flight simulators to certify trainee pilots may also conjure up feelings of stress and pressure to perform (Kao & Ruan, 2022). Negative emotions such as anxiety, fear, stress, and pressure can be reduced by training pilots to control their emotions (Tichon et al., 2014). In a high stress environment, such as the aviation industry, emotional awareness plays an important role in reducing the likelihood of human error from occurring (Stipp, 2017; Tichon et al., 2014). According to Stipp (2017), pilots who can regulate their emotions are able to maintain situation awareness and thus safely operate the aircraft. Situation awareness is defined as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1988, p.97). Situation awareness is important in order to gain competence in operating an aircraft as is enables pilots to monitor the aircraft's systems and performance, be aware of the surrounding air traffic and terrain, and anticipate and react to potential accidents/incidents (Endsley, 1999; Stanton et al., 2001; Wickens, 2002; Wickens et al., 2013). Cognitive overload negatively influences an individual's working memory which is crucial in knowledge acquisition and training as it contributes to how an individual retrieves and mentally represents essential information to performing a task (Wickens et al., 2013). This issue can be reduced by developing training programmes from the perspective of the trainee (Baldwin et al., 2017). Approaching the development and design of training programmes from this perspective will ensure the creation of accurate mental models which allow the trainee pilot to assess the scenario they have encountered and predict how their actions/inputs might influence the behaviour of the flight simulator (Wickens et al., 2013). These mental models may be curated through experience with the simulator, via training, and through supportive feedback.

According to Riccio and Stoffregen (1991), a loss of postural stability combined with computer-generated imagery can result in motion sickness. This effect on trainee pilots can be reduced by using hardware and software to "monitor postural control and use this information to predict and/or prevent motion sickness in users" (Stoffregen et al., 2000, p. 468). Negative transfer of skills is a consequence that is of most concern regarding the use of immersive technology in training pilots and is influenced by factors such as motion sickness and anxiety. A negative transfer of skills may result in increased human error and/or accidents and incidents as the trainee pilot may grow complacent during training as they are aware that they are in a simulation and not an aircraft (Buttussi & Chittaro, 2017; Caro, 1973). The trainer plays a critical role in ensuring successful flight simulator training sessions. (Myers et al., 2018). The trainer needs to know the capabilities and limitations of the flight simulator, the objectives of the training session, and how to adapt their training style to meet the individual needs of each trainee pilot. Knowledgeable and adaptive trainers can optimise the time spent in the flight simulator and ensure successful knowledge acquisition and transfer of skills. The simulation may also insufficiently develop trainee pilots' self-efficacy and thus their ability to adaptively problem-solve and make decisions- a crucial skill for mitigating potential risks and incidents (Zheng et al., 2017). This challenge can be reduced by introducing changes of situational conditions to reduce complacency in pilots training in a flight simulator (Parasuraman & Manzey, 2010). Introducing changes of situational conditions encourages trainee pilots to remain aware of the task they are performing as well as accountability for their actions. This can also develop flexible and adaptive problem-solving in trainee pilots.

Advancements in technology have allowed the training of pilots to evolve and become safer, efficient, effective, and cost effective. Introducing technologies such as flight simulators allows trainee pilots to develop the skills and knowledge necessary to flying an actual aircraft. Using flight simulators in training programmes is useful for acclimatising trainee pilots to the environment of the aircraft and in developing their understanding of the tasks and procedures required for flying an aircraft. The research conducted on the use of immersive technology in the aviation industry is limited and exhibits a gap in the literature. Numerous studies have been conducted in other industries to assess the effectiveness of immersive technology as a method of exploring psychological and societal phenomena. One such study was conducted by Peck et al. (2013) who found that an individual immersion into a VR world can in fact transform negative interpersonal attitudes using an avatar. Other research has examined the usefulness of immersive technologies and experience when approaching training in the process industry (Fracaro et al., 2022). A review of the literature available on the process industry showed that incorporating immersive technologies in the training of operators developed their ability to respond quickly and problem-solve when faced with dangerous and non-stationary situations (Manca et al., 2013; Nazir et al., 2013; Skripcak et al., 2013). These studies show the effectiveness of immersive technologies in developing trainees' cognitive abilities such as decision making and problem-solving (Manca et al., 2013), pattern recognition (Nakai, 2015; Nazir & Manca, 2013), situation awareness (Nakai, 2015; Nazir et al., 2015), and knowledge acquisition (Colombo & Golzi, 2016). In the healthcare sector, multiple studies have identified the benefits of using immersive technology in the development of core behavioural outcomes. There is evidence that using VR technology and simulations in training medical students improved their psychomotor skills required for conducting a laparoscope (Grantcharov et al., 2004; Thijssen & Schijven, 2010; Verdaasdonk et al., 2009), developed their manipulation skills required for conducting an endoscopy (Shirai et al., 2008), and enabled them to acquire basic skills comparable to experienced physicians and surgeons (Goldmann & Steinfeldt, 2006; Seymour et al., 2002). In the aviation industry, immersive technology has been shown to be effective in the training of pilots (Brown, 2017; Fussell & Hight, 2021; Moesl et al., 2021; Taylor & Clayton, 2021). However, the literature available is predominantly focused on the effectiveness of immersive technologies in training aviation professionals as well as the cost benefits and efficiency associated with such technologies. There is a dearth of literature available, however, on understanding the impact of immersive technology on trainee pilots' perceptions of their learning and behavioural outcomes. Thus, this was the aim of the research project.

2.5 Rationale

Pilot training in a real aircraft is associated with many risks and costs. When training in a real aircraft, the number of training hours required for the trainee pilot to reach a proficient level is much higher compared to training in a flight simulator (Smode et al., 1966). This training is also associated with high costs of operating and maintaining the aircrafts used in training. Training in a real aircraft requires coordination with other services such as air traffic control and the need for appropriate weather conditions (Allerton, 2010). Training in a real aircraft poses an additional cost to the environment due to factors such as fuel consumption, gas emissions, noise pollutions, waste generation, and resource use (Allerton, 2010). Ultimately, organising training in a real aircraft is costly and requires a great amount of time to execute (Vidakovic et al., 2021). Flight simulation, on the other hand, is a safer, efficient, and cost-effective alternative to training in a real aircraft (Dattel et al., 2023). Training in a flight simulation reduces the number of hours a trainee requires to reach the desired proficiency level; thus, reducing the costs of operation and maintenance (Vidakovic et al., 2021). Additionally, simulation-based training allows for training to be repeated many times, this allows learners to focus on developing and refining their skills without risk (Harris et al, 2023). By simulating interactions with other aviation professionals, weather, and visibility conditions, flight simulators reduce the need for coordination with other services and the need to wait for suitable conditions; thus, saving time (Allerton, 2010). Flight simulators also reduce the impact of training on the environment as it does not require fuel, does not emit pollutants, does not generate waste, and does not deplete resources. Training in flight simulators has also been shown to enhance skills retention and better transfer of skills due to the engaging environment it creates and by providing immediate feedback on learner performance (Schier et al., 2016). It is clear, then, that training in flight simulators provides trainee pilots with a safe and regulated environment to refine their skills, minimising the costs and risks associated with training in a real aircraft (Nisansala et al., 2015).

Overall, immersive technology has the potential to influence trainee pilots' learning and behavioural outcomes significantly and positively. Although there are many advantages associated with using immersive technology, there are also disadvantages which have the potential to negatively influence trainees transfer of knowledge and behaviours. A sufficient and in-depth understanding of the factors that influence a trainee's learning process and encourage essential behaviours is required to better design flight simulators that enable the successful transfer of skills and knowledge. Unfortunately, the literature available on the use of immersive technology on learning and behavioural outcomes is mainly situated within fields such as education (Liu et al., 2020; Merchant et al., 2014; Pribeanu et al., 2017), healthcare (Taekman & Shelley, 2010; Costell et al., 2012; Pears et al., 2020), manufacturing (Govindarajan et al., 2018; Ramalho et al., 2020), and entertainment (Bian et al., 2016; Bodzin et al., 2021; Brondi et al., 2015). There is a dearth of research examining the impact of immersive technology on trainee pilots' perceptions of their learning and behavioural outcomes.

For these reasons, research investigating trainee pilots' perceptions of the efficacy of using immersive technology on their learning and behavioural outcomes is necessary. This research provides valuable insight as to how immersive technology affects learning and behavioural outcomes. It is crucial to understand trainee pilots' perceptions of their learning and behavioural outcomes as it indicates the effectiveness or ineffectiveness of current training programmes. Gaining insight into the perceived effectiveness of flight simulation training from the perspective of trainee pilots has many real-world applications. Adjusting current training programmes to align with trainee pilots' cognitive and behavioural processes can enhance the effectiveness of training and contribute to greater transfer of skills. This research can also identify the different learning styles and preferences that trainee pilots possess, this can help create more individualised training programmes that assist trainees more effectively. Understanding how trainee pilots perceive the effectiveness of current flight simulation training can be used to enhance airline safety. By identifying elements of the current training programmes that do not enhance trainee pilots learning and behaviours, they can be re-designed in a manner that is more engaging; thus, motivating trainees to remain attentive and to adhere to safety procedures. Trainee pilots' learning outcomes was measured by assessing their attitude towards learning, enjoyment, engagement, and skill acquisition. Behavioural outcomes were measured by assessing trainee pilots' motivation, situation awareness, pattern recognition, reaction time, decision-making, and responses under various controlled conditions. Trainee pilots' perceptions are crucial to developing successful and adequate training programmes that satisfy their needs and requirements. This research can be used to improve training programmes by identifying limitations of current flight simulator training programmes and identifying possible improvements. This research also has the potential to contribute new insights into simulator learning mechanisms.

2.6 Research Aims

1. What are trainee pilots' perceptions of the impact of flight simulators on their operational knowledge acquisition, decision-making, problem-solving, processing speed, and situation awareness?
2. What are trainee pilots' perceptions of the impact of flight simulators on their communication, transfer of skills, pattern recognition, adherence to standard operating procedures, motivation, and adaptability?
3. Is there an association between age and the use of flight simulation training on trainee pilots' perceptions of their learning and behavioural outcomes?
4. Is there an association between level of experience and the use of flight simulation training on trainee pilots' perceptions of their learning and behavioural outcomes?
5. Is there an association between total flying time (hours) and the use of flight simulation training on trainee pilots' perceptions of their learning and behavioural outcomes?
6. Is there an association between total flying time in in modern flight decks and the use of flight simulation training on trainee pilots' perceptions of their learning and behavioural outcomes?

Chapter 3: Methodology

3.1 Research Paradigm

Before offering a description of the research design and strategy, the work must first be situated within a particular research paradigm which guided the research. The research paradigm provides an “understanding [of] the relationship between theory, philosophy (ontology and epistemology), methodology and methods” (Howell, 2013a, p. 2). Situating the research within a paradigm explains the nature of knowledge (ontology) and how we understand knowledge (epistemology) (Howell, 2013b). This allows one to appreciate the way in which the research was conducted as it represents the researcher’s worldview (Aliyu et al., 2015).

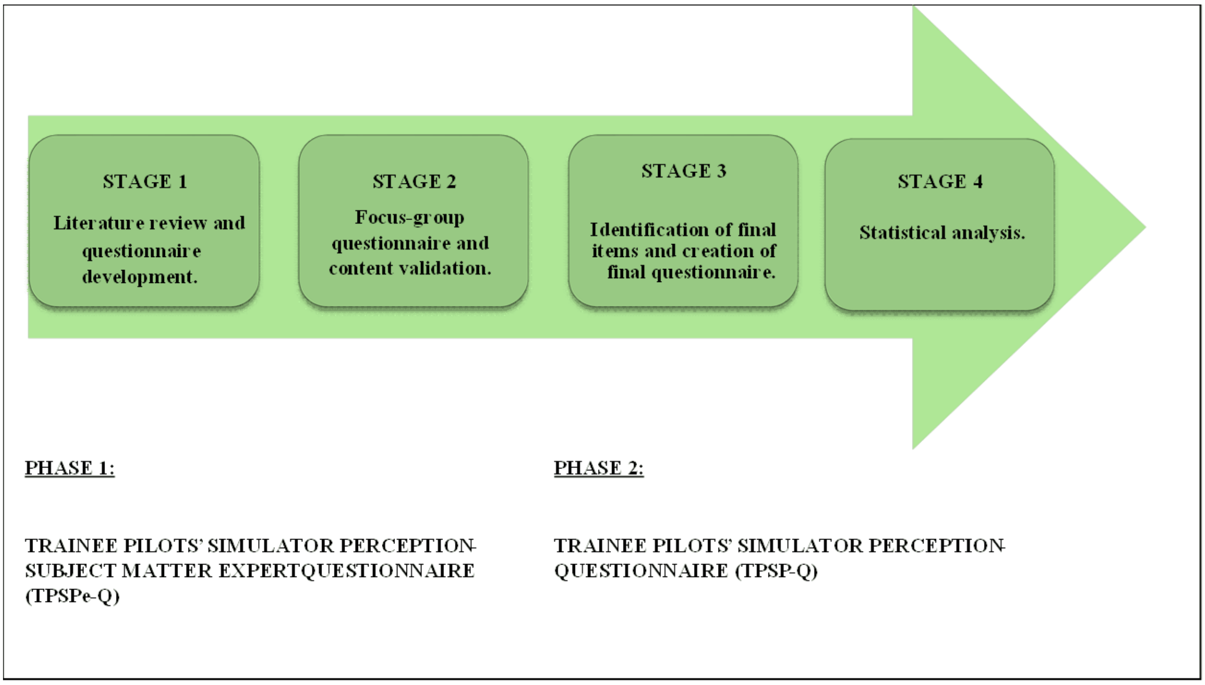
According to Crotty (1998, p.3), epistemology is defined as “the theory of knowledge embedded in the theoretical perspective and thereby in the methodology”. The research report was situated in the positivist approach. Adopting a positivist epistemological paradigm is associated with empirical observation and assumes that knowledge can be achieved objectively through scientific observation (Al-Ababneh, 2020; Howell, 2013a). For this research report, knowledge was acquired using an empirical data collection method. Therefore, it is rooted in empiricism as a questionnaire was used to observe the effect of immersive technology on trainee pilots’ perceptions of their learning and behavioural outcomes (Howell, 2013a). A quantitative ontological stance was adopted for this research as it was assumed that the phenomenon could be observed, measured, and counted (Aliyu et al., 2015).

3.2 Research Design

A quantitative, non-experimental, cross-sectional, correlational, post-test-only design was implemented to examine the impact of immersive technology on trainee pilots’ perceptions of their learning and behavioural outcomes. The research was quantitative in nature as the data collected from both the subject-matter expert questionnaire and the trainee pilot questionnaire was in numeric form (Field, 2017). It classifies as a non-experimental design as there was no manipulation or control of the independent variable (immersive technology/ flight simulators) and there was no random assignment, hence no experimental or control groups (Edmonds & Kennedy, 2019a; Field, 2017). A correlational approach was adopted as the researcher did not influence or manipulate the independent variable to observe the intended impact of immersive technology on trainee pilots' perceptions of their learning and behavioural outcomes (Field, 2017). A correlational approach was appropriate for the proposed research as the researcher was interested in assessing the relationship between immersive technology and trainee pilots' perceptions of their learning and behavioural outcomes. Furthermore, the researcher did not seek to establish a cause-and-effect relationship between trainee pilots' perceptions of their learning and behavioural outcomes and the use of immersive technology, further supporting the decision to adopt a correlational approach. The research included a subject-matter expert questionnaire consisting of flight instructors who were recognised as subject-matter experts. This was an essential phase of the research as it helped the researcher identify which questions would most effectively measure trainee pilots' perceptions of their learning and behavioural outcomes. To be considered as a subject-matter expert, participants had to have experience using flight simulators in their own training, they had to possess a certain number of flying hours, and they needed to be employed as instructors at a flight school which used flight simulators in training pilots. This focus-group questionnaire assisted the researcher in the construction of the questionnaire instrument, providing content validity of the items in measuring the impact of immersive technology on trainee pilots' perceptions of their learning and behavioural outcomes. This initial questionnaire also provided content validity of the items, ensuring that the items included in the instrument were relevant to measuring the construct of interest (Lawshe, 1975). Additionally, the research was a post-test-only design as the trainee pilots completed the final form of the instrument after undergoing training in the flight simulator and there were no comparison groups nor multiple within-subjects' observations (Edmonds & Kennedy, 2019b). This was an appropriate design because the research collected and analysed evidence of an observation in numeric form, specifically as ratio and ordinal data (Field, 2017).

Figure 5 below provides a visual illustration of the four-stage, two-phase process. The questionnaire developed in phase one was designed to ensure that the items included in the final questionnaire were relevant and representative of the content being assessed. This is consistent with Lawshe's (1975) method for establishing the content validity of a newly constructed questionnaire. The first phase of data collection involved subject-matter experts assessing the relevance of each item in measuring trainee pilots' learning and behavioural outcomes. Once Content Validity Ratio's (CVR) were calculated for each of the initial 57-items, the final questionnaire was constructed according to the cutoff value as shown in Table 5.

Figure 5:Overall Research Design



Source: Author

Once the items to be retained were identified, they were re-worded for easier reading. Furthermore, additional items were added to the questionnaire to measure themes not explored in the initial questionnaire. Once these items were added, the final questionnaire was created. As shown in Figure 5 above, the second phase of the data collection process involved administering the final questionnaire to trainee pilots as well as other pilots who had recently completed training in a flight simulator. Once this phase of data collection concluded, statistical analyses were run on the data.

3.3 Sample and Sampling

The study consisted of two samples. The initial cohort of Subject Matter Experts (SMEs) consisted of 15 healthy adults, who are flight instructors at a flying school based in Johannesburg, Gauteng that makes use of immersive technology. Participants had volunteered to participate in this phase of the research. The second sample consisted of 26 healthy adults, aged 18-70, who have undergone training in a flight simulator in order to attain a flying-related qualification, such as an instrument rating, or aircraft type rating. Participants were recruited through various flight schools based in Gauteng on a voluntary basis. To gain access to a larger sample, the researcher recruited participants through various aviation social media platforms such as LinkedIn, where a link to the research was posted along with a description of the purpose of the research and what participation involved. The response or return rate is typically expressed as a percentage. According to Haworth (1996), around half of the final responses will be obtained without the need to send participants a reminder. Another third of the responses are obtained from the first reminder. In the current study, this technique was employed to elicit additional responses from participants. The technique resulted in a response rate of 11% for the expected total sample of 100 participants. For the subject-matter expert sample, the researcher expected to obtain 50 participants, which would have provided a response rate of 22%. The response rate for the final sample was 52% assuming that a sample of 50 participants were obtained. However, the response rate for the actual sample of 30 participants was 86.6%.

The study used the non-probability convenience sampling technique for both samples, specifically volunteer sampling. This is a sampling technique in which the sample is selected based on the convenience of the researcher (Daniel, 2012). Additionally, the sample is selected according to an inclusion criterion determined by the researcher (Kalton, 1983). For the current study, the inclusion criterion required that both the subject-matter experts and the trainee pilots completed a training programme that utilised immersive technology/ flight simulators in training. The sample of the study had no exclusionary criteria in terms of race, gender, or age. The volunteer sampling method is a subtype of availability sampling in which the sample is selected from the target population based on the availability of the participant (Daniel, 2012). This sampling technique was advantageous as it is less costly, less time-consuming, and is a relatively easy procedure to implement (Daniel, 2012). However, there are limitations associated with this sampling technique. This includes the sample not being representative of the population, rendering the results of the study non-generalisable (Daniel, 2012). Additionally, the participants who did choose to participate in the study may not be representative of those who did not choose to participate (Daniel, 2012). This sampling technique, however, was appropriate for the study as it allowed for a moderate sample size to be collected in a timely and cost-effective manner. Furthermore, the sample sizes of both groups were chosen based on the convenience of the researcher. A larger sample size would be ideal, however, due to the time constraint for the data collection process and difficulty recruiting participants the chosen sample sizes are appropriate. For research of this nature, a sample between 150 and 300 is required to produce valuable insights (Al-Aidrous et al., 2021; Goretzko et al., 2021; Taherdoost et al., 2022; Waqar et al., 2023).

The ideal sample size for this research would have been 100 participants, with 50 participants in the subject-matter expert sample and 50 participants in the final questionnaire sample. This sample size would have been ideal as it reduces the possibility of sampling errors, would have provided results that are generalisable, and provides and accurate representation of the population being examined (Andrade, 2020). This method is also informed by the Central Limit Theorem (CLT) which states that a sample of 30 participants is sufficient to obtain a normal distribution (Mooney & Duval, 1993). However, due to time constraints and a lack of participation, this was unattainable. A sample size of 50 participants would have been more easily attainable should the researcher have had more time. This sample size is also considered as a reasonable minimum for running an Exploratory Factor Analysis (EFA) to produce reliable results (Chen et al., 2014; de Winter et al., 2009; Pearson, 2008). Specifically, when data have high communalities, high loadings, and a low number of factors, EFA has been found to accurately recover the underlying factor structure with samples as small as 10-20 (Preacher & MacCallum, 2002). In the present study, EFA was conducted on a sample of 26 trainee pilots who completed questionnaires on their experience with immersive technology training. While this sample size is below the commonly recommended threshold of 50 for EFA, the data shows high communalities (.560) and high factor loadings (.892 - .501), with a simple structure of two underlying factors. Based on the simulations by de Winter et al. (2009), these conditions indicate that EFA can yield reliable solutions even with this limited sample size. The high reliability and strong theoretical basis of the measures also increases confidence in the results. By taking a cautious approach to interpreting the factor solution and assessing its theoretical meaningfulness, EFA provides a valuable exploratory analysis of the experiences of trainee pilots with immersive technology. While replication with larger samples is needed, this initial EFA offers important insights that can guide further confirmatory research.

Table 3 (demographic data) shows that the mean age of the participants was 39.42 years (SD= 3.023). The sample displayed a fair degree of experience as a pilot, with a mean of 17.46 years (SD= 2.930). The mean for total flying time was 6 992.77 hours (SD= 1357.384) and the mean for total flying time in modern “glass” flight decks was 5312.019 (SD= 1 084.389), both indicating high levels of expertise in the industry. The spread for total flying time in modern “glass” flight decks was large, this can be explained by the sample size, as small samples produce high standard deviations because the sample is not an accurate estimate of the population's mean (Field, 2017).

Table 3: Demographic Data of the Final Sample (N=26)

DEMOGRAPHIC VARIABLE	COUNT	PERCENTAGE
AGE (years)		
19	1	3.85
20-29	7	26.92
30-39	7	26.92
40-49	6	23.08
50-59	2	7.69
60-69	1	3.85
70+	2	7.69
Missing	0	0
HIGHEST EDUCATION ATTAINED		
Secondary School	14	53.85
Diploma	3	11.54
Bachelor’s degree	2	7.69
Honours Degree	2	7.69
Master’s Degree	2	7.69
Doctoral Degree	0	0
Missing	3	11.54
FIELD OF STUDY		
Flying Related Qualification	10	38.46
Non-Flying Related Qualification	3	11.54
Missing	13	50

Table 3: Continued

DEMOGRAPHIC VARIABLE	COUNT	PERCENTAGE
LEVEL OF EXPERIENCE AS A PILOT (years)		
0-10	10	38.47
11-30	12	46.15
30+	4	15.38
Missing	0	0
TOTAL FLYING TIME (hours)		
0 – 15 000	20	76.92
15 001 – 20 000	5	19.23
20 001+	1	3.85
Missing	0	0
FLYING TIME IN MODERN DIGITAL FLIGHT DECKS (hours)		
0 – 15 000	25	96.15
15 001 – 20 000	1	3.85
20 001+	0	0
Missing	0	0

There is no demographic information available for the initial sample of participants. This decision was made to protect the identity and confidentiality of the SME sample. Any information collected on their age, race, level of education, flight experience, and hours of experience could have been used by the flight school to identify the instructors who participated in the research. However, based on the inclusion criteria for participation, some observations can be made. In order to participate in the initial phase of data collection, participants had to be instructors at the identified flight school. To be considered as subject-matter experts, these individuals had to have undergone training in a flight simulator and needed to have a certain amount of hours (both flying and simulator related) to become instructors.

3.4 Procedure

The data for this study were collected using a perception questionnaire instrument developed for this research (Appendix A). For phase one of the data collection process, one flying school was approached to provide access to subject matter experts. The second phase of data collection involved participation from various flying schools to gain access to a larger sample size. To gain access to the target population, the researcher approached a flight school located at the Rand Airport and provided the management with an explanation of the purpose of the research, what participation involved, and how the research could be used to improve training programmes. Management had the opportunity to ask questions related to the research and were given the researchers contact information should they have any more questions. Informing management of the potential benefits of the research gained the organisations support and the researcher obtained verbal consent to conduct the research. The management of the flight school was requested to provide written consent to allow the research to be conducted. Once written permission was granted by the flight school where the data was intended to be collected from, the researcher applied to the University of the Witwatersrand Human Research Ethics Committee (Non-Medical) to gain ethical clearance to proceed with the research. Once ethical clearance was granted, participant information sheets, consent forms, and a link to the questionnaire were sent out to the flight school manager for distribution to flight instructors/ subject-matter experts to participate in the research (Appendix B & Appendix D). These documents provided information to participants regarding the purpose of the research as well as what participation in the study entailed. Thus, the initial phase of data collection commenced.

The subject-matter experts were required to complete a questionnaire (Appendix D) consisting of 57-items and which took approximately ten-minutes to complete. These 57-items were developed by the researcher following a discussion with three pilots who assisted in identifying key questions that were relevant to the research. The researcher also consulted various other existing questionnaires which measured individuals' experiences using immersive technologies and their perceptions of learning and behavioural changes. Subject-matter experts were identified as instructors who have both received training in a simulator and provide training in a simulator. The difference between subject-matter experts and the target population was they possess expertise and have an in-depth knowledge of both the aviation industry and training in a flight simulator. The questionnaire that the subject-matter experts completed required them to rank each of the 57-items on a scale of 1-3, this will be expanded upon under the instrument section of this paper. The subject-matter expert questionnaire was distributed electronically, and a follow-up request was issued after a week. The length and depth of the subject-matter expert questionnaire impacted responses. Participant responses were collected over a three-week period resulting in a final sample size of 15, of which only 11 responses were deemed usable. Only 11 responses were used because four respondents did not provide a response for any of the 57-items. The completion of this questionnaire assisted in the construction of the final perception scale which aimed to assess the impact of immersive technology on trainee pilots' perceptions of their learning and behavioural outcomes. This phase of data collection was informed by Lawshe's (1975) approach to content validity which will be discussed further under instrument development. Once the final form of the perception instrument was constructed, the second phase of data collection commenced.

As in the initial phase of data collection, trainee pilots were sent an email including participant information sheets and consent forms, providing information regarding the purpose of the research and what participation in the study entails. Included in the email was a link, directing the trainees to the perception questionnaire for their completion. Completion of the final questionnaire was approximately 6-10 minutes. A follow-up request was issued at the beginning of each week for a three-week period. Once the desired sample size was achieved, the data was cleaned and prepared for data analysis. The population itself can be deemed to contain little variation, because it is common knowledge that pilots undergoing such training emerge through a particular development process, such as attaining a private pilot licence first, and thus complying with the certification requirements stipulated by the South African Civil Aviation Authority (SACAA). These tests can serve as a filtering mechanism. Hence, it is reasonable to assume that the *source* of the data was limited to a homogeneous cross-section of qualified pilots. A response rate of 86.6% was obtained, indicating that out of 30 potential responses 26 completed the questionnaire. The data were cleaned by identifying and removing any missing data, and irrelevant or incorrect entries, such as duplicates (Rahm & Do, 2000). Next, outliers were identified using boxplots generated by the IBM SPSS Statistical software platform, version 28 (see Appendices H(a) through H(e)). Identified outliers were either removed or transformed (Field, 2017). Variables were then sorted into ordinal and ratio to ensure the correct analysis of the data (Field, 2017). The data were organised by labelling the variables according to an identified code (Field, 2017). At the end of the subject-matter experts questionnaire and the trainee pilots questionnaire, the researcher thanked each volunteer for their participation in the study. Feedback will be provided to the organisation and participants upon request and the completion of the research report.

3.5 Instrument

To measure the constructs of this study, a perception instrument was devised. The initial instrument consisted of 57-items related to constructs such as engagement, motivation, learning experience, and behavioural outcomes to examine trainee pilots' perceptions of their learning and behavioural outcomes using immersive technology. The initial perception scale (Appendix A) required the subject-matter experts to rank each item on a scale of 1-3 where (1) is 'Essential', (2) is 'Useful but not essential', and (3) is 'Not necessary'. This was done to ensure the content validity of the final instrument (Lawshe, 1975). Lawshe's (1975) method of calculating the Content Validity Ratio (CVR) is robust as it is based on the consensus of a panel of experts. Moreover, the method is flexible and can be adapted to different job types and tasks, contributing to its usefulness as a tool for establishing sound tests (Lawshe, 1975). Once the subject-matter experts completed the questionnaire, the perception instrument was then validated by calculating the Content Validity Ratio (CVR) for each item (Lawshe, 1975). The Content Validity Ratio (CVR) value was useful in determining the degree of validity of the instrument according to the subject-matter experts' ratings (Lawshe, 1975; Rutherford-Hemming, 2018). The Content Validity Ratio (CVR) formula is CVR = $\frac{Ne - (\frac{N}{2})}{\frac{N}{2}}$ where η_e equals to the number of subject-matter experts' rating of an item as 'essential' and N equals to the total number of subject-matter experts providing a rating (Lawshe, 1975). The Content Validity Ratio (CVR) value provided for each item assisted the researcher in identifying which of the 57-items to retain and reject from the final form of the perception instrument (Lawshe, 1975). The retention and rejection of items were determined by the number of members of the content evaluation panel and the acceptable minimum value associated with this number

Minimum Values of CVR and CVR, One-Tailed Test, p = 0.5	
No. of Panelists	Min. Value*
5	.99
6	.99
7	.99
8	.75
9	.78
10	.62
11	.59
12	.56
13	.54
14	.51
15	.49
20	.42
25	.37
30	.33
35	.31
40	.29

Source: Adapted from Lawshe, 1975. (provided in Table 4).

Table 4: Lawshe's (1975) Minimum Values of CVR

Lawshe (1975, p. 568), suggests a minimum value of "0.59 is required from 11 subject-matter experts" to ensure agreement on the inclusion of the item. When using a panel of 11 experts, a CVR value of 0.59 is required to obtain the necessary validity (Lawshe, 1975). A list of 57 items was generated to measure trainees' perceptions of their learning and behavioural outcomes. Of the 57 items, 42 were identified as not essential or necessary for content validity. The results indicate that 73% of items were deemed not worthy of being in the final instruments. This may be because some of the items were not relevant to understanding trainee pilots' perceptions, some items may measure the same construct, or items may have been ambiguous or confusing. Thus, 26.3% of the original item list was retained for inclusion in the final perception questionnaire (Appendix E).

The retained items were reworded, and three additional items were included in the questionnaire to measure the constructs of the study (Table 5). The retained items were reworded to make readability easier for participants and to control for any misunderstanding or misinterpretation of the items. The final perception instrument required trainee pilots to rate each of the 19 statements on a scale from 1-7 where (1) ‘Strongly Disagree’, (2) ‘Disagree’, (3) ‘Somewhat Disagree’, (4) ‘Neither Agree Nor Disagree’, (5) ‘Somewhat Agree’, (6) ‘Agree’, and (7) ‘Strongly Agree’. While there do exist instruments that measure perceptions of learning, for instance Martin et al’s., (2020), SROL instrument, Chang and Fisher’s (2001) WEBLEI instrument, there are none that specifically measure the impact of immersive technology, such as aircraft simulators, on trainee pilots’ perceptions of their learning and behavioural outcomes. Therefore, this perception instrument was created to specifically address the purposes of this research project. The final questionnaire items are found in Table 5.

Table 5: Items Retained After Applying Lawshe's (1975) Method

Item	Statements retained based on Lawshe’s (1975) method.	Adjusted questionnaire items.	CVR
1.	There is an improvement in trainee pilots’ skills following training in the aircraft simulator.	There is an improvement in my skills following training in the aircraft simulator.	0.818.
2.	There are many advantages associated with the use of the aircraft simulator.	There are many advantages associated with using the aircraft simulator.	0.636.
3.	The aircraft simulator positively influences trainee pilots’ reaction time.	Training in the aircraft simulator positively influences my reaction time.	0.636.
4.	The aircraft simulator positively influences trainee pilots’ decision making.	Training in the aircraft simulator positively influences my decision making.	0.636.
5.	Trainee pilots’ learning experience is enhanced by using the aircraft simulator.	My learning experience is enhanced when training in the aircraft simulator.	0.636.
6.	Trainee pilots’ multitasking capabilities are improved following training in the aircraft simulator.	My multitasking capabilities are improved following training in the aircraft simulator.	0.636.
7.	The aircraft simulator develops trainee pilots’ standard operating procedures.	Training in the aircraft simulator develops my standard operating procedures.	1.000.
8.	The aircraft simulator develops trainee pilots’ ability to recognise patterns.	The aircraft simulator develops my ability to recognise patterns.	0.818.
9.	The aircraft simulator can simulate various unknown situations which develops trainee pilots’ problem-solving skills.	The aircraft simulator can simulate various unknown situations which develops my problem-solving skills.	0.818.
10.	Knowledge acquisition in the aircraft simulator is influenced by whether the trainee pilots learnt basic flying skills.	The training I’ve received in the aircraft simulator has improved my instrument flying skills overall.	0.636.

Table 5: Continued

Item	Statements retained based on Lawshe's (1975) method.	Adjusted questionnaire items.	CVR
11.	A lack of previous experience influences the outcome of the aircraft simulation training	My basic (ab-initio) flying experience plays a significant role in the outcome of my simulator training sessions.	0.636.
12.	The aircraft simulator assists trainee pilots in remembering specific rules about executing tasks.	Training in the aircraft simulator assists me in remembering specific rules about executing tasks.	0.636.
13.	The aircraft simulator allows trainee pilots to develop their decision-making skills in a safe and controlled environment, improving their ability to analyse situations and select an appropriate response.	Simulator training has helped me improve my aeronautical decision-making ability.	0.818.
14.	The aircraft simulator allows trainee pilots to develop their communication and coordination skills through simulated interactions with air traffic control and other aviation professionals.	Training in the aircraft simulator has significantly improved my interpersonal skills (such as communication) with air traffic control professionals.	0.636.
15.	By simulating realistic scenarios, the aircraft simulator facilitates the development of situational awareness, allowing trainee pilots to process information, assess their environment, and make informed decisions.	Scenarios practiced in simulator training have greatly improved my ability to choose an appropriate course of action in an abnormal situation.	0.636.
16.	The training I've received in the aircraft simulator has improved my aircraft manual handling flying skills overall.		
17.	Scenarios practiced in simulator training have greatly improved my ability to choose an appropriate course of action in an abnormal situation		
18.	Training in the aircraft simulator has significantly improved my interpersonal skills (such as communication) with other aviation professionals (either cabin crew or ground personnel).		

3.6 Data Analysis

The data collected from this study was analysed using the IBM SPSS Statistics software platform, version 28. The data were analysed using descriptive and inferential statistical methods. Descriptive statistics was used to summarise the demographic data. Additionally, the descriptive statistics were used to identify whether the data satisfied test assumption such as linearity, homoscedasticity, independence, and normality (Field, 2017; Mishra et al., 2019). The information from the descriptive statistics was used to assess the use of either parametric or nonparametric statistical methods.

Selecting parametric or nonparametric statistical methods for an Exploratory Factor Analysis (EFA) is dependent on the assumptions and properties of the data. To use parametric methods such as maximum likelihood estimation, the data needs to follow a multivariate normal distribution (Gorsuch, 2014; Hair, 2009). The data needs to be factorizable, show no multicollinearity and outliers, and the data must be normal and linear (Field, 2017). Nonparametric methods, such as principal axis factoring or unweighted least squares, are more flexible and robust to violations of assumptions (Field et al., 2021; Gorsuch, 2014; Hair, 2009; Tabachnick & Fidell, 2019). This nonparametric method was useful for the current research as the data contained outliers. The test that was used to analyse the dataset was a Regularised Exploratory Factor Analysis (REFA). The REFA is a method for conducting an exploratory factor analysis on small samples. The REFA simplifies the estimation of parameters in the factor model, which is particularly useful for small sample sizes (Jung, 2013). REFA reduces the number of parameters that need to be estimated, allowing an EFA to be conducted with a small sample (Jung, 2013; Jung & Lee, 2011; Jung et al., 2020). The current paper used a varimax rotation with Kaiser's extraction to allow for interpretation of the results. A varimax rotation was used as it allowed the researcher to increase the amount of variance in the factor loadings for each factor, this is achieved by making large loadings larger and small loadings smaller (Finch, 2020). Using this rotational method is useful as the resulting loadings reflect a clearer simple structure which allows the researcher to easily identify the underlying latent variables (Finch, 2020). Kaiser's extraction method was useful as it allowed the researcher to identify patterns of correlation in the data which assisted in identifying on which factors the items loaded (Hutcherson, 1999). As suggested by Jung (2013), a two-factor solution was used to limit the factor loadings. Using the REFA was advantageous as it reduced the number of parameters that need to be estimated, allowing an EFA to be conducted on the small sample size (Jung, 2013; Jung & Lee, 2011; Jung et al., 2020). This method also allowed for greater conceptual clarity on the extracted factors as it does not overestimate factor loadings (Jung, 2013).

Table 6: Test Assumptions for Factorability:

Measure	Value	Outcome
Correlation Matrix: Correlations	>.30	Patterns of Correlations/ REFA can be run.
	<.30	No patterns of Correlations. REFA cannot be run.
Multicollinearity.	.8, .9, or 1	There is only one factor therefore the REFA will not work.
Bartlett's Test of Sphericity	Sig. result	REFA will work.
	No sig. result	REFA will not work.
Kaiser-Meyer-Olkin Measure of Sampling Adequacy	.5 and below	Unacceptable. REFA will not work.
	.8 or .9	Meritorious/Marvellous. REFA will work.

For a Pearson's Correlation, the parametric assumptions require the data to be measured at an interval or ratio level, there should be a linear relationship between the variables, there should be no significant outliers, and the variables/data should be approximately normally distributed (Field, 2017). As the data did not satisfy the parametric assumptions of linearity or normality, a Spearman's Rank Correlation was used. This correlation allows for the assessment of the direction and strength of the relationship between the use of immersive technology and trainee pilots' perceptions of their learning and behavioural outcomes.

To conduct a Simple Linear Regression, both variables should be measured at a continuous level, there should be a linear relationship between the two variables, there should be no significant outliers, there should be independence of observations, homoscedasticity, and residuals should be approximately normally distributed (Field, 2017). As the data contained significant outliers and influential points, a Kendall's tau-b Correlation was run. This nonparametric method was useful as the two variables were ordinal in nature, the two variables represented paired observations, and there was a monotonic relationship between the two variables (Daniel, 1990; Gibbons, 1993).

To ensure the instrument measured trainee pilots' perceptions of their learning and behavioural outcomes, data extracted from the instrument were analysed using a method of

Exploratory Factor Analysis (EFA) called Regularised Exploratory Factor Analysis (REFA). Jung (2013), Jung and Lee (2011), and Jung et al. (2020) have shown that an EFA can be run on small sample sizes using a regularised approach. This approach involves using Unweighted Least Squares as the method of extraction. This approach also required a Varimax orthogonal rotation method to be used for interpretability. However, running the REFA required the same assumptions of the EFA to be satisfied. Descriptive statistics and a correlation matrix helped the researcher identify whether the assumptions were either satisfied or violated. The data included multiple variables that were measured at the ordinal level as each question was answered using a 7-point Likert-type scale. A 7-point scale was used as it offers respondents more options and can help capture more detailed feedback which is necessary when measuring constructs such as perceptions (Jamieson, 2004; Sullivan & Artino, 2013). Additionally, this scale increases granularity of the item, allowing for a greater level of detail to be obtained (Miller, 2015). However, the greater level of detail may lead to increased frustration for the participant as the item/s may be difficult to interpret. This scale is also useful for reducing the likelihood of respondents choosing a neutral point as a default (Krosnick & Fabrigar, 1997; Sullivan & Artino, 2013). Finally, the scale also provides more statistical variability and enhances the reliability and validity of the data collected (Krosnick & Fabrigar, 1997). As such, the first assumption was satisfied. The second assumption required linearity which was tested by producing a scatterplot with a few variables. As such, the second assumption was satisfied. The third assumption required no outliers, it was assessed through the data cleaning process, and no outliers were identified, thus this assumption was satisfied. The fourth assumption required a large sample size (Field, 2017). This assumption was adapted to allow the REFA to be run on the small sample size of 26 participants (Naidoo & Vermeulen, 2014). The small sample size is not uncommon in the aviation field as many airline companies may have restrictions over the use of their data and thus limit aviation professionals' participation in research of this nature (Rice et al., 2017). The fifth assumption required the data to be factorizable and for there to be no evidence of multicollinearity. To assess the factorability of the data and multicollinearity, the correlation matrix was assessed. There were correlations of .3 and higher, indicating the factorability of the data. Bartlett's Test of Sphericity also indicated the factorability of the data ($p<0.001$). No values of .8 or .0 were identified, eliminating the possibility of multicollinearity. Once these assumptions were satisfied, the REFA was run.

The following research aims guided the study:

Research Aims 1 and 2: To determine how the use of immersive technology influences trainee pilots' perceptions of their learning and behavioural outcomes. This research question was expected to be analysed using Pearson's correlation. To determine if the data could be analysed using Pearson's correlation, descriptive statistics were run. The data showed to violate the assumption of linearity and normality hence the decision to run a Spearman's Rank Correlation (Field, 2017). To conduct this analysis, the data had to satisfy three assumptions. The first assumption required two variables to be measured on a continuous and/or ordinal variable. This assumption was satisfied as both variables were ordinal in nature. The second assumption required the variables to represent paired observations. These assumptions were satisfied as the instrument was measured using a 7-point Likert type scale. The observations were also paired as participants responded to all items on the questionnaire. The third and final assumption required a monotonic relationship between the two variables. This assumption was checked and satisfied by plotting and visually inspecting a scatterplot. As all the assumptions were satisfied, the Spearman's Rank Correlation was run.

Is there an association between trainee pilots' perceptions of their learning and behavioural outcomes? It was expected that this research question would be analysed using a Simple Linear Regression analysis however, the data could not be used to run a Simple Linear Regression analysis, hence the use of Kendall's tau-b correlation (τ_b). This nonparametric test is used to measure both the strength and direction of association between two variables that are measured on an ordinal scale (Daniel, 1990; Field, 2017; Kendall, 1945). The data satisfied the three assumptions of Kendall's tau-b. These include having two constructs- cognitive effort and flying competence- measured on at least an ordinal scale, the variables representing paired observations, and monotonic relationship between the variables. As all assumptions were satisfied, the Kendall's tau-b correlation was run.

Is there an association between age, level of experience, total flying time (hours), total flying time in modern "glass" flight decks and trainee pilots' perceptions of their learning and behavioural outcomes using flight simulation? To assess the associations between the demographic characteristics and trainee pilots' perceptions of their learning and behavioural outcomes using flight simulation, a Kendall's tau-b Correlation was run. This nonparametric test is used to measure both the strength and direction of association between two variables that are measured on an ordinal scale (Chen & Popovich, 2002; Field, 2017; Siegel & Castellan, 1988). The data satisfied the three assumptions of Kendall's tau-b. These include having two variables measured on at least an ordinal scale, the variables representing paired observations, and monotonic relationship between the variables. As all assumptions were satisfied, the Kendall's tau-b correlation was run.

Chapter 4: Results

This chapter provides the results of the Regularised Exploratory Factor Analysis (REFA), Spearman's Rank Correlation, and the Kendall's tau-b Correlation. First, the results of the REFA and the reliability tests that were run on the Trainee Pilots' Simulator Perception-Questionnaire are provided. This is followed by the results of the Spearman's Rank Correlation and the Kendall's tau-b Correlation.

A Regualrised Exploratory Factor Analysis (REFA) was run on an 18-item questionnaire that measures trainee pilots' perceptions of their learning and behavioural outcomes using aircraft simulators when training. As such, the dataset resulted in an analysis of 26x18 data points. The suitability of REFA was assessed prior to analysis. Based on Tabachnik and Fidell's (2013) suggestion, any items with Kaiser-Meier-Olkin Measure of Sampling Adequacy values below .30 should be removed and the analysis should be re-run. The initial Anti-Image Correlation table revealed three problematic items, namely question 2, question 10, and question 16 with KMO MSA values of .471, .327, and .484 respectively. This is indicative of what is known as Heywood Cases which is a statistical phenomenon that occurs in factor analysis (Farooq, 2022). Heywood cases occur when the estimated variances in the factor analysis model result in negative values or values larger than 1 (Farooq, 2022; Rindskopf, 1984). Such cases are problematic as they show that the estimated model does not represent the underlying data structure (Dillon et al., 1987). As such, these three items were removed, and the REFA was re-run. Inspection of the correlation matrix showed that all variables had at least one correlation coefficient greater than 0.3. The overall Kaiser-Meyer-Olkin (KMO) measure was 0.671 with individual KMO measures all greater than .5. Bartlett's test of sphericity was statistically significant ($p < .001$), indicating that the data was likely factorable.

REFA revealed three components that had eigenvalues greater than one and which explained 46%, 16%, and 11% of the total variance, respectively. Visual inspection of the scree plot indicated that three components should be retained however, the decision was made to limit the factors retained to two as recommended by Jung and Lee (2011). This was conducted to identify which items load on the two constructs being measured, namely cognitive abilities and flying competence. Jung (2013) further contends that the usefulness of this method by demonstrating its benefits after limiting the number of factors extracted to just four, in this case. limited their factors to a four-factor solution. By doing this, the author gained valuable insight into the factor structure which assisted in the interpretation process. In addition, a two-component solution met the interpretability criterion., because as an alternative to traditional factor rotation, REFA offers the advantage of less ambiguity, specifically for applied research. Goretzko (2023; p. 12) argue that simplicity is achieved when "…the level of sparsity in the loading pattern can actually be determined in a data-driven way". As such, two components were retained. The two-component solution explained 62.7% of the total variance. A Varimax orthogonal rotation was employed to aid interpretability. The rotated solution exhibited 'simple structure' which refers to a pattern of factor loadings (Thurstone, 1947). This is useful as it shows the relationships between variables and factors, identifying which factor each variable primarily loads on thus making it easier to understand and interpret (Thurstone, 1947). The interpretation of the data was consistent with the perceptions of learning and behavioural outcomes the questionnaire was designed to measure with strong loadings of cognitive abilities (learning outcomes) on Factor 1 and strong loadings of interpersonal skills (behavioural outcomes) on Factor 2. Component loadings and communalities of the rotated solution are presented in Table 7.

The Trainee Pilots' Simulator Perception - Questionnaire (TPSP-Q) was employed to measure different, underlying constructs. One construct, 'cognitive ability' measuring learning outcomes, consisted of seven items. The scale had a high level of internal consistency, as determined by a Cronbach's alpha of .889. The second construct, 'interpersonal skills' measuring behavioural outcomes, consisted of eight items. The scale had a high level of internal consistency as determined by a Cronbach's alpha of .853 (Table 8 and 9). Obtaining a Cronbach's alpha of .90 and would have indicated redundancy of items, however, the present values indicate good to excellent internal consistency (DeVellis & Thorpe, 2021). The Eigenvalues obtained was 16.31% and the percentage variability was 62.70%. The scree plot is also provided (Figure 6).

Table 7: Rotated Loadings Matrix

Rotated Structure Matrix for ULS with Varimax Rotation of a Two Component Questionnaire			
Items	Rotated Component Coefficients		
	Factor 1	Factor 2	Communalities
Qu14	**.892**		.837
Qu15	**.831**		.722
Qu9	**.795**	.392	.786
Qu4	**.698**	.306	.581
Qu18	**.695**		.560
Qu12	**.646**	.330	.526
Qu11	**.645**		.464
Qu7		**.864**	.779
Qu8		**.818**	.725
Qu6		**.763**	.590
Qu5	.340	**.628**	.511
Qu1		**.596**	.361
Qu13		**.574**	.360
Qu3	.336	**.531**	.395
Qu17	.465	**.501**	.467

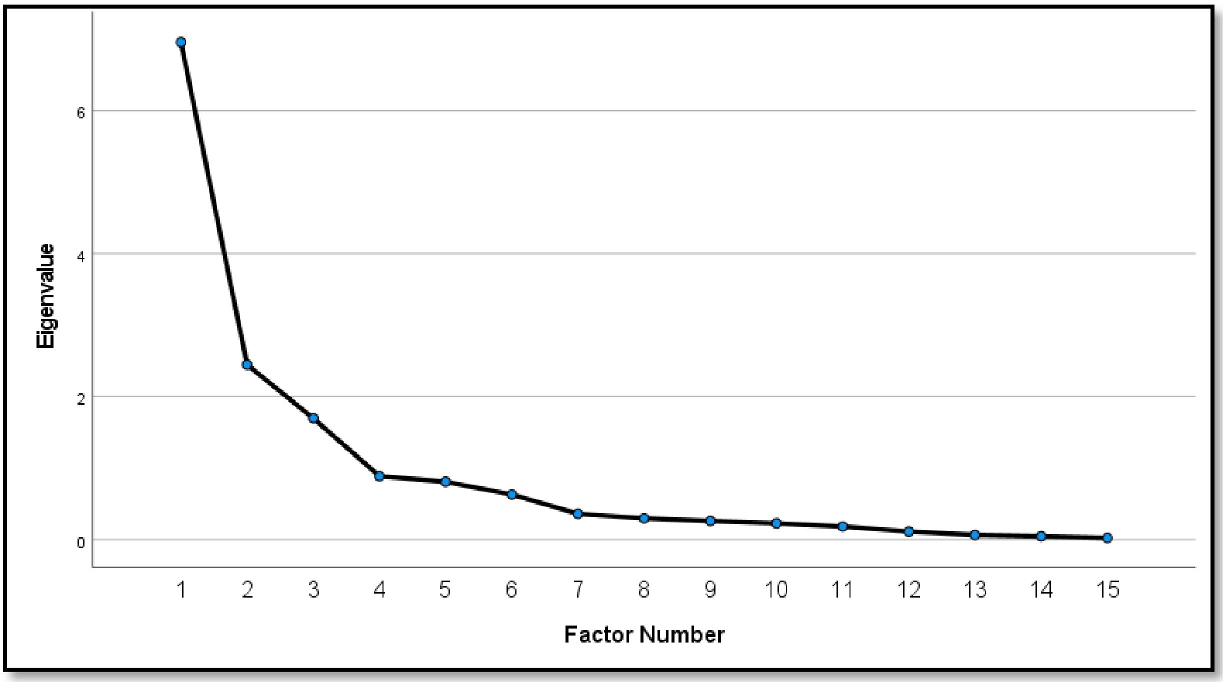
Table 8: Reliability and Item Statistics for Factor 1: Cognitive Effort (N= 26)

Item Statistics	Sk	Ku	Mean	Standard deviation	Corrected item total correlation	Cronbach's alpha if the item is deleted
Qu4: Training in the aircraft simulator positively influences my decision-making.	-1.806	3.203	6.31	1.050	.715	.869
Qu9: The aircraft simulator can simulate various unknown situations which develops my problem-solving skills.	-.471	-.673	6.31	.679	.830	.871
Qu11: The training I've received in the aircraft simulator has improved my aircraft manual handling flying skills overall.	-.613	.171	5.31	1.350	.675	.874
Qu12: My basic (ab-initio) flying experience plays a significant role in the outcome of my simulator training.	-.778	-.515	5.23	1.681	.660	.888
Qu14: Simulator training has helped improve my aeronautical decision-making ability.	-2.355	7.409	6.08	1.093	.706	.870
Qu15: Scenarios practised in simulator training have greatly improved my ability to choose an appropriate course of action in an abnormal situation.	-2.018	5.014	6.15	1.190	.797	.858
Qu18: By simulating realistic scenarios, the aircraft simulator facilitates the development of situational awareness, allowing me to process information, assess my environment, and make informed decisions.	-.799	-.076	6.08	.935	.652	.877
Reliability Statistics				N of Items	Mean inter-item correlation	Cronbach's alpha
				7	.719	.889
Scale statistics				Mean	Variance	Standard deviation
				41.46	40.658	6.376

Table 9: Reliability and Item Statistics for Factor 2: Flying Competence (N= 26)

Item Statistics	Sk	Ku	Mean	Standard deviation	Corrected item total correlation	Cronbach's alpha if the item is deleted
Qu1: There is an improvement in my skills following training in the aircraft simulator.	-1.645	2.048	6.69	.549	.491	.850
Qu3: Training in the aircraft simulator positively influences my reaction time.	-.915	-.571	6.42	.758	.555	.841
Qu5: My learning experience is enhanced when training in the aircraft simulator.	-1.633	3.132	6.46	.761	.588	.838
Qu6: My multitasking capabilities are improved following training in the aircraft simulator.	-1.042	.359	6.19	.939	.652	.829
Qu7: Training in the aircraft simulator develops my standard operating procedures.	-1.241	.473	6.38	.898	.817	.811
Qu8: Training in the aircraft simulator develops my ability to recognise patterns.	-.672	-.448	6.04	.958	.847	.805
Qu13 Training in the aircraft simulator assists me in remembering specific rules about executing tasks.	-1.385	2.404	6.04	.999	.594	.835
Qu17: Training in the aircraft simulator has significantly improved my interpersonal skills (such as communication) with other aviation professionals(either cabin crew or ground personnel).	-.214	-.979	4.42	1.815	.582	.873
Reliability Statistics				N of items	Mean inter-item correlation	Cronbach's alpha
					.640	
				8		.853
Scale statistics				Mean	Variance	Standard deviation
				48.65	32.875	5.734

Figure 6: Scree Plot for Factorability



Source: Author

A Spearman's rank-order correlation was run to assess the relationship between trainee pilots' perceptions of their learning outcomes and their perceptions of their behavioural outcomes. Twenty-six participants were recruited. Preliminary analysis showed the relationship to be monotonic, as assessed by visual inspection of a scatterplot (Figure 6). There was a statistically significant, strong positive correlation between cognitive effort and flying competence, r_s (26) = .735, p < .001. The results of the Spearman's rank-order correlation (Table 10) shows that when pilots received training in the simulator, positive perceptions of their Cognitive Effort were directly related to their overall perception of their Flying Competence.

Table 10: Spearman's rho Correlations

Correlations				
			Cognitive Effort	Flying Competence
Spearman's rho	Cognitive Effort	Correlation Coefficient	1.00	.735**
		Sig. (2-tailed)		<,001
		N	26	26
	Flying Competence	Correlation Coefficient	.735**	1.00
		Sig. (2-tailed)	<,001	
		N	26	26

**. Correlation is significant at 0.01 level (2-tailed).

A Kendall's tau-b correlation (Table 11) was run to determine the relationship between trainee pilots' perceptions of their learning and behavioural outcomes using immersive technology amongst 26 participants. There was a strong, positive association between perceptions of learning outcomes and perceptions of behavioural outcomes, which was statistically significant, τ_b = .583**, p <,001. The results of the Kendall's tau-b correlation (Table 10) shows that when pilots received training in the simulator, they experienced positive gains in both their Cognitive Effort and their Flying Competence. There was a strong positive association between perceptions of cognitive effort and flying competence, and the total Trainee Pilots' Simulator Perception- Questionnaire score, which was statistically significant, $\tau_{b\,=}$ .834**, p <,001, and τ_b = .772**, p <,001.

Table 11: Kendall's tau-b Correlations

Correlations					
			Cognitive Effort	Flying Competence	TPSP-Q
Kendall's tau_b	Cognitive Effort	Correlation Coefficient	1.000	.583**	.834**
		Sig. (2-tailed)	.	<,001	<,001
		N	26	26	26
	Flying Competence	Correlation Coefficient	.583**	1.000	.772**
		Sig. (2-tailed)	<,001	.	<,001
		N	26	26	26
	TPSP-Q	Correlation Coefficient	.834**	.772**	1.000
		Sig. (2-tailed)	<,001	<,001	.
		N	26	26	26

**. Correlation is significant at 0.01 level (2-tailed).

Additional nonparametric correlation analyses were run to determine the association between age, level of experience as a pilot, total flying time, and total flying time in modern digital flight decks and the use of flight simulation training on trainee pilots' perceptions of their Cognitive Effort and Flying Competence (Table 12).

Table 12: Correlations for Demographic Variables

Correlations							
			TPSP- Q Total	Age Categories	Level of Experience as a Pilot Categories	Total Flying time (hours) Categories	Flight Time in Modern Flight Decks Categories
Kendall's tau_b	TPSP-Q Total	Correlation Coefficient	1.00	-.066	-.141	-.115	-.117
		Sig. (2-tailed)	.	.642	.320	.414	.412
		N	26	26	26	26	26
	Age Categories	Correlation Coefficient	-.066	1.00	.739**	.691**	.675**
		Sig. (2-tailed)	.642	.	<,001	<,001	<,001
		N	26	26	26	26	26

**. Correlation is significant at 0.01 level. (2-tailed).

The correlations produced showed no significant correlations between age, level of experience as a pilot, total flying time, flying time in modern flight decks, and scores on the Trainee Pilots' Simulation Perception- Questionnaire. The correlations show a very weak association between these variables, indicating that those variables had no association with participants' scores on the questionnaire. Age was shown to have the most positive and significant association with the variables level of experience as a pilot, total flying time, and flying time in modern flight decks (.739**, .691**, and .675** respectively, effect size= 9.351). Therefore, there is insufficient evidence to accept the hypothesis which states that age, level of experience as a pilot, total flying time, and flying time in modern flight decks is associated with trainee pilots' perceptions of their learning and behavioural outcomes using flight simulators.

4.1 Ethical Considerations

To ensure that all ethical considerations of this study were satisfied, the researcher applied for ethical clearance from the University of the Witwatersrand Human Research Ethics Committee (Non-Medical). To gain access to the target population, the researcher sent out a letter requesting permission to conduct research at the chosen flight school based in Johannesburg (Appendix D). Once ethical clearance from the University was attained and permission from the organisation was granted, the researcher sent the participant information sheets, the consent forms, and the link to the online questionnaire to the manager of the flight school to distribute to prospective participants (Appendix B and C). These documents provided prospective participants with information regarding the purpose of the research, what participation involved, and the collection and storage of the data. The two phases of data collection occurred online, therefore, to ensure participants provided their voluntary and uncoerced informed consent, they were given the option to provide their email address. If participants did not provide their email address and therefore their informed consent, their responses were not recorded nor used for data analysis. The participants personal and physiological data has been kept confidential and volunteers in the study had the right to withdraw at any time. To ensure anonymity of questionnaire responses, no personal information was collected. Participants were not required to provide their names; however, they were given the option to provide their email address should they wish to receive a summary of the research report. To protect this information, the email addresses provided were copied and stored in a password-protected document that only the researcher has access to. Once these participants receive the summary of the research, their email addresses, like the data, will be stored for two years and then securely deleted. Data collected for the purposes of this research was stored on a password-protected database that only the researcher and her supervisor have access to. Upon completion of the research report, the data will be stored for two-years and then it will be securely deleted. The participants were also debriefed at the end of the study to ensure they had a full understanding of the purpose and outcomes of the study. There was no incentive, no punishment, or negative consequences for choosing not to participate in the study. Should participants have any questions or concerns related to the ethics of the study, they were provided with the contact information of the University of the Witwatersrand Human Research Ethics Committee (Non-Medical) as well as the contact information of both the researcher and her supervisor.

This research was characterised as low risk. The only identifiable risk was that of discomfort, or some sensitivity involved in terms of the questions asked. The study procedures and questionnaire questions are classified as low risk because the “probability and magnitude of harm or discomfort anticipated in the research are not greater in and of themselves than those ordinarily encountered in daily life” (Kopelman, 2004, p. 360). Had a participant experienced distress whilst participating in the research project, they would have been referred to a registered and qualified professional who could assist in managing their distress. The participant would have remained in the research; however, their participation would have been placed on hold until they decided if they were comfortable to continue participating or if they would choose to withdraw. Had a participant wished to withdraw participation from the research, their complete or incomplete questionnaire would have been destroyed immediately to respect their confidentiality and anonymity. In this case, the researcher may have asked the chosen organisation in assisting with finding additional participants to account for the loss of participants. Throughout the two phases of data collection, no participant expressed distress when completing the questionnaire.

Cultural sensitivity was crucial when conducting this research in South Africa. This was done to ensure the research respected and accounted for the diverse landscape of the country. Both phases of data collection were administered in English. The researcher was unable to secure translators to translate the questionnaires into various South African language. As such, the research can only apply to trainee pilots who are fluent in and are trained in the English language. It is important to note that this research neglects to explore the experiences of a majority of trainee pilots’ perceptions of their learning and behavioural outcomes using flight simulators. Power dynamics also play a key role in the South African society, considering the influence of the country’s complex history. Historically, researchers provided intellectual and pseudo-scientific justifications for the perpetuation of racial segregation (Laher & Cockcroft, 2013). This has affected how individuals view researchers and their motivations for conducting research. As such, the researcher made a concerted effort to clearly state the intentions of the research and highlight the use of the research findings to contribute to improved training designs.

Chapter 5: Discussion and Implications

The training of pilots has experienced significant evolution over the years, with technological advancements playing a crucial role in this development. The implementation of immersive technology in pilot training has played a pivotal role in shaping pilots' competencies and behaviours by simulating the environment and situations they may encounter in the actual aircraft. This is effective for trainee pilots' training as the flight simulator "[imitates] a real-life process or situation" (Merchant et al., 2014, p. 30) that the trainee will encounter in the actual aircraft. This contributes to the successful transfer of training to the actual aircraft as trainees are equipped with essential knowledge of handling the aircraft and responding to any situation they may encounter (Bailey et al., 2017; Macchiarella et al., 2006). As mentioned earlier, there are many studies available that explore both the positive and negative influence of immersive technology on learning and training. For instance, Dahlstrom et al. (2009) explore the relationship between simulator fidelity and the quality of training in safety-critical industries such as aviation and maritime transport. The authors suggest that high-fidelity simulators are advantageous as they effectively develop trainees' procedural skills and acclimatises trainees to the specific technical systems they will encounter in their operational context (Dahlstrom et al., 2009). However, a disadvantage of these simulators is its over-emphasis on developing procedural details, overlooking the cultivation of situation awareness, decision-making, and communication skills which are necessary for adapting to uncertain and abnormal situations (Dahlstrom et al., 2009). Furthermore, there is limited research available within the aviation industry, specifically, examining how trainees perceive the effects of flight simulation on their learning and behavioural outcomes (Mittelstadt et al., 2024; White & Padfield, 2006).

The main goal of this research study was to develop a valid and reliable instrument to measure trainee pilots' perceptions of their learning and behavioural outcomes using flight simulators. A secondary goal was to explore the relationships between the demographic categories and trainee pilots' perceptions of immersive technology. The third and final goal, was to examine the potential benefits and limitations of using flight simulators in training pilots. This research can potentially contribute to future designs of flight simulators as it focused on how trainee pilots' experience training in flight simulators. Specifically, there is a dearth of research exploring South African trainee pilots' perceptions of their learning and behavioural outcomes using flight simulators in their training, hence the purpose of this research report. In the following chapter, the results of the study will be discussed, highlighting key findings. Limitations of the study will also be discussed along with recommendations regarding important areas of interest for future researchers looking to expand upon this important area of work.

5.1 Overview of Findings

The results of the Regularised Exploratory Factor Analysis (REFA) confirmed that the constructed Trainee Pilot's Simulator Perception- Questionnaire does measure trainee pilots' perceptions of their learning and behavioural outcomes. The results suggested that items 4, 9. 11, 12, 14, 15, and 18 measure trainee pilots' perceptions of their cognitive effort (Table 13). The results also suggested that items 1, 3, 5, 6, 7, 8, 13, and 17 measure trainee pilots' perceptions of their flying competence (Table 13). When these items were combined, a total score measuring both perceptions of cognitive effort and flying competence using flight simulators was obtained. Having this tool available can be of great use to simulator designers as well as flight schools. This tool can be used to measure whether or not the simulator is effective for trainee pilots' learning and behavioural outcomes. It can also contribute to the design and development of new and more effective flight simulators that meet the training needs of pilots.

Table 13: Items Included in Final Trainee Pilots' Simulator Perception Questionnaire

Items	Measuring Trainee Pilots' Perceptions of Learning Outcomes	Items	Measuring Trainee Pilots' Perceptions of Behavioural Outcomes
Q4	Training in the aircraft simulator positively influences my decision-making.	Q1	There is an improvement in my skills following training in the aircraft simulator.
Q9	The aircraft simulator can simulate various unknown situations which develops my problem-solving skills.	Q3	Training in the aircraft simulator positively influences my reaction time.
Q11	The training I've received in the aircraft simulator has improved my aircraft manual handling flying skills overall.	Q5	My learning experience is enhanced when training in the aircraft simulator.
Q12	My basic (ab-initio) flying experience plays a significant role in the outcome of my simulator training sessions.	Q6	My multitasking capabilities are improved following training in the aircraft simulator.

Q14	Simulator training has helped improved my aeronautical decision-making ability.	Q7	Training in the aircraft simulator develops my standard operating procedures.
Q15	Scenarios practised in simulator training have greatly improved my ability to choose an appropriate course of action in an abnormal situation.	Q8	Training in the aircraft simulator develops my ability to recognise patterns.

Table 13: Continued

Items	Measuring Trainee Pilots' Perceptions of Learning Outcomes	Items	Measuring Trainee Pilots' Perceptions of Behavioural Outcomes
Q18	By simulating realistic scenarios, the aircraft simulator facilitates the development of situational awareness, allowing me to process information, assess my environment, and make informed decisions.	Q13	Training in the aircraft simulator assists me in remembering specific rules about executing tasks.
		Q17	Training in the aircraft simulator has significantly improved my interpersonal skills (such as communication) with other aviation professionals (either cabin crew or ground personnel).

5.2 Factors Influencing Learning and Behavioural Outcomes

5.2.1 Learning Outcomes – Cognitive Effort

The first component, measuring learning outcomes, explains the positive impact of flight simulators on trainee pilots' learning outcomes measured by knowledge acquisition, decision-making, problem solving, processing speed, and situation awareness. The skills measured under cognitive effort were informed by the International Air Transport Association's (2023) competency framework for pilots. By including items that relate to trainees' application of knowledge, application of procedures and compliance with regulation, problem solving and decision-making, situation awareness and management of information, and workload management (IATA, 2023), the Trainee Pilots' Simulator Perception – Questionnaire (TPSP-

Q) assesses if simulators contribute to the cultivation of pilots' necessary knowledge, skills, and behaviours (Table 14).

Table 14: IATA Core Competencies and the Related Items in the TPSP-Q

IATA Core Competency	Related Item
Application of Knowledge	Q14: Simulator training has helped improved my aeronautical decision-making ability. Q12: My basic (ab-initio) flying experience plays a significant role in the outcome of my simulator training sessions. Q13: Training in the aircraft simulator assists me in remembering specific rules about executing tasks.
Application of Procedures and Compliance with Regulations	Q13: Training in the aircraft simulator assists me in remembering specific rules about executing tasks. Q7: Training in the aircraft simulator develops my standard operating procedures
Communication	Q17: Training in the aircraft simulator has significantly improved my interpersonal skills (such as communication) with other aviation professionals (either cabin crew or ground personnel).
Aeroplane Flight Path Management, Automation	Q1: There is an improvement in my skills following training in the aircraft simulator
Aeroplane Flight Path Management, Manual Control	Q11: The training I've received in the aircraft simulator has improved my aircraft manual handling flying skills overall Q8 Training in the aircraft simulator develops my ability to recognise patterns:
Leadership and Teamwork	Q17: Training in the aircraft simulator has significantly improved my interpersonal skills (such as communication) with other aviation professionals (either cabin crew or ground personnel).
Problem Solving and Decision Making	Q4: Training in the aircraft simulator positively influences my decision-making. Q9: The aircraft simulator can simulate various unknown situations which develops my problem-solving skills Q3: Training in the aircraft simulator positively influences my reaction time.
Situation Awareness and Management of Information	Q18: By simulating realistic scenarios, the aircraft simulator facilitates the development of situational awareness, allowing me to process information, assess my environment, and make informed decisions
Workload Management.	Q6: My multitasking capabilities are improved following training in the aircraft simulator.

The high loadings of cognitive efforts on Factor 1 indicate that there is an association between flight simulation and trainee pilots' learning outcomes. This aligns with existing literature which emphasise the efficacy of simulations in fostering cognitive skills and positively impacting learning outcomes (Sitzmann, 2011; Vogel et al., 2006). This is supported by Merchant et al's. (2014) findings where simulation was shown to be more effective on students' knowledge-based learning outcomes than on their skill-based outcomes. Recent research has found that high-immersion environments can drastically improve students' learning due to how involved they are in their environment (Alhalabi, 2016; Osti et al., 2021; Passig et al., 2016; Webster, 2016), thus supporting the findings of the current research paper. In their research, Passig et al. (2016) identified how 3D immersive VR environments can enhance children's learning outcomes due to the possibilities associated with using the technologies. According to the study, such immersive technologies can present learners with abstract and challenging concepts through a visual, 3D experience, allowing them to explore information from various perspectives (Passig et al., 2016). Consequently, learners can dissect problems and use the knowledge they have acquired to problem-solve effectively and innovatively. Webster's (2016) study provides additional support for the current papers finding. Webster (2016) showed that highly immersive environments, such as simulators, increased learners' engagement, interaction, and motivation; thus, leading to increased learning. This is consistent with the findings of the paper in which trainee pilots experienced greater engagement and therefore increased learning outcomes using simulation training techniques. Osti et al's. (2021) article found that using virtual reality in training construction workers significantly improved their knowledge and skills. Specifically, the authors found the virtual reality training system positively impacted construction workers knowledge retention, learning speed, and task performance (Osti et al., 2021). Furthermore, Xie et al. (2023) analysed 51 research studies examining the effects of using immersive VR for science education. The outcome of this study identified immersive VR as leading to more positive learning outcomes than other media forms of teaching. This is because learning via IVR environments allows students to have a more personalised experience and affords them more autonomy on how and where to focus their attention (Xie et al., 2023). The results of the current research study show a positive impact of flight simulation on trainee pilots' knowledge acquisition. Sitzmann (2011) conducted a meta-analytic examination of the effectiveness of computer-based simulation games on learning outcomes. The results of this examination indicate that those taught using simulation experience greater training outcomes in relation to declarative and procedural knowledge (Sitzmann, 2011)- both of which are involved in the knowledge acquisition process. This finding is also supported by the research of Lee (2016) and Ng & Chu (2021). The results of these studies both suggest that training in simulators fosters knowledge acquisition by providing deeply engaging simulations which enable trainee pilots to respond to various aviation challenges that they may encounter in an actual flight. This is in line with the findings of the current research paper. It was hypothesised that the immersive environment of the flight simulator creates a highly engaging learning environment thus contributing to trainee pilots' greater knowledge acquisition.

The results of the current study suggest that trainee pilots perceive flight simulation to have a positive effect on their decision making, problem-solving, processing speed, and situation awareness abilities- all considered as key learning outcomes. A study conducted by Sieberichs and Kluge (2021) highlights that incidents and accidents caused by decision-making and problem-solving errors are reported less frequently. This limited reporting of incidents related to these two core competencies pose a risk to the design of pilot training programmes (Sieberichs & Kluge, 2021). The study emphasises the need enhance pilots' decision-making and problem-solving capabilities to prevent incidents and accidents from occurring. It can be suggested, then, that training in a flight simulator is effective in developing those cognitive abilities in trainee pilots' due to its flexibility. These technologies can simulate various dynamic and challenging scenarios which encourage trainees to assess the information they have available, make decisions quickly and effectively, and identify the best solution available (Thomas et al., 2023). According to Risukhin (2015), trainees' decision-making skills are enhanced through flight simulators as it allows trainees to revisit specific, challenging scenarios that are designed to refine their responses and behaviours. It is clear, then, that flight simulations immerse trainee pilots in exercises that encourage them to make decisions to learn the consequences of their decisions (Sitzmann, 2011), which in the aviation industry has life-or-death consequences. Flight simulation has also been shown to effectively develop pilots' problem-solving skills through the simulation of challenging scenarios (Barnes et al., 2000; Fleishman & Quaintance, 1984). These simulations also contribute to the enhancement of trainees' processing speed abilities as they are required to compare letters, number, objects, and patterns in a quick and effective manner (Barnes et al., 2000).

Furthermore, flight simulation has been shown to be effective in developing trainees' situation awareness- a key learning component that ties the above-mentioned cognitive abilities together. According to Endsley (1995, p. 36), "situation awareness is the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future". This implies that situation awareness is an ongoing cognitive effort that allows one to maintain an in-depth understanding of their environment, contributing to their ability to make decisions and adapt to uncertain environments (Wickens et al., 2013). There are three levels of situation awareness including perception, comprehension, and projection (Endsley, 1995). The first level in developing situation awareness involves perceiving changes in the environment (Endsley, 1995; Wickens et al., 2013). The second level involves understanding the changes in the environment by using existing information to understand what is happening in the environment (Wickens et al., 2013). The third level is projection, and this requires individuals to predict possible disruptions in their environment to ensure safe actions are implemented (Wickens et al., 2013). These levels of situation awareness can be developed through flight simulators as it is capable of simulating scenarios that requires continuous systematic scanning, prioritisation, and critical thinking skills. By simulating challenging scenarios, the flight simulator can develop situation awareness as it encourages the establishment of mental models to help pilots process information quickly and efficiently whilst maintaining communication with other aviation professionals. Existing literature has identified flight simulation as being effective in the development of situation awareness through its ability to simulate changing conditions that the trainee must continuously monitor (Bailey et al., 2017; Liu et al., 2020; Merchant et al., 2014; Parong & Mayer, 2018). This develops situation awareness as trainees are required to operate the virtual aircraft safely whilst remaining in communication with other aviation professionals, reading instruments, and scanning for potentially dangerous events.

5.2.2 Behavioural Outcomes – Flying Competence

The second component, measuring behavioural outcomes, explains the positive impact of flight simulators in shaping trainee pilots' behaviour outcomes measured by their pattern recognition, situation awareness, adherence to standard operating procedures, motivation, and adaptability. The skills measured under flying competence were also informed by the International Air Transport Association's (2023) competency framework for pilots. By including items that relate to trainees' communication, aircraft flight path management automation and manual control, situation awareness and management of information, and leadership and teamwork (IATA, 2023), the Trainee Pilots' Simulator Perception – Questionnaire (TPSP-Q) assesses key behavioural outcomes essential for safe and effective operation of an aircraft. This high loadings of flying competence on Factor 2 indicate that there is an association between flight simulation and trainee pilots' behavioural outcomes. This aligns with existing literature which indicates the effectiveness of simulation training on behavioural outcomes (Makransky et al., 2019). The study conducted by Makransky et al., (2019) shows that students who received training in immersive virtual reality performed better on behavioural transfer tests than those who learned using conventional media such as PowerPoint presentations. Communication is one of the key behavioural outcomes that was examined in this paper. The results suggest that immersive technology is effective in developing trainee pilots' communication skills. Existing literature indicates that immersive technology, such as flight simulators, play an important role in developing pilots' communication skills (Risukhin, 2015). This is done by simulating interactions with other aviation professionals such as air traffic control and/or cabin crew to allow pilots to practice their communication skills (Ziccardi et al., 2020; Zuluaga-Gomez et al., 2023). Pattern recognition is another key behaviour that trainee pilots develop using the flight simulator. By exposing trainees to a range of scenarios, the flight simulation provides opportunities for trainees to identify and recognise patterns in the scenarios (Kaukoranta et al., 2003). The results of this study indicate that training in flight simulators has a positive impact on behavioural outcomes such as standard operating procedures and carrying out manual checks. This is supported by the research conducted by Palla et al., (2018) who found that trainees who received checklist instructions in the immersive environment found it effective in boosting their proficiency in carrying out checks. Due to the ever-changing environment of flying, it is essential for trainee pilots to develop adaptability (Bruskiewicz et al., 2007). This is enhanced in flight simulators by exposing trainees to dynamic and unpredictable scenarios to encourage them to be adaptable and flexible (Cross et al., 2022). Motivation is the final important flying competency that affects trainee performance and success in the flight simulation (Ng & Chu, 2021). The research shows that when trainees are given interesting and demanding scenarios, they are motivated to learn, encouraged to perform well, and develop their flying competencies which results in positive behavioural outcomes.

5.3 Lack of Association with Demographic and Experience Variables

Contrary to the initial hypotheses, age, level of experience as a pilot, total flying time, and total flying time in modern flight decks had no significant association with trainee pilots' perceptions of their learning and behavioural outcomes. A potential explanation for this is the small sample size and missing data. The small sample size (N= 26) presented a few issues during the data analysis phase of this research project. The small sample size reduced the statistical power, increasing the likelihood of not being able to detect a statistically significant relationship (Field, 2017). The small sample size also interferes with the confidence intervals, leading to wider confidence intervals thus, making the association less certain (Field, 2017). Finally, the small sample size also reduced the generalisability of the results, as those who did participate may not accurately represent the diversity of the population of interest (Field, 2017). A few participants refrained from providing their age, level of experience as a pilot, total flying time, and total flying time in modern flight decks when completing the questionnaire.

5.4 Theoretical and Practical Implications

5.4.1 Cognitive Abilities in Pilot Training

The Regularised Exploratory Factor Analysis (REFA) has revealed a unique component that reflects cognitive abilities. This finding highlights the potential impact of immersive technology on improving trainee pilots' cognitive abilities. It is implied by the strong loadings of learning outcomes on Factor 1 that flight simulators play a major role in the development of knowledge and skills. This is consistent with the cognitive theory of learning (Gagne, 1985), which highlights the value of simulators as useful instruments for skill transfer and active learning.

5.4.2 Interpersonal Skills and Decision-Making

The interpersonal skills component found in Factor 2 of the Regularised Exploratory Factor Analysis (REFA) suggests that flight simulators influence trainee pilots’ decision-making, problem-solving, and other related interpersonal skills. This is in line with the theory of situated learning (Lave & Wenger, 1991), which emphasises learning in relation to practice. Theoretically, this means that the immersive quality of flight simulations fosters the development of practical decision-making abilities, strengthening the generalisability of simulator training.

5.4.3 Transferability of Skills

The positive correlation between learning outcomes (cognitive abilities) and behavioural outcomes (interpersonal skills) supports the notion that the skills acquired in the flight simulation are transferable to actual aircrafts. This is in line with the principles of transfer of learning (Perkins & Salomon, 1992), which suggests that the competencies developed in flight simulations can transfer seamlessly to the complex and dynamic nature of actual flight situations. As discussed by Dahlstrom et al. (2009), simulator fidelity plays an important role in the quality of training as well as training outcomes. The authors focused their analysis on simulator training in the aviation and maritime industries, identifying the differences between high-, mid-, and low-fidelity simulations. High-fidelity simulations develop essential procedural and technical skills by including technology such as realistic visual displays, sophisticated haptic feedback, and accurate physical controls (Dahlstrom et al., 2009). This is supported by Dourado and Martin (2013), who identify high-fidelity simulators of civilian flights as being successful in ensuring transfer of skills to the actual aircraft due to its accurate replication of the operational context. However, Dahlstrom et al. (2009) suggest adopting a balanced approach, incorporating the use of both mid- and lower-fidelity simulators in conjunction with high-fidelity simulators. When used in combination, high-fidelity simulators enhance technical skills while mid- and lower-fidelity simulators develop adaptivity and flexibility (Dahlstrom et al., 2009).

5.5 Practical Implications

5.5.1 Curriculum Design and Integration

These findings have significant practical ramifications for curriculum developers and aviation training facilities. The obvious differences between learning and behavioural outcomes point to the necessity of an integrated, well-rounded curriculum. More thorough and efficient pilot education can result from intentionally incorporating immersive technology into training programs to address both cognitive and competency aspects. Traditional pilot training has often focused on developing theoretical knowledge and standard operating procedures and regulations, the more cognitive aspects of the profession. Equally important, is making sure this knowledge translates into behaviours. Flight simulation encourages the integration between the cognitive effort required and the flying competencies needed. The immersive environment of the flight simulation provides trainee pilots with challenging scenarios that test their decision-making, critical thinking, and problem-solving skills (Bailey et al., 2017;

Whitehurst et al., 2019). This ensures that the pilot can apply their theoretical knowledge to real-world situations. Additionally, flight simulators provide an opportunity for the development of an adaptive training system which can track the trainees' performance and adjust the training they undertake to target their weaknesses and strengths. This can boost efficiency of training as it allows trainees to progress at their own pace.

5.5.2 Training Programme Standardisation

The consistent positive relationship between learning and behavioural outcomes suggests that flight simulators could be used to assess and improve pilot competencies. This has consequences for training facilities and regulatory agencies trying to set uniform standards for pilot training.

One of the key advantages of using flight simulators is its ability to provide a safe and controlled environment for trainee pilots to practice and refine core skills. As such, training facilities would need to be equipped with a range of simulators differing in fidelity to provide effective training. Initially, the cost of flight simulators can be expensive, however, in the long-term training facilities will save money as the simulator exposes trainees to a range of scenarios without the need for actual flights. Simulators can also allow training facilities to develop customised training sessions to meet the needs of individual trainees. Furthermore, flight simulators allow for the continuous evaluation of trainees, making it easier to identify areas for improvement and implement targeted interventions. The positive relationship between simulator training and pilot competencies emphasises the need to implement assessments into the training protocols. As such, regulatory agencies will need to continuously update existing standards to meet the requirements for simulator training. Moreover, as the use of flight simulators increases, it is essential for regulatory agencies to validate and approve the different simulators in use. This should be done regularly to ensure that the simulators in use are effective, reliable, and contribute to pilot competencies. To ensure that trainees' core competencies are being developed, regulatory agencies must implement regular assessments of simulator capabilities.

Flight simulators should also be used in non-jeopardy sessions as it allows trainees to focus on developing their skills without facing the consequences of undergoing training in a real aircraft. Flight simulators are a very valuable tool in the learning process as trainees can practice and reinforce skills and knowledge without the need for actual flight time. Flight simulators allow for trainees to enhance their instrument handling, practice standard operating procedures, and acclimatise to the cockpit setting. These training sessions further contribute to developing trainees stress management and decision-making skills. By simulating various unknown and challenging scenarios, the simulator effectively introduces controlled stressors, enhancing their resilience in high-pressure situations.

5.3 Limitations and Recommendations for Future Research

While this study provides valuable insights, it is not without limitations. Though adequate for the REFA conducted, the sample size was problematic and influenced the analyses run and the results obtained. The sample size was considerably small due to the voluntary nature of the research. Accessing a moderate to large sample of subject-matter experts proved challenging as they do not have specific office hours, nor do they work in an office environment. This sample was also limited as there were a few instructors in the chosen flight school compared to trainees. Furthermore, the subject-matter expert sample were required to complete a 57-item questionnaire which took approximately 15-20 minutes to complete. From feedback gathered from the management of the flight school, this time commitment was too high and as such, the instructors could not find the time to participate in the research. The trainee pilots' sample was small as completion of the questionnaire was not mandatory nor was it linked to their training and/or learning outcomes. There were no risks or consequences for choosing to either participate or refrain from participating. It is recommended that future studies gain access to a larger sample size to ensure the constructed Trainee Pilots' Simulator Perception- Questionnaire is appropriate to assess trainee pilots' perceptions of their learning and behavioural outcomes, and to ensure generalisability of the results. Due to time constraints, the researcher was unable to distribute the Trainee Pilots' Simulator Perception- Questionnaire to many institutions and in languages other than English. As such, the findings of the research represent a very small population within the South African context, neglecting to assess the experiences of the majority. Additionally, future research should focus on exploring the long-term retention of skills and knowledge that is acquired through immersive technology. Future research should also closely examine the transferability of these skills and knowledge to actual flight scenarios. It is suggested that future research consider administering the questionnaire on a larger sample size. Demographic variables should also be taken into account when administering the questionnaire on a larger sample size. The questionnaire should also be administered to various industries, such as education or manufacturing, to determine if the effectiveness of simulated learning is transferable to other environments.

5.4 Conclusion

The aim of the current research was to create a questionnaire that measured trainee pilots' perceptions of the usefulness of flight simulation training on their learning and behavioural outcomes. This was achieved by investigating the literature available on the use of immersive technology in training pilots. The study also examined the relationship between age, level of experience, total flying time, and total flying time in modern flight decks, and the use of flight simulation training on trainee pilots' perceptions of their learning and behavioural outcomes. The results of the current study found there to be a significant relationship between the use of immersive flight simulation training and trainee pilots' learning and behavioural outcomes. On the other hand, age, level of experience as a pilot, total flying time, and total flying time in modern flight decks had no significant association with trainee pilots' perceptions of their learning and behavioural outcomes.

In conclusion, this research report contributes to the literature by examining how trainee pilots perceive the use of flight simulators in the South African context. Due to the positive associations found between immersive technology and learning and behavioural outcomes, there are implications for curriculum design, the standardisation of training programmes, and the applicability of flight simulators across diverse pilot demographics. This study provides the groundwork for further research and advancements in aviation training methodologies, contributing to the safety and proficiency of future aviators.

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Appendices

Appendix A: Initial Pilots' Perceptions Scale

This survey aims to measure student pilots' perceptions of the impact of immersive technology on their learning and behavioural outcomes. The survey measures the engagement, motivation, enjoyment, self-efficacy, and presence students experience after undergoing training in a flight simulator. Below are definitions of each of these constructs:

Engagement: the mental state of involvement in a task (Schaufeli, 2013), characterised by high degrees of attention, interest, and curiosity.

Motivation: a mental state that encourages active and sustained behaviour towards a goal (Abbas et al., 2022).

Enjoyment: the degree to which the student pilot finds the immersive training fun and pleasant (Makransky & Lilleholt, 2018).

Self-efficacy: refers to the student pilots' confidence in their ability to perform an action/task (Abbas et al., 2022).

Presence: a 'sense of being there', a blurring of boundaries between the real world and the virtual environment (Steuer et al., 1995).

Item	**Rank (please circle the number)**		
	Essential	Useful but not essential	Not necessary
1. Aircraft simulation is an effective tool for student pilots' learning.	1	2	3
2. There is a positive change in the behaviour of student pilots following aircraft simulator training.	1	2	3
3. Student pilots are more confident in their knowledge following training in the aircraft simulator.	1	2	3
4. Student pilots are less confident in their knowledge following training in the aircraft simulator.	1	2	3
5. There is an improvement in student pilots' skills following training in the aircraft simulator.	1	2	3
6. Student pilots display a more positive attitude following aircraft simulator training.	1	2	3

Appendix A (continued):

7. Undergoing pre-training of material improves student pilots' experience in the aircraft simulator.	1	2	3
8. There are many advantages associated with using the aircraft simulator in pilot training.	1	2	3
9. The aircraft simulator is effective in student pilots' training.	1	2	3
10. The aircraft simulator positively influences student pilots' reaction time.	1	2	3
11. The aircraft simulator positively influences student pilots' decision-making.	1	2	3
12. The aircraft simulator positively influences student pilots' attention.	1	2	3
13. The aircraft simulator develops necessary skills in student pilots.	1	2	3
14. The aircraft simulator affects student pilots' cognitive capacity.	1	2	3
15. Training in the aircraft simulator adequately prepares student pilots for flying an actual aircraft.	1	2	3
16. The aircraft simulator accurately represents the reality of flying an aircraft.	1	2	3
17. The presence of the instructor in the aircraft simulator is advantageous to the training of student pilots.	1	2	3
18. Exposure to the aircraft simulator has potential adverse effects.	1	2	3
19. Student pilots may encounter heightened levels of stress or anxiety because of the realistic nature of the aircraft simulator.	1	2	3
20. The aircraft simulator assists in improving the retention and recall of information in student pilots.	1	2	3
21. Student pilots are engaged when training in the aircraft simulator.	1	2	3
22. Student pilots appear motivated when training in the aircraft simulator.	1	2	3

Appendix A (continued):

23. The aircraft simulator supports continuous learning for student pilots.	1	2	3
24. The aircraft simulator supports continuous development for student pilots throughout their career.	1	2	3
25. Student pilots' learning experience is enhanced by using the aircraft simulator.	1	2	3
26. The aircraft simulator is easy for student pilots to use.	1	2	3
27. The aircraft simulator allows for student pilots to progress at their own pace.	1	2	3
28. Student pilots are confident in their abilities when undergoing training in the aircraft simulator.	1	2	3
29. Student pilots are able to accurately interact with the controls of the aircraft simulator.	1	2	3
30. The aircraft simulator helps student pilots to anticipate unsafe aircraft actions.	1	2	3
31. Student pilots' situational awareness is developed by aircraft simulator training.	1	2	3
32. Aircraft simulation training assists in the seamless transition to flying an actual aircraft.	1	2	3
33. The aircraft simulator can potentially foster a sense of complacency among student pilots.	1	2	3
34. Student pilots' multitasking capabilities are improved following training in the aircraft simulator.	1	2	3
35. The aircraft simulator develops student pilots' standard operating procedure.	1	2	3
36. The aircraft simulator develops student pilots' ability to recognise patterns.	1	2	3
37. The aircraft simulator can simulate various unknown situations which develops student pilots' problem-solving skills.	1	2	3

Appendix A (continued):

38. Knowledge acquisition in the aircraft simulator is influenced by whether the student pilot learnt basic flying skills.	1	2	3
39. A lack of previous experience influences the outcome of the aircraft simulation training.	1	2	3
40. The aircraft simulator adequately prepares student pilots for the complexity of the actual aircraft.	1	2	3
41. The aircraft simulator assists student pilots in remembering specific rules about executing tasks.	1	2	3
42. Student pilots' motor skills are developed when training in the aircraft simulator.	1	2	3
43. Using the aircraft simulator helps improve student pilots' knowledge of how the aircraft functions.	1	2	3
44. The aircraft simulator helps student pilots achieve proficiency in flight controls, including understanding their functions and how to manipulate them.	1	2	3
45. The aircraft simulator helps develop student pilots' navigation skills through various scenarios, including reading instruments, planning routes, and interpreting data.	1	2	3
46. The aircraft simulator helps develop student pilots' competence in responding to critical situations through simulated emergency scenarios.	1	2	3
47. The aircraft simulator is effective in helping student pilots to identify safety risks when flying.	1	2	3
48. The aircraft simulator allows student pilots to develop their decision-making skills in a safe and controlled environment, improving their ability to analyse situations and select an appropriate response.	1	2	3
49. The aircraft simulator allows student pilots to develop their communication and coordination skills through simulated interactions with air traffic control and other aviation professionals.	1	2	3

Appendix A (continued):

50. By simulating realistic scenarios, the aircraft simulator facilitates the development of situational awareness, allowing student pilots to process information, assess their environment, and make informed decisions.	1	2	3
51. The aircraft simulator improves student pilots' competency in adhering to standard operating procedures, checklists, and protocols.	1	2	3
52. The aircraft simulator enables student pilots to familiarise themselves and adhere to aviation regulations, including airspace rules, safety protocols, and operational guidelines.	1	2	3
53. The control buttons of the aircraft simulator allow the student pilot to interact with the virtual environment when performing tasks, such as landing the aircraft.	1	2	3
54. Previous experience with technology influences usability of the aircraft simulator.	1	2	3
55. Training in the aircraft simulator helps prevent the deskilling of student pilots.	1	2	3
56. Student pilots are able to transfer the skills learnt in the aircraft simulator to an actual aircraft.	1	2	3
57. Student pilots enjoy learning in the aircraft simulator.	1	2	3

Appendix B: Participant Information Sheet

Psychology

School of Human & Community Development

University of the Witwatersrand

Private Bag 3, WITS, 2050

Tel: (011) 717 4500 Fax: (011) 717 4559

Good day

My name is Sarita Naidoo, and I am a Master's candidate in Organisational Psychology at the University of the Witwatersrand, Johannesburg. As part of my coursework, I am required to conduct a research project. Using aircraft simulation as the primary instrument, I am investigating the effect of immersive technology on student pilots' perceptions of their learning and behavioural outcomes. I am specifically interested in the effect of flight simulators on students' knowledge acquisition, skills, attitudes, and values. I am also looking to assess the effect of flight simulators on student pilots' attitudes towards learning, engagement, motivation, and problem-solving skills. The research will be conducted under the supervision of Dr. Preven Naidoo (Department of Psychology).

This project focuses on investigating the impact of immersive technology or experiences within a virtual reality environment, on your learning outcomes and perceptions of behavioural changes. Participation in this study will involve answering an online questionnaire after undergoing training in an aircraft flight simulator. The questionnaire consists of 15 questions and will take approximately 15-20 minutes to complete.

Your insights and feedback will be invaluable to the success of this research project. Your participation is completely voluntary, and you have the right to withdraw at any time or choose not to answer any question. Please be assured that your participation will be confidential and anonymous. Your identity will not be disclosed, and a random code will represent your participation in the final research report. The completed questionnaires will be stored securely in a password-protected database, and only the researcher and supervisor will have access to the information. Your participation in this project will have no personal cost to you, and you will not receive any direct benefits or disadvantages. Should the results of this research project

Appendix B (continued):

be published, your response will be aggregated, and no identifiable information will be published.

If you have any questions during or after the research project, please do not hesitate to contact me. Upon request, I will be more than happy to send you a summary of the research report.

If you have any concerns or complaints regarding the ethical procedures of this study, you can contact the University Human Research Ethics Committee (Non-Medical) at Shaun.Schoeman@wits.ac.za or Charmaine.Khumalo@wits.ac.za.

Thank you for your time and consideration. We look forward to your response.

Yours sincerely,

Sarita Naidoo

Researcher:

Sarita Naidoo

Email: 2202443@students.wits.ac.za

074 414 8017

Supervisor:

Dr Preven Naidoo

Email: prevendren.naidoo@wits.ac.za

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Appendix C: Consent Form

Psychology

School of Human & Community Development

University of the Witwatersrand

Private Bag 3, WITS, 2050

Tel: (011) 717 4500 Fax: (011) 717 4559

Title of project: Exploring Immersive Technology in Flight Training: Student Pilots' Perceptions of Behavioural Outcomes.

Researcher: Sarita Naidoo

By completing this survey, I understand that I am providing my voluntary consent to participate. The study has been explained to me, and I understand what my participation will involve. I have read and understood the information about the study provided in the Participation Information Sheet. I agree to the following:

- Participation in this study is voluntary, and you have the right to refuse to answer any questions or withdraw from the study at any time.
- Your identity and any other information disclosed will remain confidential and will be identified only by a pseudonym, such as Participant A or B.
- There are no benefits or disadvantages associated with participating in this research.
- By agreeing to complete this survey questionnaire, you acknowledge that the results will be used for a research report required for the completion of a Master's Degree in Organisational Psychology.
- The researcher may use anonymous quotes in the research report.
- Please note that this research may be presented at local or international conferences and/or published in a journal or book.
- If you have any questions or concerns about your participation in this study, please feel free to contact the researcher.

If you would like to receive feedback on the study's findings, please enter your email address in the space provided below. Please keep in mind that providing your email address is entirely optional, you may still participate in the study even if you do not provide it. If you provide us with your email address, we will send you a summary of the study's findings once it is completed. Your email address will be kept confidential and will not be used for any other purpose.

Appendix C (continued):

Email Address (optional): ______________________________________

Date: ___________________

Sarita Naidoo

Email: 2202443@students.wits.ac.za

074 414 8017

Supervisor: Dr Preven Naidoo

Email: prevendren.naidoo@wits.ac.za

011 717 1000

Appendix D: Subject-Matter Expert Participant Information Sheet

Psychology
School of Human & Community Development
University of the Witwatersrand
Private Bag 3, WITS, 2050
Tel: (011) 717 4500 Fax: (011) 717 4559

Good day

My name is Sarita Naidoo, and I am a Master's candidate in Organisational Psychology at the University of the Witwatersrand, Johannesburg. As part of my coursework, I am required to conduct a research project. Using aircraft simulation as the primary instrument, I am investigating the effect of immersive technology on student pilots' perceptions of their learning and behavioural outcomes. I am specifically interested in the effect of flight simulators on students' knowledge acquisition, skills, attitudes, and values. I am also looking to assess the effect of flight simulators on student pilots' attitudes towards learning, engagement, motivation, and problem-solving skills. The research will be conducted under the supervision of Dr. Preven Naidoo (Department of Psychology).

This project focuses on investigating the impact of immersive technology or experiences within a virtual reality environment, on student pilots' learning outcomes and perceptions of behavioural changes. Participation in this study will involve answering an online questionnaire. The questionnaire consists of 57 questions and will take approximately 60 minutes to complete.

Your insights and feedback will be invaluable to the success of this research project. Your participation is completely voluntary, and you have the right to withdraw at any time or choose not to answer any question. Please be assured that your participation will be confidential and anonymous. Your identity will not be disclosed, and a random code will represent your participation in the final research report. The completed questionnaires will be stored securely in a password-protected database, and only the researcher and supervisor will have access to the information. Your participation in this project will have no personal cost to you, and you will not receive any direct benefits or disadvantages. Should the results of this research project be published, your response will be aggregated, and no identifiable information will be published.

Appendix D (continued):

If you have any questions during or after the research project, please do not hesitate to contact me. Upon request, I will be more than happy to send you a summary of the research report.

If you have any concerns or complaints regarding the ethical procedures of this study, you can contact the University Human Research Ethics Committee (Non-Medical) at Shaun.Schoeman@wits.ac.za or Charmaine.Khumalo@wits.ac.za.

Thank you for your time and consideration. We look forward to your response.

Yours sincerely,

Sarita Naidoo

Researcher:

Sarita Naidoo

Email: 2202443@students.wits.ac.za

074 414 8017

Supervisor:

Dr Preven Naidoo

Email: prevendren.naidoo@wits.ac.za

011 717 1000

Appendix E: Final Perception Questionnaire

Trainee Pilots’ Perceptions of the Impact of Aircraft Simulation

Participant Information Sheet

Good day

My name is Sarita Naidoo, and I am a Master’s candidate in Organisational Psychology at the University of the Witwatersrand, Johannesburg. As part of my coursework, I am required to conduct a research project. Using aircraft simulation as the primary instrument, I am investigating the effect of immersive technology on trainee pilots’ perceptions of their learning and behavioural outcomes. I am specifically interested in the effect of flight simulators on trainees’ knowledge acquisition, skills, attitudes, and values. I am also looking to assess the effect of flight simulators on trainee pilots’ attitudes towards learning, engagement, motivation, and problem-solving skills. The research will be conducted under the supervision of Dr. Preven Naidoo (Department of Psychology).

This project focuses on investigating the impact of immersive technology or experiences within a virtual reality environment, on your learning outcomes and perceptions of behavioural changes. Participation in this study will involve answering an online questionnaire about your training in an aircraft flight simulator. The questionnaire consists of 17 questions and will take approximately 15-20 minutes to complete.

Your insights and feedback will be invaluable to the success of this research project. Your participation is completely voluntary, and you have the right to withdraw at any time or choose not to answer any question. Please be assured that your participation will be confidential and anonymous. Your identity will not be disclosed, and a random code will represent your participation in the final research report. The completed questionnaires will be stored securely in a password-protected database, and only the researcher and supervisor will have access to the information. Your participation in this project will have no personal cost to you, and you will not receive any direct benefits or disadvantages. Should the results of this research project be published, your response will be aggregated, and no identifiable information will be published.

If you have any questions during or after the research project, please do not hesitate to

Appendix E (continued):

contact me. Upon request, I will be more than happy to send you a summary of the research report.
If you have any concerns or complaints regarding the ethical procedures of this study, you can contact the University Human Research Ethics Committee (Non-Medical) at Shaun.Schoeman@wits.ac.za or Charmaine.Khumalo@wits.ac.za.

Thank you for your time and consideration. We look forward to your response.

Yours sincerely,
Sarita Naidoo.

Contact information:

Sarita Naidoo

Email: 2202443@students.wits.ac.za

Tel: 074 414 8017

Supervisor:

Dr Preven Naidoo

Email: prevendren.naidoo@wits.ac.za

Tel: 011 717 1000

Informed Consent

Title of project: Exploring Immersive Technology in Flight Training: Trainee Pilots' Perceptions of Behavioural Outcomes.
Researcher: Sarita Naidoo

By completing this survey, I understand that I am providing my voluntary consent to participate. The study has been explained to me, and I understand what my participation will involve. I have read and understood the information about the study provided in the Participation Information Sheet. I agree to the following:

Appendix E (continued):

• Participation in this study is voluntary, and you have the right to refuse to answer any questions or withdraw from the study at any time.
• Your identity and any other information disclosed will remain confidential and will be identified only by a pseudonym, such as Participant A or B.
• There are no benefits or disadvantages associated with participating in this research.
• By agreeing to complete this survey questionnaire, you acknowledge that the results will be used for a research report required for the completion of a Master's Degree in Organisational Psychology.
• The researcher may use anonymous quotes in the research report.
• Please note that this research may be presented at local or international conferences and/or published in a journal or book.
• If you have any questions or concerns about your participation in this study, please feel free to contact the researcher.

If you would like to receive feedback on the study's findings, please enter your email address in the space provided below. Please keep in mind that providing your email address is entirely optional, you may still participate in the study even if you do not provide it. If you provide us with your email address, we will send you a summary of the study's findings once it is completed. Your email address will be kept confidential and will not be used for any other purpose.

Contact Information:

Sarita Naidoo

Email: 2202443@students.wit.ac.za

Tel: 074 414 8017

Supervisor:

Dr Preven Naidoo

Email: prevendren.naidoo@wits.ac.za

Tel: 011 717 1000

Appendix E (continued):

1. Email (optional)”

Demographic Questionnaire

To gather data for comparative purposes, please complete the following questions. The information gathered from this demographic questionnaire will remain confidential and your anonymity is guaranteed. This information is important in order to compile an accurate description of the sample.

2. What is your age (years)?

3. What are your academic qualifications? Please also specify your field of study in the space provided.

- ☐ Secondary School
- ☐ Diploma
- ☐ Bachelor’s Degree
- ☐ Honours Degree
- ☐ Master’s Degree
- ☐ Doctorate
- ☐ Field of study:

Appendix E (continued):

4. Indicate your total level of experience as a pilot (years):

5. Indicate your total flying time (hours):

6. Indicate your total flying time in modern digital ("glass") flying decks (hours):

Perception Scale

This survey aims to measure trainee pilots' perceptions of the impact of immersive technology (aircraft simulation) on their learning and behavioural outcomes. Please read each statement carefully and rank, on a scale of 1 to 7, your agreeableness with each statement. Please answer all questions.

*7. There is an improvement in my skills following training in the aircraft simulator.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
☆	☆	☆	☆	☆	☆	☆

*8. There are many advantages associated with using the aircraft simulator.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
☆	☆	☆	☆	☆	☆	☆

Appendix E (continued):

*9. Training in the aircraft simulator positively influences my reaction time.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
☆	☆	☆	☆	☆	☆	☆

*10. Training in the aircraft simulator positively influences my decision making.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
☆	☆	☆	☆	☆	☆	☆

*11. My learning experience is enhanced when training in the aircraft simulator.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
☆	☆	☆	☆	☆	☆	☆

*12. My multitasking capabilities are improved following training in the aircraft simulator.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
☆	☆	☆	☆	☆	☆	☆

Appendix E (continued):

*13. Training in the aircraft simulator develops my standard operating procedures.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
☆	☆	☆	☆	☆	☆	☆

*14. Training in the aircraft simulator develops my ability to recognise patterns.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
☆	☆	☆	☆	☆	☆	☆

*15. The aircraft simulator can simulate various unknown situations which develops my problem-solving skills.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
☆	☆	☆	☆	☆	☆	☆

*16. The training I've received in the aircraft simulator has improved my instrument flying skills overall.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
☆	☆	☆	☆	☆	☆	☆

Appendix E (continued):

*17. The training I've received in the aircraft simulator has improved my aircraft manual handling flying skills overall.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
☆	☆	☆	☆	☆	☆	☆

*18. My basic (ab-initio) flying experience plays a significant role in the outcome of my simulator training sessions.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
☆	☆	☆	☆	☆	☆	☆

*19. Training in the aircraft simulator assists me in remembering specific rules about executing tasks.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
☆	☆	☆	☆	☆	☆	☆

*20. Simulator training has helped improve my aeronautical decision-making ability.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
☆	☆	☆	☆	☆	☆	☆

Appendix E (continued):

*21. Scenarios practised in simulator training have greatly improved my ability to choose an appropriate course of action in an abnormal situation.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
☆	☆	☆	☆	☆	☆	☆

*22. Training in the aircraft simulator has significantly improved my interpersonal skills (such as communication) with air traffic control professionals.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
☆	☆	☆	☆	☆	☆	☆

*23. Training in the aircraft simulator has significantly improved my interpersonal skills (such as communication) with other aviation professionals (either cabin crew or ground personnel).

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
☆	☆	☆	☆	☆	☆	☆

Appendix E (continued):

*24. By simulating realistic scenarios, the aircraft simulator facilitates the development of situational awareness, allowing me to process information, assess my environment, and make informed decisions.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
☆	☆	☆	☆	☆	☆	☆

Appendix F: Flight School Permission Letter

Psychology

School of Human & Community Development

University of the Witwatersrand

Private Bag 3, WITS, 2050

Tel: (011) 717 4500 Fax: (011) 717 4559

Subject: Request for Permission to Conduct Research Study at Your Organisation

Dear [Recipient],

I hope this message finds you well. My name is Sarita Naidoo, and I am a Master's candidate in Organisational Psychology at the University of the Witwatersrand, Johannesburg. I am currently conducting a research project as a requisite for my degree, under the supervision of Dr. Preven Naidoo. The primary objective of this study is to investigate the influence of immersive technology on student pilots' learning outcomes, with a particular focus on aircraft simulation as the principal instrument. We aim to explore trainees' perceptions of their behaviour and performance from using such technology. This research project is in the process of receiving ethical clearance from the University of the Witwatersrand Human Research Ethics Committee (Non-Medical).

We are seeking your kind permission to conduct this research at your esteemed organisation by surveying student pilots who are enrolled in your training programs as well as your training instructors. The data collection process will occur in two stages. The first stage will require the training instructors to complete either an online or hardcopy survey. Comprising 57 items, the survey is estimated to require no more than 60 minutes for completion. The second stage will entail participants completing either an online or hardcopy questionnaire after undergoing a training session in a flight simulator. Comprising 20 questions, the questionnaire is estimated to require no more than 15 to 20 minutes for completion. The data collection process is expected to begin in mid-July and should take approximately 3-weeks.

Rest assured, the collected data will be securely stored on a password-protected platform, accessible solely by the researcher and supervisor. The data collected will be used solely for the purposes of this research project and will not be shared with third party entities.

Appendix F (continued):

Confidentiality and anonymity will be maintained throughout the process, as no identifying information will be solicited. Your organisation's involvement will be acknowledged in the final research report (if you so wish), and a summary of the findings will be provided upon your request.

We understand the importance of maintaining the highest ethical standards and respecting the policies and guidelines of your organisation. In this regard, we are committed to ensuring minimal disruption to your operations and guaranteeing the utmost professionalism throughout the research process. The results of this research may benefit your organisation by enhancing training programmes and better understanding students' perceptions of their learning and behavioural outcomes.

We would be deeply grateful for your support in our academic endeavour. We thank you for your time and consideration. Should you have any inquiries or require further information, please do not hesitate to contact me using the information provided below. We look forward to your positive response and the opportunity to collaborate with your prestigious organisation.

Sincerely,

Sarita Naidoo

Sarita Naidoo

Email: 2202443@students.wits.ac.za

074 414 8017

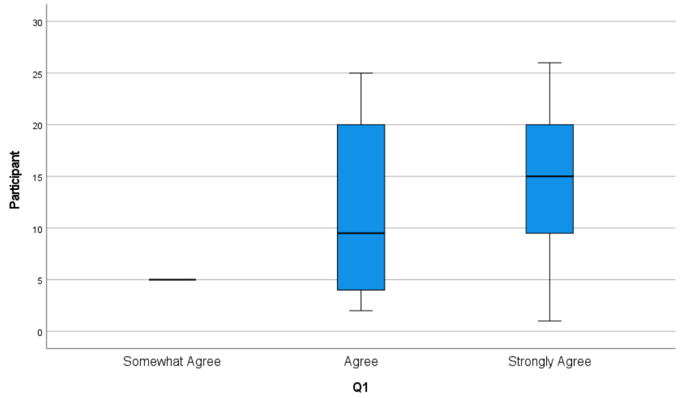
Supervisor: Dr Preven Naidoo

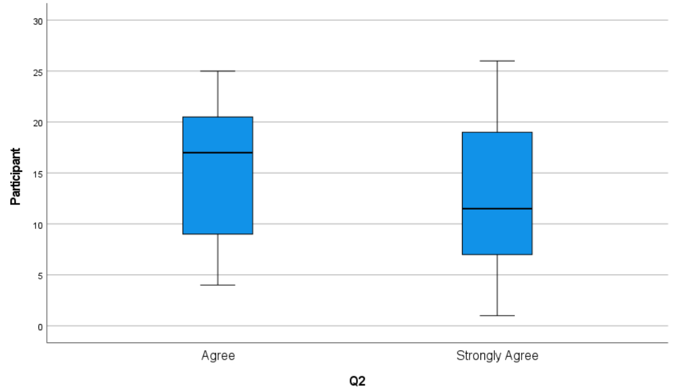
Email: prevendren.naidoo@wits.ac.za

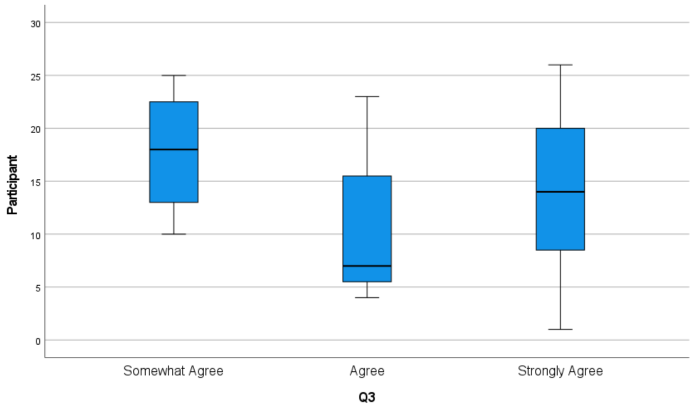
011 717 1000

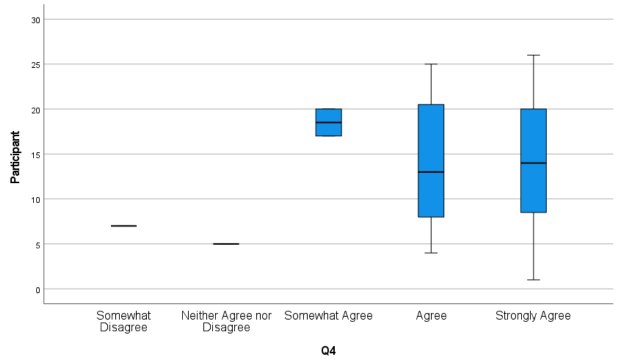
For any information regarding the ethical procedures of this study, you can contact the University Human Research Ethics Committee (Non-Medical) at Shaun.Schoeman@wits.ac.za Charmaine.Khumalo@wits.ac.za.

Appendix G(a) – G(e): Outlier Boxplots for each Question









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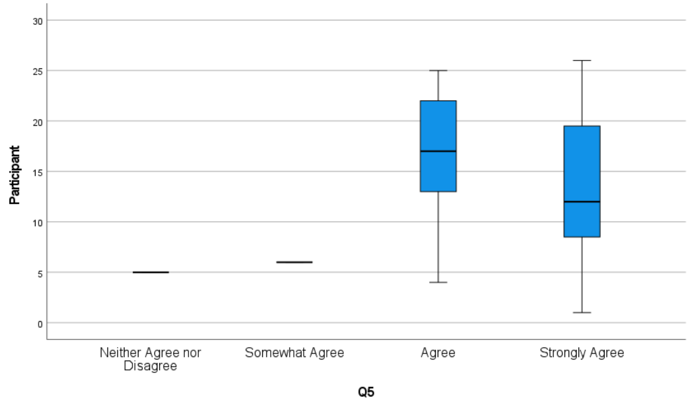

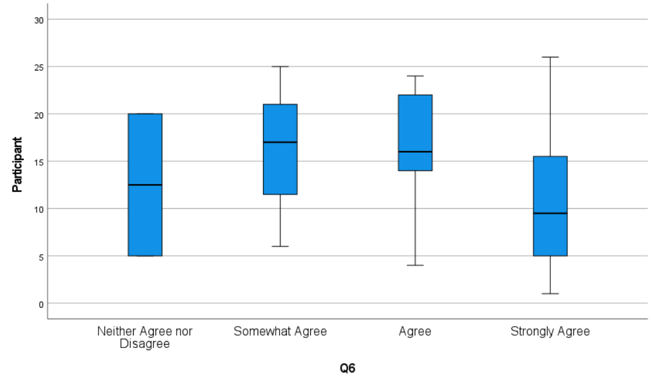

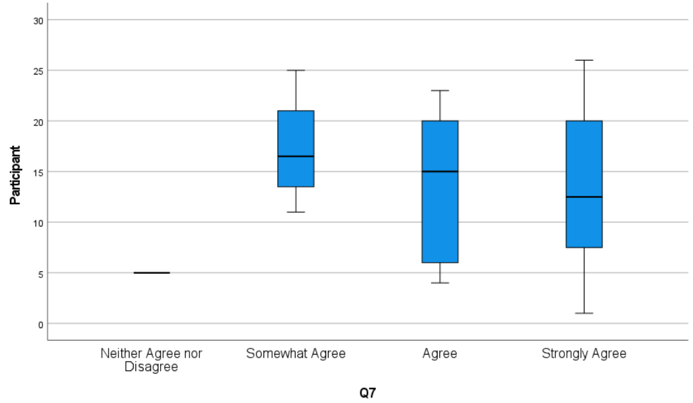

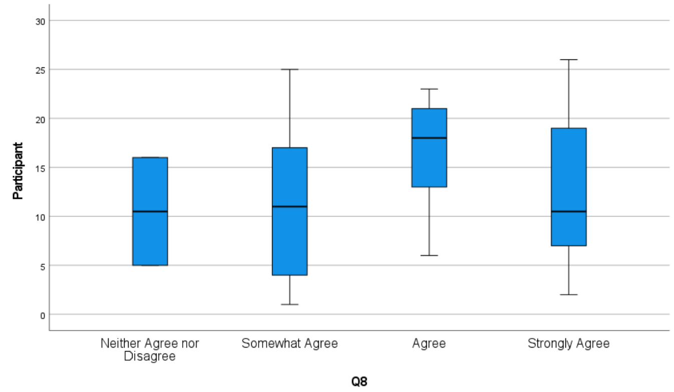

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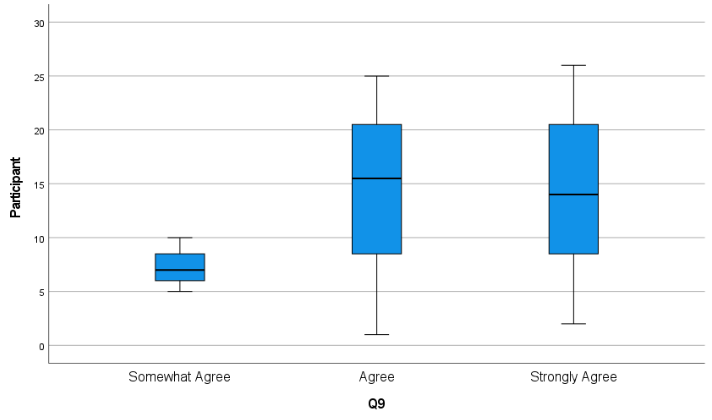

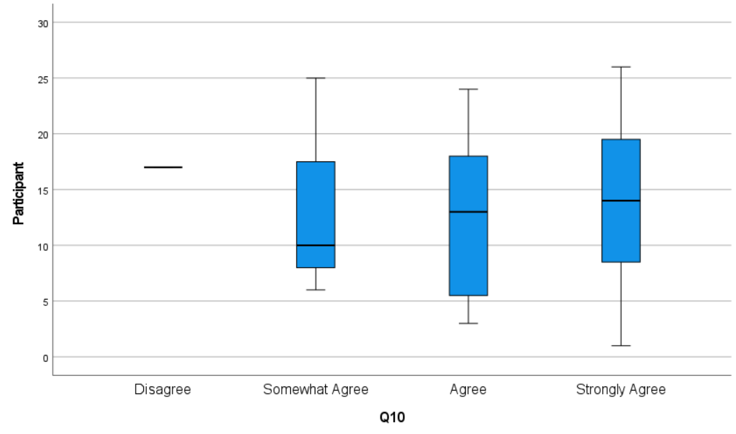

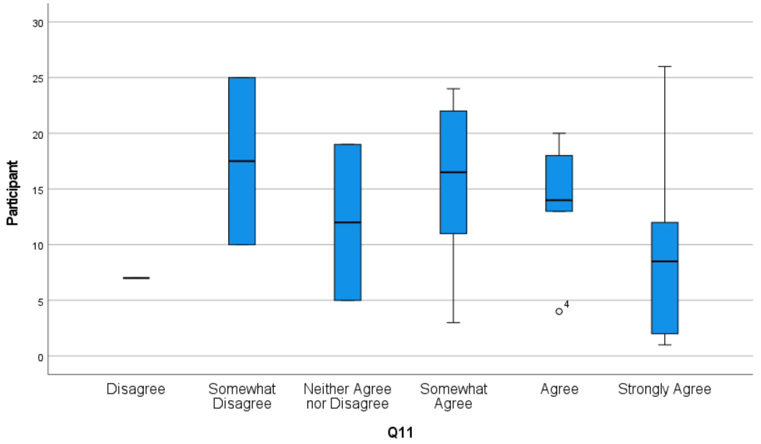

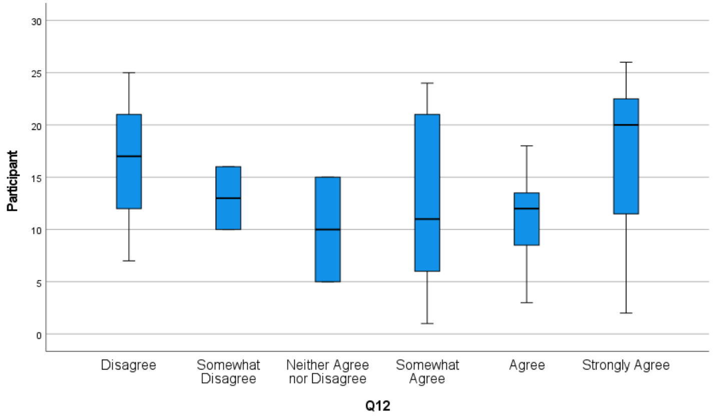

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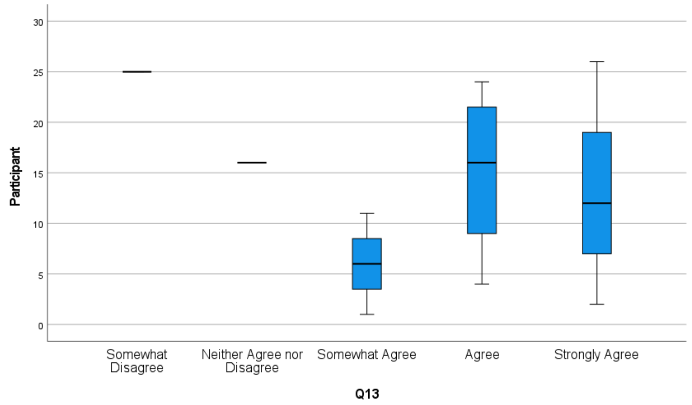

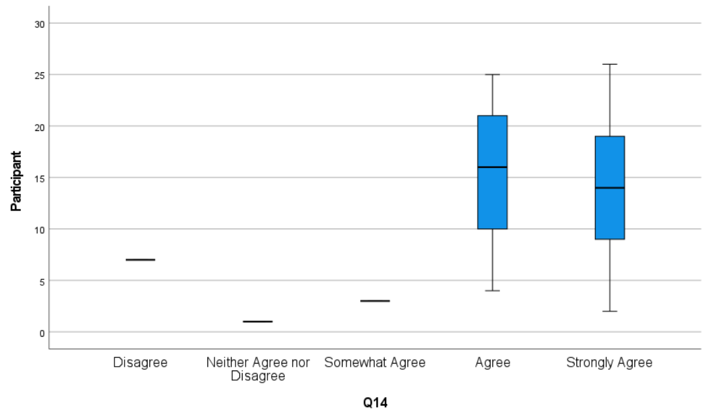

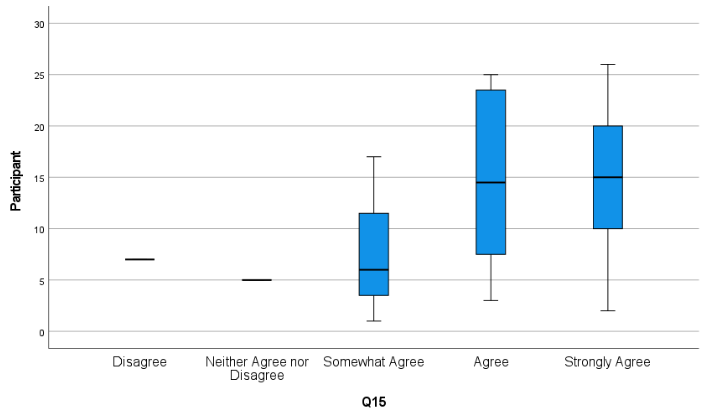

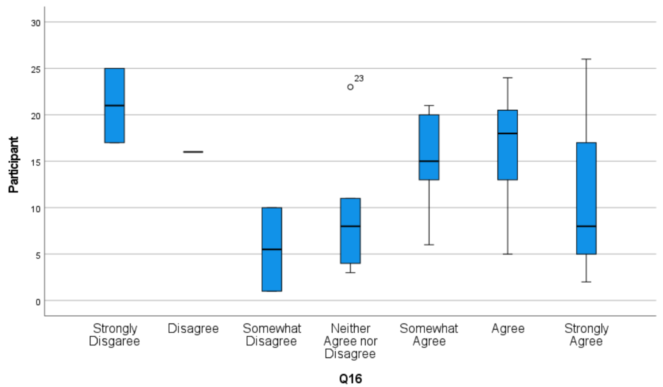

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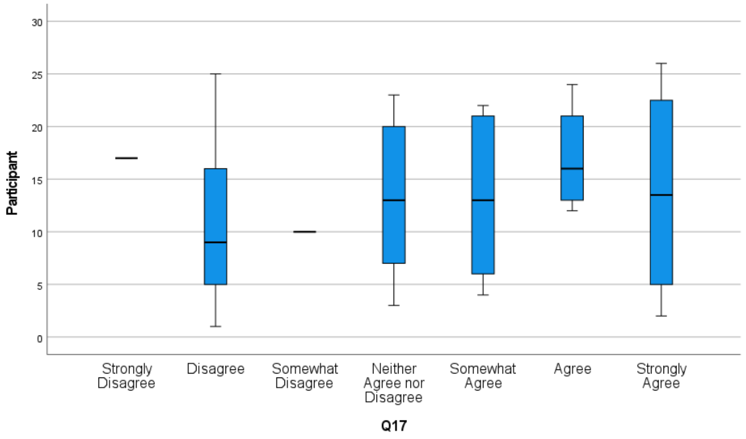

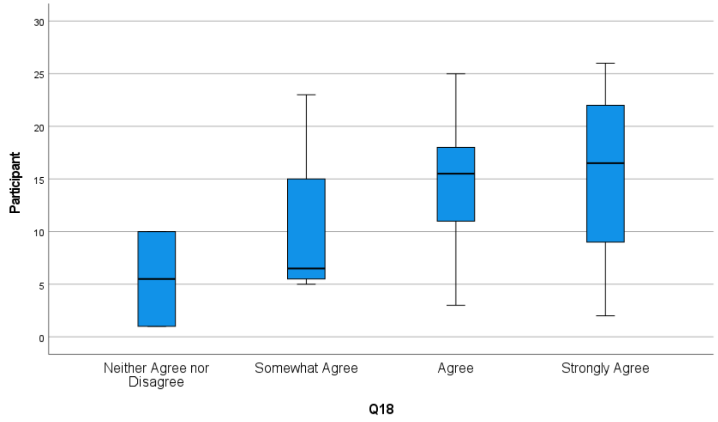

Appendix H: Official Consent from Flight School

Main Terminal Building
Rand Airport
Rand Airport Road
Germiston
Gauteng
Tel: +27 11 824 3528
Email: info@aaacademy.co.za

Africa Aviation Academy
SACAA/1138/0355

PO BOX 11323
Aston Manor
1630
Gauteng

06 June 2023

Sarita Naidoo

Researcher

University of the Witwatersrand

Private Bag 3, WITS, 2050

Subject: Consent to Conduct Research at AAA Flight School

Dear Sarita Naidoo,

We hope this letter finds you well. I am writing on behalf of Africa Aviation Acadmey to grant consent for Sarita Naidoo to conduct research at our premises. We are pleased to support Sarita's valuable study and recognise the potential benefits it may bring to our organisation and the wider research community.

Sarita has provided us with a detailed research proposal outlining the purpose, objectives, and methodology of the study. After careful review, we are confident in the merit and ethical considerations of the research project.

We hereby grant Sarita permission to access our premises, including any necessary facilities, resources, and data, required to carry out her research effectively. Our organisation will provide Sarita with reasonable assistance and cooperation throughout the research period.

Please note that Sarita will comply with all applicable laws, regulations, and ethical standards while conducting her research at our premises. She will ensure the confidentiality and security of any proprietary or sensitive information they may encounter during the research process. Moreover, any data or findings obtained as a result of the research will be used solely for academic or scholarly purposes, and any publication or dissemination of the research outcomes will be subject to prior approval from our organisation.

Locaros T/A Africa Aviation Academy 2008/018190/07 Director Mr N Seebran SACAA/1138

Appendix H (continued):

Main Terminal Building
Rand Airport
Rand Airport Road
Germiston
Gauteng
Tel: +27 11 824 3528
Email: info@aaacademy.co.za

Africa Aviation Academy
SACAA/1138/0355

PO BOX 11323
Aston Manor
1630
Gauteng

We trust that Sarita will conduct herself in a professional manner and maintain a respectful and collaborative relationship with our staff and other stakeholders during the research process. Should any concerns or issues arise during the course of the study, we encourage open communication to address them promptly.

We look forward to the valuable insights that Sarita's research will generate and the potential impact it may have on our organisation and the broader field. We appreciate the opportunity to contribute to advancing knowledge through this collaboration.

If you require any additional information or have any questions regarding this consent, please do not hesitate to contact me at 061 430 6388. Thank you for considering this request, and we eagerly anticipate a successful research endeavor.

Yours sincerely,

Ashveer Rajpal

Manager

Africa Aviation Academy

Tel- 011 824 3528

Email- Info@aaacademy.co.za

Kind Regards

Mr. Ashveer Rajpal
Manager
Africa Aviation Academy
+27 84 737 8000
Info@aaacademy.co.za

Africa Aviation Academy
SACAA 0355

Appendix I: Ethics Certification

Certificate

March 14, 2023

This is to certify that Ms. Sarita Naidoo has successfully completed the Macquarie University Human Research Ethics Online Training Module for the Social Sciences and Humanities.

Macquarie University

Appendix J: Ethics Clearance

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

SCHOOL OF HUMAN AND COMMUNITY DEVELOPMENT ETHICS COMMITTEE
CONSTITUTED UNDER THE UNIVERSITY HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)

CLEARANCE CERTIFICATE **PROTOCOL NUMBER: MAORG/23/09**

PROJECT TITLE:	Exploring Immersive Technology in Flight Training: Student Pilots' Perceptions of Learning and Behavioural Outcomes.
INVESTIGATOR	Naidoo Sarita (2202443)
SCHOOL/DEPARTMENT OF INVESTIGATOR	SHCD/Psychology
DATE CONSIDERED	13 June 2023
DECISION OF THE COMMITTEE	Approved unconditionally
RISK LEVEL	Minimal Risk
EXPIRY DATE	31 December 2025

ISSUE DATE OF CERTIFICATE 05 June 2023 **CHAIRPERSON** ____________________
(Dr Aline Ferreira Correia)

cc: Dr Preven Naidoo (Supervisor) *Dr Preven Naidoo*

DECLARATION OF INVESTIGATOR

To be completed in duplicate and **ONE COPY** returned to the Chairperson of the School/Department ethics committee.

I/we fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure be contemplated from the research procedure as approved, I/we undertake to submit an amendment of the protocol to the Committee.

Naidoo
____
Signature

Date 06/ 07 / 2023

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES