EXAMINING THE IMPACT OF INCORPORATING VIRTUAL REALITY INTO AIRLINE PILOT TRAINING: A MIXED METHODOLOGY STUDY

By

MATTHEW JOHNSTON

Bachelor of Science in Management
United States Air Force Academy
Colorado Springs, Colorado
2001

Master of Business Administration
Colorado State University
Fort Collins, Colorado
2010

Master of Arts in National Security and Strategic Studies
United States Naval War College
Newport, Rhode Island
2015

Master of Science in National Security Strategy
National Defense University
Washington, D.C.
2020

Submitted to the Faculty of the
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Oklahoma State University
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Dissertation Approved:

Dr. Timm Bliss

Dissertation Adviser

Dr. Chad Depperschmidt

Dr. Kathryn Gardner-Vandy

Dr. Tim Passmore

Name: MATT RODERICK JOHNSTON

Date of Degree: MAY, 2022

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Abstract: The purpose of this study was to analyze the potential of Virtual Reality (VR) employment in airline pilot training. Specifically, this study conducted an experiment that introduced VR equipment into the Multi-Crew Cooperation (MCC) course in the United Kingdom (UK). Increasing pilot throughput in airline pilot training is critical as demands for airline pilots will increase over the next decade. The review of literature includes United States Air Force use of VR in pilot training, VR cognitive efficacy, self-efficacy, and the civil aviation industry's use of immersion technology. The review of literature indicates positive outcomes in flying modalities and self-efficacy. The study used a mixed methodology analysis to answer the following questions: 1) Can VR increase the average Synthetic Flight Training session scores in an MCC course? 2) Can VR increase scores on the MCC course key competencies of situational awareness, workload management, knowledge and procedures, aircraft management (manual control), and aircraft management (automation)? 3) Can VR increase the score of the MCC course Final Assessment? 4) Does VR increase the quality of training experienced by the students in a typical MCC course? 5) Can VR increase self-efficacy in flying related skills and airline aviation training programs? Findings of the study showed VR did not significantly improve outcomes. VR employment did marginally improve quality of training, specifically in motivation and enjoyment. Implications of the analysis is that VR may improve outcomes if provided to student pilots two weeks to one month prior to the MCC course. Additionally, matching the aircraft operating procedures in the VR software with the Standard Operating Procedures (SOPs) that students are required to use in their MCC course Synthetic Flight Training simulator events may improve outcomes.

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CHAPTER I

INTRODUCTION

The global airline industry is expected to grow at five percent over the next decade (United States Bureau of Labor Statistics, 2020). This growth creates challenges for airlines to train pilots to meet the demand. The global airline industry faces a shortage of approximately 260,000 pilots by 2030 (CAE, 2017). The United States (U.S.) alone faces a shortage of 80,000 pilots by 2030 (CAE, 2017). Europe anticipates requiring 95,000 new commercial pilots by 2034 (AeroProfessional, 2021). This is not a short-term crisis either. According to a 2017 Boeing analysis 600,000 pilots may be needed between now and 2037 (Cercelli, 2018). Current methods of training pilots may prove inadequate to meet market demands. Airlines face challenges increasing pilot production to meet the demands of the coming years while maintaining the current quality standards.

The United States Air Force (USAF) has been struggling with pilot production over the last decade. An understanding of its pilot demand issues may offer lessons for civil aviation. The USAF has approximately 2,400 fewer pilots than it requires (Losey, 2017). Pilots fill two important rolls in the USAF. They fly airplanes, and they rotate into staff positions. Pilots will usually rotate into a staff position for three years, then return to flying again. The staffs serve at various USAF headquarters and assist the headquarters' commanders with planning, personnel, logistics, and budgeting. The USAF "fills" cockpits by leaving these staff positions vacant. The Air Force is addressing the pilot shortage in part by under-manning staff positions. According to the Government Accounting Office (2017) as of 2017, the USAF filled staff positions at 73 of its authorized allotment for pilots. By not filling staff assignments the USAF does not have the level of subject matter expertise required for optimum function. Not filling staff positions is only a stopgap measure as the USAF attempts to increase pilot production and retention of already trained pilots. However, despite these efforts the USAF has been unable to increase pilot manning.

In addition to a pilot shortage, the USAF faces a coming shortfall in aircraft capacity to train future pilots. The Air Force does not have a replacement for the T-1A training aircraft which requires a major engine overhaul or replacement by 2030 (Neal, 2020). The Air Force has signaled that it does not plan to replace the T-1A. Pilot trainees marked to fly mobility aircraft spend approximately six months training in the aircraft.[1] Faced without a T-1A replacement, and a 2,400 pilot shortage, the Air Force had no choice but to innovate.

Before 2018, the USAF utilized a standard ground school, simulator phase, then flying phase protocol. This is a model like civil aviation training. But in 2018 the USAF introduced Pilot Training Next (PTN) to create innovative solutions to the crisis. PTN relies significantly on Virtual Reality (VR) to train its students. Results from PTN classes indicate the same quality of

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[1] Mobility is a USAF term to describe fixed-wing aircraft capable of carrying cargo or personnel.

pilot graduate but in less time and cost. The USAF is incorporating lessons from PTN to address the phase-out of the T-1A and to solve the pilot crisis. Civil aviation can learn lessons from the USAF that may help solve its own pilot crisis as well.

Background of the Problem

The airline industry faces many challenges to meet the pilot demand that include Federal Aviation Administration (FAA) regulations, profitability requirements, and union negotiations (Zhang, 2018). The FAA requires that new hires have a minimum of 1,500 hours of flight time and carry an Airline Transport Pilot certification (Department of Transportation, 2020). The 1,500 flight hour requirement reduces the pool of pilots available to hire. The European Union Airline Safety Agency (EASA) requires fewer flight hours, but the cost of training is placed on the pilot. These costs can be prohibitive which also reduces the pool of pilots available to hire in the European Union (EU). Additionally, shareholders put pressure on airlines for short-term financial gains, which are then prioritized over long-term strategic planning. It may behoove airlines to start hiring pilots as quickly as possible to hedge against the high pilot demand in the years to come. However, that would increase short-term costs substantially, which may be an unfeasible course of action for airlines.

Additionally, the airline industry is a low-profit margin sector, albeit at large economies of scale. It is also subject to strong market perturbations beyond its control, e.g., 9/11, and COVID-19. Airlines cannot necessarily maintain large overhead, such as excess pilots, in preparation for increased demands in the future. Airlines must also negotiate with pilot unions that limit the airlines' ability to modulate pilot salaries. The airlines cannot necessarily train many new pilots at lower pay in preparation for increased pilot demand, particularly as the world continues to respond to the COVID-19 pandemic.

The COVID-19 pandemic has had a two-fold effect on the airline industry. First, in the short run, it dampened domestic and international travel. Second, it led to the early retirement of tens of thousands of airline pilots (Gibson, 2020). However, one can presume that the travel industry will eventually recover based on global COVID-19 response progress. Airline travel has increased 15 percent in 2021 when compared to early 2020 when "stay at home orders" severely reduced flights (Josephs, 2021). The growing global population trend should equate to increasing airline travel in the decades to come (Roser, 2019). Additionally, major airlines are starting to hire pilots again anticipating the increase in travel. United Airlines announced it will start hiring pilots and has even invested in a pilot training schoolhouse, which will create more pilots that can fly for United Airlines (Josephs, 2021). In other words, travel will most likely resume and grow in the coming years while the qualified pilot supply is significantly reduced.

It is important to distinguish between the U.S. model for producing airline pilots overseen by the FAA from that of the EU model overseen by the European Union Aviation Safety Agency.[2] The U.S. model has two sources of pilots. The first is military pilots. The military pilots usually meet the 1,500 hour minimum and can enter the airline type-rating course. To make themselves potentially more hirable military pilots may seek other civilian certifications such as the Airline Transport Pilot certification. The second source of pilots is civilian pilots. These pilots usually pay for all their certifications on their own and work for small regional commercial carriers and passenger operations until they reach the 1,500-hour mark. Regardless, the vast majority of pilots that seek to fly for the airlines, whether civilian or former military pilots, will apply to the airlines before attending type-rating training. Once hired by one of the

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[2] Note that since 31 December 2020 the United Kingdom (UK) exited the EU and as a result EASA. The UK's Civil Aviation Authority (CAA) has sole regulatory responsibility for aviation safety in the UK. UK CAA and EASA regulations are nearly identical currently (CAA, 2022).

U.S. airline carriers the airlines will send the pilot to a training center for a type-rating at no cost to the new hire.

The EU and United Kingdom (UK) model is slightly different than that of the United States. Pilots seeking to fly for an airline only require 200-hours of flying time before entering the training pipeline for the airlines. Whether former military, or civilian, pilots seeking to be hired by the airlines must first attend an Airline Pilot Standards Multi-Crew Cooperation (APS-MCC) course (referred to as the “MCC course” from this point forward). The MCC course is an introduction to flying an aircraft as a crew member versus as a single pilot. Following the MCC course students enroll in a type-rating course. Following the type-rating course, pilots’ interview for a pilot position with the various airlines. There are some exceptions where European airlines may sponsor a pilot through training, but this only applies to a minority of pilots.

Statement of the Problem

The airline industry may not be able to produce the quantity of pilots required to meet market demand in the next decade. Current training protocols do not leverage available technology to increase the efficiency of pilot training syllabi. Airlines will encounter challenges to train enough pilots to meet demand with current training methods without large scale investments in additional infrastructure, simulators, and instructors, all at great cost.

Purpose of the Study

The purpose of this study is to determine the efficacy of VR technology in the Boeing 737 MCC pilot training course. If VR can improve training outcomes in a standard 737 MCC pilot training class, it may provide insight for more efficiencies in follow-on syllabi. It is possible that VR may reduce the number of simulator missions currently required in MCC training and type-rating syllabi. Specifically, this study seeks to understand the qualitative experiences of pilot trainees as they undergo an MCC syllabus that employs VR. Additionally, the study captures quantitative data that should indicate any efficiencies gained by VR.

The research questions explored in this study include:

1. Can VR increase the average Synthetic Flight Training session scores in an MCC course?
2. Can VR increase scores on the MCC course key competencies of situational awareness, workload management, knowledge and procedures, aircraft management (manual control), and aircraft management (automation)?
3. Can VR increase the score of the MCC course Final Assessment?
4. Does VR increase the quality of training experienced by the students in a typical MCC course?
5. Can VR increase self-efficacy in flying related skills and airline aviation training programs?

The hypothesis for this study is that average session scores, the five key competencies scores, and the Final Assessment score will increase, and the pilots' sense of quality of training and self-efficacy will increase.

Definition of Terms

Airbus 320 (A320) – Narrow-body aircraft that pilots initially fly at some major airlines.

Airline Pilot Standards Multi-Crew Cooperation (APS-MCC) Course– Required course for pilots prior to type rating training by the European Union Aviation Safety Agency (EASA). Referred to in the dissertation as simply “MCC”.

APS-MCC Competencies – See Appendix A for competency descriptions and behavioral indicators.

- **Motivation and Professional Attitude (MPA)** – Takes responsibility for own training with the attitude to achieve the very highest of standards.
- **Situational Awareness (SA)** – Perceives and comprehends all the relevant information available and anticipates what could happen that may affect the operation.
- **Problem Solving and Decision Making (PSDM)** – Accurately identifies risks and resolves problems. Uses the appropriate decision-making processes.
- **Leadership and Teamwork (LT)** – Demonstrates effective leadership and teamwork.
- **Workload Management (WM)** – Manages available resources efficiently to prioritize and perform tasks in a timely manner under all circumstances.
- **Effective Communication (EC)** – Demonstrates effective oral, nonverbal, and written communications, in normal and non-normal situations.
- **Knowledge and Application of Procedures (KAP)** – Identifies and applies procedures in accordance with published operating instructions and applicable regulations, using the appropriate knowledge.
- **Aircraft Management, Manual Control (AMMC)** – Controls the aircraft flight path through manual flight, including appropriate use of flight management system(s) and flight guidance systems.

- **Aircraft Management, Automation (AMA)** – Controls the aircraft flight path through automation, including appropriate use of flight management system(s) and guidance.
- **Briefings (B)** – Conducts effective briefings for departures, arrivals and non-normal events.
- **Pilot Monitoring (PM)** – Supports and monitors pilot flying, challenges as appropriate, to enhance flight safety and operational efficiency.
- **Energy Management (EM)** – Plans and executes successful descent profiles.

Approved Training Organization (ATO) – A pilot training organization approved by a Civil Aviation Authority to train pilots on certifying aviation related programs.

Aviation Training Device (ATD) – a simulator that can be used for ground and flying operations training. The FAA rates ATDs as basic (BATD) or advanced (AATD).

Boeing 737 (B737) – Narrow-body aircraft that pilots initially fly at some major airlines.

Civil Aviation Authority (CAA) – National governing body that sets policies and procedures for flying in its airspace. For example, the CAA for the United States is the Federal Aviation Administration and for the European Union it is the European Aviation Safety Agency.

Computer Based Training (CBT) –Currently, VR is considered CBT by the FAA.

Data Glove – Gloves that can be worn in VR that provide haptic feedback.

European Aviation Safety Agency (EASA) – The European Union CAA.

Federal Aviation Administration (FAA) – CAA for the United States.

Field of Regard – The total available degrees that can be captured by the sensor (360 degrees in the case of a VR headset). The field of view is what the participant can see at any given moment (limited by the human lens).

Flight Simulation Training Device (FSTD) – Broad term that includes a spectrum of training devices from basic cockpit layouts to full-motion simulators. The FAA defines FSTDs as Flight Training Devices or Full Flight Simulators.

Flight Training Device (FTD) – Accurate partial cockpit with a computer monitor that simulates windshields and outside visuals. The FAA rates FTDs from 4 (least capable) to 7 (most capable). They are further defined in syllabi as FTDA and FTDB. FTDA is taught by a systems expert technician. FTDB is taught by an instructor pilot and covers normal and non-normal operations while airborne.

Full Flight Simulator (FFS) – Full surround cockpit with a full-motion simulator. The FAA rates FFS capability from A (least capable) to D (most capable).

Flying Missions – A sortie in an actual aircraft versus a simulator mission.

Gradebook – An MCC course student's record of all Synthetic Flight Training events and scores for each of the twelve key competencies.

Haptic Feedback – Tactile sensation provided by gloves or a controller that provides a somatosensory response to the user.

Head Mounted Display (HMD) – HMDs are worn over the head and position a screen directly in front of the wearer's eyes. Typically, they include "blinders" that occlude peripheral vision.

Immersion – Computer generated environment. Immersion can be generated by simulators or VR.

Pipeline – The series of training courses a pilot trainee must undergo to complete certification in their type aircraft.

Pilot Training Next (PTN) – Exploratory USAF flying training program that utilizes VR and the T-6A. Graduates receive their “wings” and move on to follow on aircraft (air-refueling, mobility, fighter, or bomber).

Retraining Event – If a pilot trainee does not meet the standard for a particular training objective, they are required to repeat the event. These events can include tests and simulator missions.

Sortie – Military term for a mission from take-off to landing (i.e., a single flight).

Specialized Undergraduate Pilot Training (SUPT) – Initial USAF pilot training program that utilizes the T-6A, T-1A, and T-38C to certify USAF pilots and grant graduates their “wings.” SUPT takes approximately one year. Graduates go on to a follow-on pipeline course to learn their mission aircraft; either fighter, bomber, mobility (cargo), air-refueling, etc.

Standard Operating Procedures (SOP) – The normal and not-normal procedures pilots are required to comply with when operating an aircraft. SOPs are specific to the operator of the aircraft (e.g., one MCC course may have different SOPs then another MCC Course even though they both operate B737 simulators).

Synthetic Flight Training (SFT) – Simulator missions conducted during Multi-Crew Cooperation (MCC) training.

T-1A Jayhawk – SUPT trainer aircraft flown post-T-6A phase by pilots bound for air-refueling tanker or mobility aircraft. Trainees normally fly the T-1A for approximately six months (80 hours). Cost per flying hour: $2,187.

T-6A Texan II – Initial aircraft flown by pilot trainees in Specialized Undergraduate Pilot Training (SUPT). Pilot trainees fly the aircraft for approximately five months (about 80 hours). Cost per flying hour: $783.

T-7A Red Hawk – Future trainer aircraft that will replace the T-38C Talon. Cost Per flying hour: unknown, in development.

T-38C Talon – SUPT trainer aircraft flown post-T-6A phase by pilots bound for fighter and bomber aircraft. Trainees normally fly the T-38C for approximately five months (89 hours). Cost per flying hour: $4,703.

Virtual Reality (VR) – The computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors.

Significance of the Study

In the near-term, this study could assist the adoption of VR by additional MCC courses in the UK and the EU and airlines for use in current type-rating syllabi (Department of Transportation, 2020). No airline type-rating program currently employs VR. Possibly only a handful of pre-type rating training programs employ VR. Some colleges that support aviation programs employ VR. The U.S. military is well ahead of civilian aviation programs in the use of VR across multiple levels of training from initial pilot training through advanced training on major weapons systems (i.e., combat and mobility aircraft). VR could improve the experiences of the trainees as they complete the syllabus. This could lead to better syllabus directed test scores as well as increased learning in the Flight Simulation Training Devices (FSTDs). Lastly, VR could increase self-efficacy for student pilots which could lead to increased motivation to successfully complete the syllabus.

In the long-term, this study could pave the way for replacing many simulator training missions with VR. Simulators are expensive, located in specific cities, and have limited availability due to high demand. VR is inexpensive, readily available, and is not constrained by location. If some simulator missions are replaced by VR missions, airlines would be able to reduce training costs. Additionally, they would be able to increase pilot throughput in the same amount of time as legacy syllabi. For example, if VR replaced 10 percent of simulator missions in a type-rating syllabus, it is conceivable that 10 percent more pilots could be added per class. Reducing the simulator requirement and time to graduate could save the airline industry tens of millions of dollars in training costs. See Appendix B for an example airline type-rating syllabus for more detail on simulator requirements.

Assumptions

This study utilizes a mixed methodology design. A qualitative phenomenological study of the trainees' experiences necessitated the following assumptions:

1. The study assumed participants honestly answered questions posed as part of the study.
2. The study assumed that experimental participants did employ the VR equipment. Nominally, this required participants to use the VR equipment a minimum of one time (which they agree to in the consent form, Appendix C).

Additional assumptions applied to the quantitative data which was acquired in two ways: student surveys and gradebooks that rated the students' performance over ten simulator missions they accomplished during the MCC course:

1. The students filled out survey data accurately.
2. The MCC program instructors accurately and consistently recorded student performance per the course standards over all classes involved in the research project.

Limitations

This study was limited to observing six classes enrolled in an MCC course. Each class had two to eight students. The aircraft simulators used modeled a Boeing 737. All participants underwent the same syllabus. Appendix D is an example of a training syllabus for illustrative purposes only. The study did not observe differences in syllabi or experiences of pilot trainees in different airline pipelines.

The VR equipment hardware and the software did not change during the study. However, the VR equipment will change routinely as it adopts more capable hardware and software. This study only observed the initial fielding of a specific VR system with a limited software load. It had a 100 percent representative flight deck and is useful for normal cockpit-oriented ground operations and some non-normal operations. The test VR software is not useful for flying related normal or non-normal operations.

Due to the current VR equipment's capabilities, the study focused primarily on its effects on the initial stages of airline training. While VR offers the possibility of reducing simulator requirements in future syllabi this is limited to current syllabi with full simulator requirements and no identified VR objectives or training events. Experimental participants used VR at their discretion, in addition to the training modalities identified in the current syllabus. It was observed some students used VR more than others. The surveys capture how much time each experimental participant utilized VR. See Appendix E for an example of a typical VR setup.

The EASA Approved Training Organization (ATO) center's cooperation was critical. The ATO allowed the researcher to conduct the project as part of the training. The ATO provided student gradebooks and forwarded email addresses for consenting students. The gradebooks contained the Synthetic Flight Training (SFT) scores as well as if any retraining events occurred.

Delimitations

Although airline pilot shortages are a global problem, potentially foremost in Asia, this research limits its scope to primarily U.S. and European sectors. The reason is three-fold. First, EASA is the world's largest Civil Aviation Authority (CAA) and employs the MCC program. This study's participants are in the UK undergoing an MCC program in accordance with UK CAA regulations. Second, VR use in airline training is in its infancy and is currently being used by a single MCC program in the UK. Lastly, the USAF has dramatically increased its use of VR and has agreements with the FAA that allows pilots certified by the military to operate in the National Airspace System.

Therefore, the analysis is more complete if it contains considerations that include the U.S. and Europe. Asia, which represents the largest percentage of airline customers, is composed of many CAAs. These CAAs all comply with International Civil Aviation Organization (ICAO) standards and recommended practices but would introduce too many considerations to the current study. Certainly Asia, as well as Africa, South America, Central America, Australia, and other North American countries are important airline sectors but are beyond the scope of this research project.

Although some flying schools utilize VR presently, no entry level airline aircraft type-rating programs do (i.e., B737 and A320). The only program that utilizes VR for airline training is a UK based MCC course. Therefore, to test the efficacy of VR in airline training the MCC training program is the only feasible option. According to VA Airline Training (2019) the MCC course seeks to:

> Develop the technical and non-technical components of the knowledge, skills and attitudes required to operate a multi-crew aircraft this, also includes advanced swept-wing training and airline operational training, to better equip a pilot prior to commencing initial type rating training with the standards required by a commercial air transport (CAT) (p. 20).

The MCC program is required for pilots that have flown single-pilot required aircraft that seek to fly for a crew required aircraft such as the B747 or A320. The program takes approximately three weeks. The first week is ground school that prepares the students for the following two weeks of simulator training where they become familiar with B747 or A320 tasks while operating as a crew (see Appendix D for sample MCC program).

The control group was composed of three classes of approximately seven to eight students and the experimental groups was composed of three classes of two to four students. This study collected quantitative and phenomenological qualitative data that contributed to the analysis. All members of both groups were included in the research. VR equipment was supplied and supported by a single for-profit company. The company has an agreement with the MCC training organization to provide the equipment and was already employing the VR equipment before the experiment started. During the study the VR equipment employed did not collect data such as eye-tracking or usage information. No data was collected for the study from the equipment.

Organization of the Study

The purpose of the study, as well as the research questions and significance, have already been presented to the reader. The next section, the Literature Review, offers relevant exploration of the U.S. Air Force's experience with VR, VR cognitive efficacy, and the airline industry's use of immersive technology as well as implication for self-efficacy. The review seeks to inform the reader of what VR is presently doing in aviation and the possibility it presents for the future. Following the Literature Review, the Methodology section orients the reader to the research questions and provides an explanation of the methodology design to answer those questions. The fourth section presents the findings of the study that was conducted from October 2021 through February 2022. Lastly, the fifth section provides a conclusion that holistically summarizes the study with recommendations for future research.

CHAPTER II

REVIEW OF THE LITERATURE

Introduction

The use of VR technology in MCC or airline type-rating training is unprecedented. Furthermore, research on the efficacy of VR in airline training has not been conducted. The U.S. Air Force is an early adopter of VR for its undergraduate pilot training and that was just initiated in 2018. Therefore, this literature review seeks to inform the reader of the most pertinent aspects of available research surrounding VR and aviation. Specifically, the review of literature is centered on the following three areas:

1. The review of the literature provides information on the use of VR in the USAF PTN test program.
2. The review of literature explores research into VR’s cognitive efficacy, its potential to improve learning outcomes, and its effects on self-efficacy.
3. The review of literature explores the aviation industry’s use of simulator technology to immerse the pilot in a realistic training environment.

USAF use of VR in Pilot Training

An examination of the USAF’s use of VR illuminates the potential for its incorporation into civil aviation training. According to Global Horizons (2013), a USAF strategic guidance document for research and procurement, the AF must understand how students learn to deepen that learning and achieve performance outcomes more rapidly. This strategy is critical to maintaining a ready military force while driving costs down. As part of this strategy, the USAF has adopted VR and leveraged it for years to better train its pilots. In 2018 it launched PTN as a testbed to develop innovative means to produce more pilots for less cost.

PTN is fundamentally based on the learning concepts from Dan Coyle’s *The Talent Code*. According to Coyle (2009), every human skill is transmitted by electrical impulses through the nervous system. By practicing particular skills, humans are able to increase the density of the myelin sheath that protects the neurological pathway the signals are transmitted through. The more effective the practice the more myelin is produced, and the skill is developed further. Coyle calls effective skill development “deep learning.” But deep learning is not all that is required to master an activity. Coyle argues that one must be sufficiently motivated. He calls the proper level of motivation “ignition.” Ignition is a profound passion for learning the skill that motivates a student to work tirelessly to master it. Lastly, Coyle argues that deep learning and ignition will only lead to skill mastery with effective coaching. Effective aviation coaching is possible when instructor pilots tailor their teaching to what each individual student needs, versus teaching to strict course objectives.

PTN has incorporated Coyle’s three components of deep learning, ignition, and coaching into their five guiding principles they refer to as pillars. PTN’s pillars continually evolve but include seamless and early access, immersive technology, student-centered learning, quality instruction, and human performance (Trudell, 2020). PTN leverages VR which touches on components of all five pillars. Specifically, they leverage VR to assist the students in deep learning. VR has also been found to increase motivation and enjoyment of the training objectives (D. Calkins, personal communication, 19 November 2020). Lastly, the USAF provides coaching during many of the students' VR training missions.

According to Tadjdeh (2020), PTN identified key components that enabled increased outcomes that reduced time in training and flight hours (which directly translates to reduced cost). PTN identified increased exposure to instruction during increased simulator hours and missions. PTN utilizes VR with very accurate visuals that allowed the student to efficiently transition to flying in the local area as they recognized ground references needed to navigate to, from, and around the airfield. PTN let individual student performance drive the student's timeline and graduation date. PTN's student management differed from legacy pilot training programs that grouped students together and kept them on the same schedule and with the same graduation date.

Additionally, PTN indicated positive outcomes for early access to curriculum and student-centric instruction. Before PTN, all students received the same instruction in terms of content and time. PTN identifies the right amount of instruction each student needs for optimal performance. When accomplishing various flying tasks, PTN weighs more difficult tasks such as flying an approach in bad weather to landing minimums manually over flying an approach on autopilot in good weather. A student that challenges himself with more difficult tasks in PTN and successfully accomplishes them is rewarded with less training. If a student accomplishes fewer or less challenging tasks, they will have to accomplish tasks it increases time to train. Lastly, PTN showed the importance of 24/7 access to training equipment. Students were able to train during periods simulators were unavailable due to the hour of the day, weekends, or capacity (Tadjdeh, 2020).

The lessons learned from PTN are now being incorporated into USAF pilot training syllabi. The USAF is currently fielding Pilot Training 2.5 which integrates VR into the T-6A syllabus (Trudell, 2019). Pilot Training 2.5 is how the USAF operationalizes the PTN experiment. PTN is conducted in a test environment whereas Pilot Training 2.5 will now be utilized to produce every pilot in the Air Force. Multiple Pilot Training 2.5 classes have been conducted and results are promising. Of note, the Pilot Training 2.5 classes are soloing in the T-6 ten flights sooner than those using legacy training methods. As PTN continues to innovate with new VR technology the USAF should continue to field updated training programs to their pilot training bases to capitalize on the benefits PTN brought to Pilot Training 2.5. The Air Force has signaled it will continue to evolve the Pilot Training X.X concept as they introduce Pilot Training 3.0 sometime in the near future (Tadjdeh, 2020).

If the USAF incorporates PTN as the model for all five of its pilot training bases it could potentially meet pilot manning requirements in as short as 30 months (Pope, 2019)[3]. As PTN replaces actual flying hours with low-cost VR it realizes substantial cost savings. According to Pope (2019), the combat pilot track (those pilots transitioning into fighters or bombers) could realize savings of over one million dollars per pilot. PTN has produced combat pilot graduates at a cost of $400,000 per pilot versus legacy training at $1.47M per pilot. The mobility pilot track

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[3] Note that the USAF must also factor in throughput concerns at the "b-courses" where recent pilot training graduates learn to fly their major weapons system (e.g., fighter, mobility, air-refueling, etc.). The USAF does have some future plans, such as *Reforge*, to expedite pilots through their b-courses as well.

(those pilots transitioning into cargo and personnel transport aircraft), via PTN, has been reduced from $979,000 to $410,000 per graduate. Most of the savings come from the cost of flying hours of the T-38C and T-1A. PTN graduates skipped these follow-on aircraft completely and went directly from initial training aircraft (T-6A) to their major weapons system (fighter, mobility, air-refueling, etc.) training. Currently, the T-38C costs $4,703 per hour to fly and the T-1A costs $2, 107 per hour to fly (United States Department of Defense, 2020). Additional savings come from fuel, maintenance personnel and equipment, instructor pilot cadre, and other personnel costs.

Legacy (no VR) Pilot Training:

Legacy USAF pilot training syllabi dictate rigid training protocols regardless of any skills a student may bring into training.[4] Previous flying experience or certifications are not leveraged to modify the syllabus requirements. For instance, if a student is already an instrument-rated private pilot, they will undergo the same amount of instrument focused ground school, simulator missions, and flights as a student who has no flying experience at all.

All students accomplish T-6A ground school for approximately one month. Simulators are then introduced and incorporated throughout the rest of the syllabus to introduce new concepts prior to live flying them in the aircraft. After the trainee has been taught normal and emergency procedures in the simulator, they begin flying training in an actual aircraft. The student will then fly a set number of sorties over approximately the next five months. Students can expect to fly between 47-56 sorties and 70.5-84 hours (United States Air Force, 2019a).

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[4] Note that the U.S. Navy primarily uses a proficiency-based system. It too, is introducing VR technology into its training.

Once a class of student pilots complete the T-6A program the students are all ranked by merit. In other words, the better the student's performance in T-6A training the higher they are placed on the order of merit. The top graduates are offered spots for the combat track. Students who elect the combat track will then fly a similar syllabus in the T-38C jet. Again, they will be rank ordered by merit. Top T-38C graduates generally go on to fighter aircraft assignments.[5] Lower merit ranking students will normally go on to bomber assignments. T-6A graduates who elect the mobility track go on to fly the T-1A aircraft in a similar syllabus to the T-6A. Once complete they will go on to fly mobility aircraft in the USAF. In all, the legacy pilot training syllabi dictate students will receive approximately 78 hours in the T-6A. They will receive an additional 77 sorties and 89 hours in the T-38C or T-1A depending on combat or mobility track (United States Air Force, 2019b). Pilot training takes approximately one year from start to graduation. No VR is incorporated in the legacy form of pilot training.

<u>PTN Differences from Legacy Pilot Training</u>:

Unlike legacy pilot training, PTN is competency-based, upon a student's progress toward proficiency versus a set number of events. VR equipment is provided to students at the beginning of training. Students accomplish set training missions in the VR and are monitored virtually by instructor pilots. Students can also use the VR in a free play mode. The VR includes a physical throttle and stick along with software with full three-dimensional (3D) maps of their pilot training base and local flying area. Additionally, students can interact with virtual FAA controllers in their headsets (Hunter, 2021). PTN found students spent many hours training in the VR equipment in addition to their required syllabus events. This allowed the students to progress

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[5] Note that some top T-6A graduates choose the mobility track. Similarly, some top T-38C graduates choose the bomber track.

through the syllabus rapidly by meeting benchmark objectives vice simply accomplishing an event a specified number of times.

In legacy pilot training, a student may have to accomplish eight formation flights before they are scheduled for a formation check-ride. In PTN if the student meets the benchmark after two flights, they can progress to the check-ride without incurring the cost of six additional flights. Individual student's VR systems link together so students can learn from one another and practice formation flying. PTN has also forgone sending its T-6A graduates to the T-1A or T-38C. After flying for approximately six to eight months in the T-6A the pilots undergo additional simulator missions then go directly into their primary combat or mobility aircraft training pipeline.

To date, PTN has graduated three classes of students that are titled version one, two, and three. All three classes met or exceeded USAF pilot training graduation standards. PTN graduates have gone on to successful follow-on combat and mobility track training programs. Ultimately the USAF intends to incorporate PTN lessons into its standard pilot training syllabi. Figure One shows a comparison of PTN version one and two students, a projection of version three students, and their performance at their follow-on training for their major weapons system aircraft. The figure clearly indicates that PTN graduates met or exceeded standards in their follow-on training. It is critical to note that PTN is ambitious and progressed very quickly to provide maximum value and information for the Air Force to apply to pilot training. However, not all data was collected and therefore it is difficult to do a full analysis of PTN efficacy.

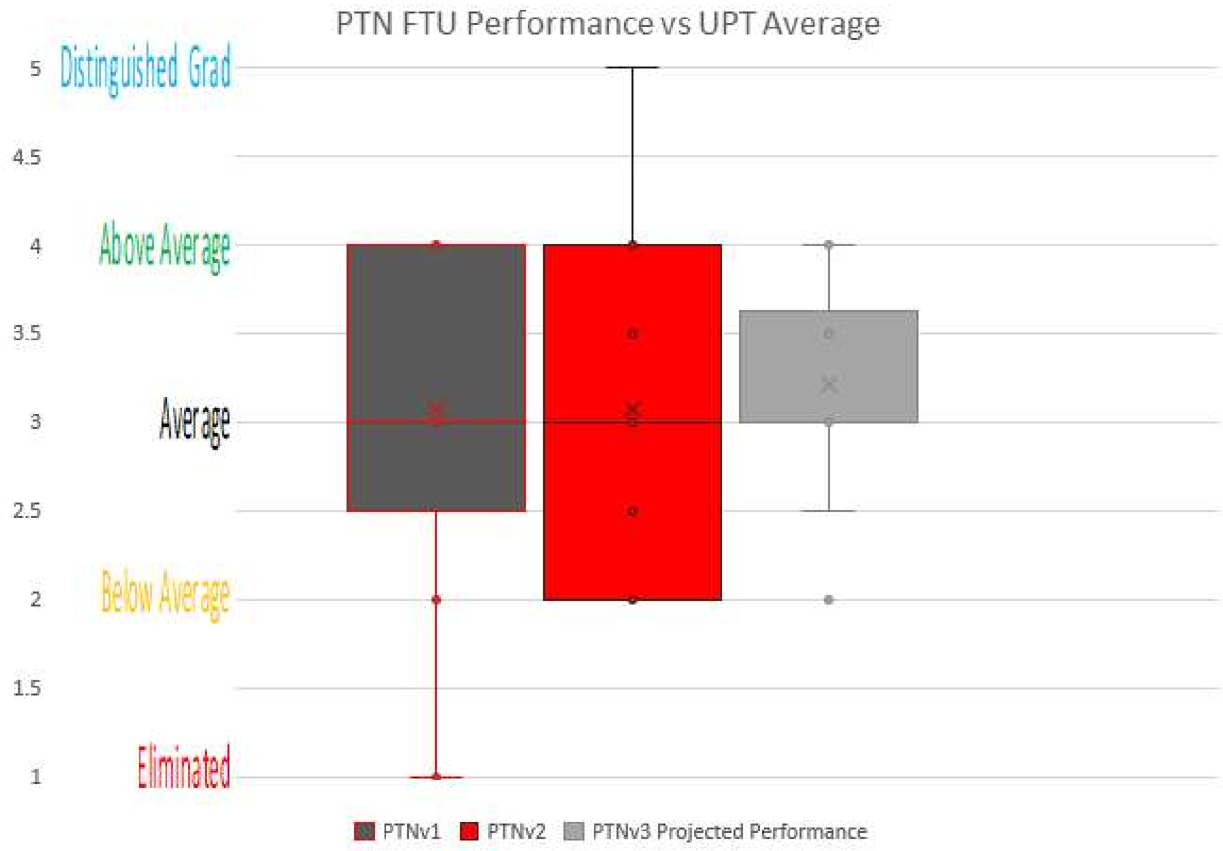

Figure 1: *PTN versus traditional UPT averages (Pope, 2019)*

In addition to the PTN experiment, there are other experiences within military aviation that point to the efficacy of immersive technology. For example, a USAF helicopter training squadron incorporated VR into a recent class. Pilots were able to qualify on the UH-1N Huey, HH-60G Pave Hawk, and the CV-22 Osprey in 20 percent less time than previous classes (Bolinger, 2019).

The USAF's experience with adding VR into syllabi and reducing flight time is bolstered by research conducted by Holden. Holden (2016) summates, "scientific literature has demonstrated the use of proficiency-based training over fidelity training" (p. 259). Further, he states, "The adoption of new training strategies based on training proficiencies using the VR training environments combined with reduced real-world flight training would yield more effective training than using present training strategies based on the number of flight hours (both in simulator and aircraft)” (p. 259). This assertion is based on the ability to maximize challenges in the VR environment versus what is possible in an actual aircraft (i.e., bad weather and emergency situations).

Holden’s argument is that there is an over focus of hours spent in the aircraft and simulator than the quality of those hours. He contends there is more value in access to challenging scenarios in VR environments versus continual investment in higher fidelity simulators or more flight hours. PTN and other programs have shown that the current VR training environment is sufficiently realistic. High cost, limited availability of simulators, and flying missions are less impactful than they were in previous syllabi. Holden (2016) concludes that programs should leverage low-cost VR to reduce their dependency on high-cost simulation or flying missions.

While testifying before the House Armed Services readiness subcommittee in March 2021, the Vice Chief of Staff of the U.S. Air Force, Gen David Allvin noted the ability of VR to tailor training specifically to individual student needs, the ability for students to work asynchronously and the resultant reduction in training timeline (Cohen, 2021). The USAF’s innovative use of VR has the potential to save it hundreds of millions of dollars and solve its pilot crisis. The same efficiencies the USAF is discovering might be possible for the airline industry as well. Next is a review of how VR may improve learning outcomes.

Virtual Reality Cognitive Efficacy

Virtual Reality has been shown to increase cognition. Miran (2014) indicates that technology allows humans to move up a learning continuum more effectively from simple knowledge to actual comprehension and a useable understanding. An ancient anonymous Chinese proverb helps illuminate the concept, “tell me and I’ll forget, show me and I may remember, involve me and I’ll understand.” VR allows users to understand learning objectives through interaction with the system. Users are embodied in the environment they are attempting to learn and understand, versus simply reading or hearing the information.

Pilot Training Next has proven the benefits of VR in aviation. However, VR learning is not limited to aviation modalities. Papanikolaou (2019) states that teaching hospitals need to adopt VR simulation technology to increase efficiency, reduce costs, and improve patient safety. VR technology supports many aspects of the health industry such as dentistry, laparoscopic surgery, and investigating cellular compartments of neural tissue (Khunger, 2016). Darger (2015) posits the future of surgical training is immersive VR. According to Rasmussen’s model of human behavior, a surgeon’s errors could be based on rule, skill, or knowledge based. Due to risks to human patients, surgeons in training must learn their skills on animals, cadavers, box trainers, simulations, or VR. Darger (2015) states VR is the only practical training medium that can affect all aspects of Rasmussen’s model of human behaviors. These behavior changes facilitate learning and are not limited to surgery or aviation.

In addition to being an effective learning platform, VR technology is advancing quickly (Li, 2019). Test systems can track where users are looking, determine facial expressions, and detect emotions. The purpose of these capabilities is to make VR as realistic as possible.

Additionally, by tracking where users' eyes are looking the software can tailor the experience to aid faster learning or provide feedback to the user.

VR is not without some safety considerations. Markiewicz (2019) summarizes many of the current industry concerns. Manufacturers of VR headsets suggest children under the age of 13 do not use the systems. Some users experience symptoms like motion sickness, most likely based on latency in the system. Latency is noticed when a user moves their eyes or head quickly and the software cannot update the environment fast enough to build the new "picture." People with pre-existing health considerations are also warned to consult their health care providers prior to using the sets. Lastly, users could experience more lasting effects due to fear, surprise, or anxiety. Unlike a movie that may produce similar reactions, VR is immersive and could produce negative emotional conditions that are longer lasting than other technologies. Pilots in type-rating training make ideal VR users. They are adults that must pass a FAA required medical examination. Additionally, they are accustomed to an immersive environment based on previous simulator training.

VR combines learning modalities according to Pagano, Haddad, and Crosby (2017). The current U.S. education system is designed on the industrial education model. This is the required Kindergarten through 12th-grade education system adopted by the U.S. since the late 1800s. In this model, most learning is lectured and provided in textbooks. Before the adoption of the industrial education model, most youths were educated with the apprenticeship and journeyman model (Perrin, 2017). Young people would become apprentices for craftsmen and learn the trade or skill over years. They would learn from *watching and doing*, not from textbooks or lectures. VR allows the apprenticeship model to be overlaid over the industrial education model (F. Maguire, personal communication, November 17, 2020). In other words, VR training allows users to conduct (*do*) tasks they have learned initially from texts or lectures. Being able to *do* tasks in VR is linked to high rates of user acceptability and allows real-time feedback and more effectiveness than classroom training alone (Pagano, 2017).

Curtin University in Perth, Australia ran a VR experiment with 145 of their physiotherapy students (Stefanic, 2016). The simulation allowed students to visit nominal patients in their homes to assess risk from falls. Student feedback from the experiment was overwhelmingly positive. Of the students, 88 percent stated the simulation was more effective than reading about the subject and nearly as good as an actual site visit. Further, 100 percent of students said they enjoyed the experience. Lastly, 92 percent of students stated they wanted previous exercises replaced with the VR simulation. Stefanic's research not only indicates the efficacy of VR platforms but also the *acceptability* of users. Acceptability with VR learning may manifest in higher user enjoyment.

Research by Pantelidis (2009) found that VR was highly motivating and allowed for new perspectives. Students were challenged with and interested in interacting with a 3D environment and the ability to create within it. Previous research by Mikropoulos, Chalkidis, Katsikis, and Emvalotis (1998) indicated participants had positive attitudes about using VR in the learning environment (Pantelidis, 2009). Much like Stefanic's findings, Pantelidis found users enjoyed the experience of learning in VR.

Research conducted by Makransky, Borre-Gude, and Mayer (2018) compared lab safety training taught by text, desktop VR (i.e., a computer program user can interact with it much like a videogame), and VR to 105 students. Results showed similar motivational benefits of VR. Retention of new material was equivalent for all three modalities. Two skill transfer tests were measured where students took skills they learned from one of the modalities and applied them to new problems. The immersive VR modality indicated a greater understanding of the skill and how to apply it. Similarly, research by Ryan and Poole (2019) indicated "increased student satisfaction, engagement, and recall" using VR versus traditional teaching methods (p. 414). Of note, this type of VR utilizing 45-90 degrees in a standard desktop monitor setup is less immersive than wearing a headset that allows students to view 360 degrees. In other words, Makransky, Borre-Gude, and Mayer (2018) indicated the benefits of VR even without full immersion.

Pagano, Haddad, and Crosby (2017) argue the three-dimension environment produces a deeper "creation of memory" that stokes the user's sense of curiosity and enjoyment in learning. The ability to learn from the first-person point of view and see parts of your body (i.e., avatar body) produces an unconscious heightened sense of being immersed in the environment. The environment keeps the user motivated while imprinting memories for better retention. Research by Parmar (2017) indicated that VR is "greatly effective in knowledge acquisition and retention, and highly enhances user satisfaction, interest, and enthusiasm. Users experience high levels of present and are profoundly engaged in the learning activities within the immersive virtual environments" (p. ii). In addition to motivation and retention, VR has been shown to be effective at skill transfer.

Marquardson (2019) recently conducted a research project to determine if skills learned in VR could be transferred to the physical world by computer networking students. Results indicated that students did transfer many of the new skills they learned with VR. The students' perceptions of the quality and reality of the VR environment were critical to the transferable knowledge they gained. In other words, if the user perceives the virtual world as accurate, they will transfer more skills. Likewise, if they perceive the environment as unrepresentative of the physical world, they will transfer fewer skills. Additionally, access to an instructor to bridge gaps in the software-enabled increased skill transfers for the students.

Marquardson's findings support PTN's use of instructors to assist students with how best to use VR and to correct student mistakes. Similarly, his findings support Coyle's third tenant of "expert coaching" from The Talent Code (2009). Skill transfer is critical for VR to be effective. If students can learn using relatively inexpensive VR, then *transfer those skills* to a Full Flight Simulator (FFS) and aircraft, VR will reduce the cost of training. Typical type-rating programs include approximately 19 separate FSTD missions totaling 76 hours (see Appendix B). If VR can replace some expensive FSTD missions airlines could realize significant savings.

Pagano, Parmer, and Marquardson's research reinforce Coyle's (2009) argument that high skill ability is achieved by deep learning, ignition (i.e., motivation), and coaching. VR is shown to provide an environment for deep learning. The VR experience is enjoyable and therefore motivates users to continue using it to learn. Lastly, with effective instructor coaching, students can achieve a higher level of skill achievement. Coyle's argument appears validated by this research and the PTN outcomes. VR does have aspects that specifically benefit aviation-related tasks.

VR components of telepresence and interactivity show positive effects on pilot situational awareness (Ommerli, 2019). Telepresence is the user's feeling of physically being present in the virtual environment. Interactivity is the user's sense of agency within the environment. The nature of VR shows positive outcomes for situational awareness, which is a basic, but critical, aviation skill. Situational awareness is a pilot's understanding of the environment in which one is operating and the conditions of one’s performance and control within the environment. Effective situational awareness is critical to flight safety in reducing the loss of control and pilot error.

Self-Efficacy

Research has shown the relationship between high self-efficacy and high motivation. The concept of self-efficacy, and its effect on outcomes was pioneered by Bandura. Bandura (1977) stated that self-efficacy is critical to outcomes from changed behavior. A person may understand that certain behaviors lead to certain outcomes. For instance, if one stops smoking the outcome expectation is that their lungs will be healthier, and they will live a longer life.

However, successful outcomes are more complex than simply performing a behavior. Bandura (1977) states that “efficacy expectation is the conviction that one can successfully execute the behavior required to produce the outcomes” (p. 193). In other words, a smoker may have the outcome expectation that smoking cessation will improve their health, but they may not have the confidence to stop smoking. High self-efficacy would indicate someone who has confidence they can execute the behavior, whereas low self-efficacy indicated low confidence in the specific behavior. Bandura (1977) further explains that self-efficacy is “limited to specific domains, such as flying skills, and does not infer certain personality characteristics or global traits” (p. 204). Numerous studies have shown self-efficacy to have significant impact on motivation and learning outcomes across myriad modalities. One such study was conducted by Strecher, Mcevoy Devellis, Becker, and Rosenstock in 1986.

Strecher, Mcevoy Devellis, Becker, and Rosenstock (1986) state that “self-efficacy affects people’s choices of behavioral settings, the amount of effort they expend on a task, and the length of time they will persist in the face of obstacles” (p. 75). Self-efficacy also affects emotional reactions and thought patterns. For instance, if one has low self-efficacy, they may focus time on their distress following a failure, rather than spend that time on behaviors that produce positive outcomes. A 2018 study by Buttusi and Chitarro indicated the link between VR immersion and increased self-efficacy.

Buttusi and Chittarro tested self-efficacy using three different VR setups and an aircraft safety evacuation simulation (2018). Their results showed that regardless of field of regard and fidelity, participants' self-efficacy in their ability to deal with an emergency evacuation increased after training. Similarly, Shu, Huang, Chang, and Chen (2019), had comparable results with HMD VR participants versus desktop VR participants in earthquake preparedness training. This study adopted a single-group repeated measure design where the participants used both desktop and HMD VR. Compared with the control group, the VR participants indicated significantly more self-efficacy on posttest surveys. Another experiment was conducted by Makransky, Borre-Gude, and Mayer in 2019 and indicated similar linkages between VR and high self-efficacy.

Makransky, Borre-Gude, and Mayer (2019) conducted an experiment comparing laboratory safety training taught using a manual, desktop VR, and immersive VR. The students in the immersive VR group showed significantly more positive changes in self-efficacy from pretest to posttest than the manual group. Similarly, Ledger and Fischetti (2019) provided initial teacher education (ITE) supported by VR called "Micro-teaching 2.0". Pre-service teachers (PST) traditionally use multiple methods to learn how to be effective teachers in the classroom. Generally, the learning is conducted through situated learning and reflective practice. The study used immersive VR to assist the PSTs through situated learning simulations. The study indicated significant gains in self-efficacy by the PSTs in their confidence to teach students between pre-surveys and post-surveys.

The available research on VR indicates it contributes to high efficacy—much like classic aviation simulators—for increased retention, skill development, skill transfer, motivation, and self-efficacy when compared to classic educational modalities. High self-efficacy, using VR, could lead to higher motivation and increased learning outcomes. Both motivation and better learning would be beneficial for MCC students and aid them in successfully accomplishing an airline-type rating program.

The key advantage of VR is that it is always available to the user and at a much lower cost than simulators (Science, 2020). Research results indicate VR's high efficacy. These research findings have been validated by the PTN experience through reduced training timelines and cost savings. Although civil aviation is lagging the USAF on VR adoption the industry is familiar with immersive technology. Next is a review of the use of immersion technology in civil aviation.

Civil Aviation Industry Use of Immersion Technology

Currently, VR use in the civil aviation industry is limited. However, some early adopters are using it to teach skills in entry level aircraft as well as more sophisticated and larger airline aircraft. The following section of the literature review will guide the reader through the structure of the MCC course, airline type-rating training as well the use of immersive technology in the civil aviation industry.

The MCC course was introduced by EASA in 2018 to better prepare pilots for airline type-rating training. Specifically, the training focuses transitioning one from flying as a single pilot to working as a crew. The objective of MCC is to develop the technical skills, attitude, and knowledge required to fly airline aircraft to include swept-wing training and airline operational training, prior to entering airline type-rating training (VA, 2021). The MCC course used in this study focuses its training on twelve key competencies: motivation and professional attitude, situational awareness, problem solving and decision making, leadership and teamwork, workload management, effective communication, knowledge and application of procedures, aircraft management (manual control), aircraft management (automation), briefings, pilot monitoring, and energy management. See Appendix A for a list of key competency behaviors.

An MCC course is approximately three weeks long. Students spend time in ground school learning fundamentals of crew coordination. Following ground school, students transition to a simulator (synthetic flight training or SFT) for approximately ten missions to complete the course. Following successful MCC course completion, students earn a certificate and matriculate to airline type-rating training.

Major airline syllabi for entry-level narrow-body aircraft – such as the Boeing 737 and Airbus 320 – rely on proven methods for training. A pilot can expect to learn aircraft systems with a combination of a paper cockpit diagrams and training modules hosted on a digital tablet. After passing the systems tests pilots enter a simulator phase to become oriented to the cockpit and learn both normal procedures and non-normal procedures (i.e., emergency procedures). The training culminates with an FAA certified practical (i.e., the check flight) in a full flight simulator (see Appendix B for an example airline type-rating program). After the practical, the pilot serves as a first officer for the airline in an actual aircraft. It is important to note that the FAA does not dictate events included in the type-rating syllabi. The FAA only requires that the practical be accomplished in an FAA-certified FFS or the actual type aircraft.

According to Allerton (2010) simulation has been a key part of pilot training since World War II. It is accepted by operators, regulators, and unions. Multiple types of simulators support a full range of requirements. Civil and military aviation host multiple simulation capabilities to meet the needs of the various phases of training each community requires. Aviation organizations employ a range of simulations, from simple tabletop software simulation applications to flight training devices that are partial cockpits with limited forward outside visuals, up to the full flight simulator (FFS) that are equipped with a full wrap-around cockpit, and complex hydraulics that allow full motion capability. The military utilizes simulators that include advanced 360-degree visuals and the ability to connect multiple simulators for formation and tactical training. For some training missions, simulators are more effective than the actual aircraft.

A RAND Corporation study conducted by Marken (2007) highlighted that pilots can become more experienced by complex simulator missions versus flying the aircraft. Marken interviewed a multitude of military pilots and asked them what was more helpful in creating a high quality and experienced pilot: more flying sorties, more simulators, or a mix of the two. The outcome was that pilots felt challenging simulator scenarios were more helpful at building experience than simpler flying sorties. The instructors could create challenging scenarios in the simulator that are too expensive or difficult to reproduce in flying sorties. Immersive environments allow the pilot to be exposed to very realistic and challenging scenarios. Many of these scenarios cannot be reproduced in the actual aircraft due to safety concerns. For example, extreme weather and complex system failures can be exposed to the pilot in the simulator in a safe manner.

Simulators have proven to be effective in the aviation industry, but aviation-related VR is a growth market. According to Markets and Markets (2019), the aviation VR industry will grow from the current market worth $78M to over $1.3B by 2025 based on advancements in hardware and software, and adoption by the military and commercial sectors. According to Newman (2018), VR technology is advancing fast due to the large amount of gaming software companies that support the various VR hardware systems. Juxtapose that with expensive, purpose-built simulators that only have utility for aviation purposes. VR technology should continue to advance much faster than progress seen in the simulator industry. Current issues for some systems, such as latency, are continually improving until it will no longer be an issue. In addition to being capable, VR is an acceptable modality for training.

Fussell (2020) uses a technology acceptance model to indicate that aviation students are more likely to use VR if it is incorporated effectively into the training program. In other words, if VR is simply additive, but not required, students may be less likely to use it. Likewise, if VR is actively supported by developers and educators, students are more likely to utilize the VR. In other words, for VR to be most effective, it should be fully incorporated in course syllabi versus simply allowing its use in addition to syllabus requirements. In addition to VR incorporation into syllabi, training can be conducted that is not possible in a simulator or with an actual aircraft.

For example, Embry-Riddle Aeronautical University (Pinholster, 2019) has been utilizing VR to conduct training that previously required an instructor. The university now can use VR to do a “walk-around” of an aircraft on a ramp. Previously, this was only possible to do in person with an instructor. If the aircraft was free of any defective maintenance issues, the instructor had to pose a series of questions like “what if you found an issue with X system?” Often there are no issues with the aircraft. Simulators are unable to replicate the training environment as they are built for “in-cockpit” immersion versus “out-of-cockpit.” In this example VR can introduce abnormalities a student must be prepared to find on their preflight inspection walk-around. The student can meet the training objective without the need for an instructor during the training.

This case highlights the training benefits of VR in difficult to replicate conditions. An additional benefit is that students can train to syllabus requirements on tasks that previously required an instructor thereby saving instructor time and student costs.

Similar to the PTN program, Embry-Riddle is realizing a 30 percent reduction in flight time required for solo flights in its general aviation program (Pinholster, 2022). The school also noted lower anxiety and greater confidence due to the extra hours using VR to prepare for actual flying sorties. Embry-Riddle Flight Training Manager, Nicole Hester, stated that students who employed VR finished the program in less time overall time as well (Pinholster, 2022). Embry-Riddle's new program requires students to spend the first four weeks with VR to learn preflight, checklist, and flight procedures prior to interacting with flight instructors or simulators.

The Western Michigan Aviation College has had similar success to Embry-Riddle and has integrated VR into their curriculum (Brown, 2019). They ascertain the ability of VR, augmented reality (AR), and mixed reality (MR) to develop muscle memory will lead to increased retention (Brown, 2018). The school embraces this technology as a low cost but effective training tool. The technology allows for larger classes sizes and greater access to improved education. Brown also indicates that over her 16-year career she has seen gaps in equipment and training that VR is able to fill. Both Western Michigan and Embry-Riddle cases highlight the benefits of VR.

Dorr (2000) describes the state of current airline simulation compared with VR. Industry accepted FSTDs require actual instrumentation, system layout, and complex environmental visuals. Most FSTDs are expensive, heavy, large, difficult to move, require technicians, and are specific to only one type of aircraft. Much like an aircraft they require calibration and maintenance. Generally, airlines rely on other companies to supply simulators. Dorr states that for VR to effectively mimic a simulator, certain specifications need to be met. Latency of up to 150 milliseconds (ms) is acceptable for orientation tasks, such as routine cockpit operations (flows). Advanced tasks, such as flying the aircraft require less than 80ms of latency. The field of view (FOV) should be greater than 56 degrees. Dorr was unable to test greater than 56 degree FOV but determined that 56 degrees was insufficient for cockpit orientation tasks. Resolution is also important. Specifically, an HMD resolution of 1280x1024 pixels is sufficient to view and interact with displays of eight inches or greater at a range of 33.5 inches, which is representative of actual flight-decks.

The test HMD exceeds all of Dorr's required parameters. It has latency rates below 150ms, a FOV of 101 degrees, and resolution 2048x2160 (Pico, 2020). Additionally, it utilizes Tobii eye-tracking technology not available during Dorr's test. The technology allows for high fidelity visuals directly where the user's eyes are focused. It blurs visuals in the periphery to allow the most realistic visuals centered on the eyes' foveae (Pico, 2020). Despite this capability, there are no FAA regulations that dictate required VR capability for certification as an FSTD.

Currently, FAA regulations (Department of Transportation, 2019), specifically Part 141, 142, 121, 135, and FAA-S-CS-11 (Airline Transport Pilot and Type Rating for Airplane, Airman Certification Standards) do not mention VR. Therefore, VR cannot be used in any training programs for credit as a simulator. For instance, currently, one cannot use VR to update a currency requirement, such as a night landing, that the FAA may allow in an FFS. VR is considered Computer Based Training (CBT).

Recently Lauren Basham (2020), an Aviation Safety Inspector in the FAA's General Aviation and Commercial Division's Certification Branch, AFS-840, published an article on VR. She works in the office which is responsible for regulatory and policy guidance for aviation training devices, CBT aviation devices, and evaluation and approval of new and emerging simulation technology. Basham (2020) argued that VR had the potential to be the "ultimate tool in the learning process" and that the industry must continue to advance the capability (p. 1). Not only may VR prove a valuable learning tool, but PTN has also shown it can drive training costs down.

Cost is a major component of aviation training. Airline type-rating training and certification is completely conducted in simulators based on the high cost of flying a large aircraft, such as the B737 or A320. Simulators offer a more affordable training option. Additionally, simulators allow you to safely conduct extreme weather operations and dangerous non-normal procedures as opposed to an actual aircraft. A Basic ATD with five screens, and under a 180-degree side-to-side environment (field of regard) costs about $23,000 (Elite, 2020). More sophisticated Advanced ATDs cost considerably more and range from $60,000 to hundreds of thousands of dollars (Redbird, 2020). Levels six and seven Flight Training Devices (FTDs) can cost up to $2.5M (Industry Arc, 2020). Level D, FFS devices can cost more than $10M (Parsons, 2019). All systems require technicians and large air-conditioned and humidity-controlled facilities. These requirements drive high fixed sustainment costs, in addition to the simulator procurement costs.

Juxtapose traditional simulator costs with a virtual reality setup which can cost under five hundred dollars (Greenwald, 2020). The Pico HMD utilized in this research project costs around $900 (Pico, 2020). The VR equipment is "untethered" which means the student can use it anywhere, or at any time, they want to train. Software updates can be uploaded automatically over Wi-Fi if required. Should the headset get damaged it can be replaced quickly through the mail.

VR can help the airline industry whether it remains a CBT tool or if it is certified as an BATD, AATD, or FTD. However, if the FAA authorizes it as a BATD or AATD, it could count towards *current* airline syllabi requirements that require technicians and/or instructor pilots. As an ATD the airlines could realize major savings on simulator requirements. As the technology matures it could be upgraded to an FTD which would further the airline industries' savings.

Alternatively, current airline syllabi could be replaced by competency-based curricula. VR could still be introduced as CBT. As a pilot progresses through training, the practical could be accomplished in the FFS when the pilot is ready. A set number of simulators would not be required. Again, based on the PTN experience pilots would most likely advance to the practical having undergone fewer simulator missions. The result would be course completion in less time, and at significantly less cost. This is similar to the proficiency-based progression model versus syllabus requirement model that PTN uses.

CHAPTER III

METHODOLOGY

Research Design

The research project used a mixed method with a nonrandomized control experimental design. Quantitative data was collected and analyzed primarily to answer the first three research questions.

1. Can VR increase the average Synthetic Flight Training session scores in an MCC course?
2. Can VR increase scores on the MCC course key competencies of situational awareness, workload management, knowledge and procedures, aircraft management (manual control), and aircraft management (automation)?
3. Can VR increase the score of the MCC course Final Assessment?

Qualitative data using a phenomenological framework answer the last two research questions.

4. Does VR increase the quality of training experienced by the students in a typical MCC course?

5. Can VR increase self-efficacy in flying related skills and airline aviation training programs?

For the purpose of this study, quality is defined from the student's perspective using a phenomenological approach. Patton (2015) articulates that phenomenology is interested in understanding the experiences of a person in the present. Phenomenology requires a deep understanding of the participants as it seeks to "make sense of experience and transform experience into consciousness, both individually and as shared meaning" (Patton, 2015, p.115). VR is an immersive technology that creates an environment for a user to interact and experience. A more complete understanding of this experience is why a phenomenological framework is appropriate for the study in addition to quantitative data analysis. Quality will be determined by the student's sense of motivation, enjoyment, efficiency, and effectiveness of the training.

The study uses an applied research typology. This typology's purpose is to "understand the nature and source of human or societal problems" (Patton, 2015, p. 250). By answering the research questions information was gathered that could directly improve airline preparatory training. More efficient training may help in the impending pilot shortage. This will be helpful in meeting demand for affordable airline travel. As the VR is focused on B737 cockpit-oriented ground operations, the results are specific to aviation training. The data can also inform the airline and VR industry on the efficacy of utilizing VR in MCC training and possibly type-rating training.

Control group participants were students who consented to the research project and were undergoing MCC training at a specific ATO in the UK with one class of seven in October 2021, and two classes in November 2021 of seven and eight students respectively (22 students total). Of the 22 students seven chose to participate in this research project. The control group participants did not employ any VR technology during their training (per the consent form in Appendix C, control group participants refrained from using personal VR as well).

The three experimental classes immediately followed the control group and underwent the same syllabus in the same ATO (January through February 2022) and employed VR. Specifically, the first class had four students, the second class had three students, and the last class had two students (nine students total). Of the nine students five consented to participate in the research project. It would be ideal to have control and experimental students in the same class and randomize experimental and control students. However, there was no practical way for the study to ensure the VR was not shared within the classes between control and experimental students. Additionally, the ATO was concerned students who did not have access to VR would think their classmates that were using VR had an advantage. Therefore, control group classes and experimental group classes were required. All classes underwent the same syllabus.

To increase the amount of data available for analysis the ATO provided archival data from recent classes that executed the same syllabus and training conditions from June through February 2022. The archival data included all 39 students SFT scores and retraining events. Therefore, all the classes incorporated were from June 2021 – February 2022 and totaled 51 students. The data collected encompassing over 7,600 data points and represents the total population during the period of the study (see List 1).

List 1
Data for Research

Data Source	**Period**	**Total Students**	**Used VR**	**No VR**
Archival Data	Jun 2021 – Feb 2022	39	10	29
Data Source	**Period**	**Total Students**	**Used VR**	**No VR**
Experiment Participants	Oct 2021 – Feb 2022	12	5	7
Total	Jun 2021 – Feb 2022	51	15	36

As discussed in chapter one the MCC course is a three-week course that is required by the UK CAA and EASA prior to flying multi-crew aircraft. The first week is ground school that prepares the students for the following two weeks of simulator training where they become familiar with B747 or A320 tasks while operating as a crew (see Appendix D for a sample MCC program). The two-week simulator phase includes ten SFTs and culminates in SFT #10, the Final Assessment. Successful completion of all SFTs is required to complete the MCC course.

Students are evaluated on 12 key competencies on the ten SFTs as indicated in List 2. Research question #2 focuses on five of the 12 key competencies where VR is most pertinent: Situational Awareness (SA), Workload Management (WM), Knowledge and Procedures, (KAP) Aircraft Management – Manual Control (AMMC), and Aircraft Management – Automation (AMA). Of note, at this time the VR software is not programed specifically to address the other seven competencies of Motivation and Professional Attitude (MPA), Problem Solving and Decision Making (PSDM), Leadership and Teamwork (LT), Briefing (B), Effective Communication (EC), Pilot Monitoring (PM), and Energy Management (EM) and therefore they were not analyzed. See Appendix A for a detailed description of each of the key competencies.

List 2
MCC Course Key Competencies

Motivation and Professional Attitude (MPA)
Situational Awareness (SA)
Problem Solving and Decision Making (PSDM)
Leadership and Teamwork (LT)
Workload Management (WM)
Effective Communication (EC)
Knowledge and Application of Procedures (KAP)
Aircraft Management, Manual Control (AMMC)
Aircraft Management, Automation (AMA)
Briefings (B)
Pilot Monitoring (PM)
Energy Management (EM)

The 12 key competencies are scored on each of the ten SFTs using a grading scale from one to five (see List 3). Scores of "1-4" are passing scores, and a score of "5" is unsatisfactory. A student must have a "4" or better on each of the 12 key competencies on SFT #10 (Final Assessment) to complete the MCC Course.

List 3
MCC Course Competency Standards

Grade		Competency Standard
1	Exemplary	The trainee's performance in this competency was exemplary with an outstanding effect on safety. The pilot always demonstrated all of the relevant performance indicators in this competency to an exemplary standard

2	Very Good	The trainee’s performance in this competency was very effective, which significantly enhanced safety. The pilot regularly demonstrated most of the relevant performance indicators in this competency to a very good standard
3	Good	The trainee’s performance in this competency was effective with a significant contribution to safety. The pilot consistently demonstrated most of the relevant performance indicators in this competency to a good standard
4	Satisfactory	The trainee’s performance in this competency was satisfactory with a slightly positive effect on safety. The pilot demonstrated most of the relevant performance indicators in this competency to at least a satisfactory standard
5	Unsatisfactory	The trainee’s performance in this competency was unsatisfactory with a negative effect on safety. The pilot did not demonstrate the majority of the relevant performance indicators

The experimental group classes were furnished with VR technology on the first day of MCC formal training. They maintained possession of the equipment until successful completion of the syllabus, at which point the VR equipment was returned to the company. The VR equipment was composed of a Pico Neo 2 Eye HMD and two hand-held controllers (See Appendix F for equipment specifics). Participants were provided with additional charging equipment and instructions. The company provided a tech support phone number to call in case of issues with the equipment. The equipment was provided on the first day of class for all experimental classes. The students returned the equipment back after completion of the syllabus. In the future the VR company intends to provide the VR equipment to students two weeks before the program and then returned when the student does not wish to keep using it.

Population and Participants

This study uses a complete target population strategy for quantitative data. Although the control and experimental groups that filled out surveys did provide some quantitative data the classes were too small to determine any significance in the findings. This experiment requires a sample size of 30 or more to meet the conditions of the Central Limit Theorem (LaMorte, 2016). The Theorem requires the researcher to assume the population will be normal versus skewed to determine if a reduction in sample size is possible. As this is the first introduction of VR into the MCC course no valid assumption can be made on the distribution. As the experiment would encompass 31 total students it was highly unlikely 30 would agree to participate to ensure a minimum sample size. Therefore, the decision was to not quantitatively analyze the survey data for significance although some data is presented in Chapter Four.

Participants are defined as students in the MCC classes who choose to participate in the study. All participants except for one completed the MCC course as it is required by the UK prior to being hired by a major airline. Additionally, following the MCC course the students will have to complete type-rating training and be hired by an airline. One of the participants has already been hired by an airborne surveillance company that is based in the UK.

Student participants were notified by the ATO of the project on the first day of training, and participants signed the consent form and filled out the pre-survey in the first week of training. Students were informed of their rights to not participate on the first day of class. All students who wished to participate were emailed a link to the consent form in Appendix C. Students were required to read the consent form, digitally sign, and send back to the study's researcher to participate. The study's researcher electronically maintained the documents.

Procedures

All experimental participants were allowed to utilize the VR however much they wanted and at any time during the training. All members of the experimental group, regardless of whether they choose to participate in the study, were provided VR equipment. Survey data and interviews were not conducted for students that did not consent. All experimental group participants used the VR equipment for at least one occasion during the training (this requirement is listed in the Consent Form in Appendix C and verified on the experimental post-survey Appendix G).

Unique links to the pre-survey were emailed to the participants the first day of their course (see Appendix H for pre-survey). The post-survey was emailed to the students the day after the Final Assessment, SFT #10 (see Appendix G for experimental post survey, Appendix I for the control post survey, and Appendix D for an example MCC course syllabus and timeline). Students had one week to complete the survey to ensure answers were as accurate as possible. Surveys were administered using the Alchemer survey software. Interviews were conducted for all of five of the experimental participants by the researcher over the Zoom video teleconference application (See Appendix J).

Instruments

The study collected the following data:

1. Self-efficacy: This data came from the pre-survey and post survey and interviews.
2. All syllabus-required scores: Each of the ten SFT exercises produced a score culminating in the Final Assessment (SFT Exercise #10).
3. The number of SFT retraining events for each participant: This data came from the ATO gradebook.
4. The quality of training experience of experimental participants was measured through the post survey (Questions #10 and #11 on the experimental post survey, Appendix G).

5. Qualitative interview of experimental participants (Appendix J). The interview was primarily conducted to capture the quality of the training. The quality data captured by the interview was qualitatively analyzed.

The VR equipment provided should have the greatest impact on systems and ground operations knowledge. The survey is specifically designed to collect data on the experience of the user in the training program where systems and ground knowledge has the most impact.

Research Questions

The research questions being explored in this study include:

1. Can VR increase the average Synthetic Flight Training session scores in an MCC course?
2. Can VR increase scores on the MCC course key competencies of situational awareness, workload management, knowledge and procedures, aircraft management (manual control) and aircraft management (automation)?
3. Can VR increase the score of the MCC course Final Assessment?
4. Does VR increase the quality of training experienced by the students in a typical MCC course?
5. Can VR increase self-efficacy in flying related skills and airline aviation training programs?

Quantitative Data Analysis

Quantitative data was used to answer the first three questions. Test scores for the control and experimental groups was compared using an independent t-test. Analysis was conducted using the Statistical Package for the Social Sciences (SPSSv24) tool. The single variable is VR use. The control group did not use VR and the experimental group did use VR.

Qualitative Data Analysis

Qualitative data was used primarily to answer the fourth and fifth research questions. The open-ended interview questions referenced the quality of the experience. Data obtained from the interviews was analyzed for patterns. Quality factors included motivation, enjoyment, efficiency, and effectiveness of the training. Other questions included in the interview sought to understand the participant's self-efficacy after using VR. Lastly, the interview sought to understand what future utility the participant believes VR could have in type-rating training.

Ethical Assurances

The research study was conducted based on Institutional Review Board (IRB) approval (Appendix K). The researcher obtained the approval, IRB approval number IRB-21-37, prior to any research involving human subjects was conducted. Informed consent for all participants was obtained using the Consent Form in Appendix C through the Alchemer survey application. The researcher acknowledged and complied with all required ethical standards.

CHAPTER IV

FINDINGS

Findings of the study were collected from October 2021 through February 2022. Findings are organized in this chapter in the following order:

1. Demographic Data
2. Flying and VR Experience
3. Self-Efficacy Data
4. VR Survey Data
5. Interview Trends
6. Results of MCC SFT Analysis
7. Did Not Graduate and Retrain Data

Demographic Data

Twelve subjects consented to participate in the research project. Table 1 provides demographic data for the participants. The demographic data was acquired from the pre-survey that was collected within the first week of the program (Appendix H).

Table 1
Demographic Data

Gender Identified	
Male	11
Female	1
Age	
Age 20-24	4
Age 25-29	1
Age 30-34	6
Age 35-40	1
Ethnicity	
White (English, Welsh, Scottish, Northern Irish, British, Irish, Gypsy, Irish Traveler, any other White Background):	11
Black/African/Caribbean/Black British (African, Caribbean, any other Black or African or Caribbean background):	1

Flying and VR Experience

Table 2 below provides flying and VR experience information that was collected from the pre-survey (Appendix H).

Table 2
Flying and Virtual Reality Experience

Flying Experience	
Less than 200 hours	11
1500-3000 hours	1
Flying Certifications	
No Type Ratings	11
Previous military flying, not an aircraft commander	1
Virtual Reality Experience	
None	8
Some (less than 5 hours total)	4

Self-Efficacy Survey Results

Five self-efficacy questions were asked to all participants on the pre-survey (Appendix H) and post surveys (experimental post survey Appendix G, control post survey Appendix I). Due to a lack of adequate sample size as discussed in Chapter Three, the data in Tables 3, 4, and 5 was not analyzed for significance. See Table 7 Interview Trends for additional information on self-efficacy. Tables 3, 4, 5, and 6 contain a seven point Likert scale. List 4 indicates the assigned value for the participant's response options.

List 4
Likert Scale Values

Likert Scale Values	
Strongly Disagree	1
Disagree	2
Somewhat Disagree	3
Not agree or disagree	4

Somewhat Agree	5
Agree	6
Strongly Agree	7

Table 3 only presents self-efficacy data provided in the post survey and does not answer any research questions.

Table 3
Self-Efficacy Post Survey Results (N=8)

Question 1: I can execute normal and non-normal ground procedures on any aircraft an airline may require me to operate. ***Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree***		
Group	**Mean**	**Std Dev**
Experimental	5.80	1.095
Control	6.00	.816
Question 2: I am a well above average pilot. ***Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree***		
Group	**Mean**	**Std Dev**
Experimental	5.60	1.517
Control	5.00	1.414
Question 3: I can accomplish any required airline training without failing any ground training. ***Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree***		
Group	**Mean**	**Std Dev**
Experimental	5.80	1.304
Control	5.50	.577
Question 4: I can accomplish any required airline training without failing any simulator sessions. ***Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree***		
Group	**Mean**	**Std Dev**
Experimental	5.80	1.304
Control	5.50	.577

Question 5: I can overcome failed events to ensure I complete the full airline training program (MCC through type-rating training). ***Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree***		
Group	**Mean**	**Std Dev**
Experimental	6.40	.894
Control	6.25	.500

Tables 4 and 5 below do not answer any research questions but provide useful information. The tables present only analysis within the control and experimental group and not between them. Table 4 identifies differences in data between the control group pre and post surveys.

Table 4
Control Group Only (N=3) Self-Efficacy Survey Results (Pre to Post Survey)

Question 1: I can execute normal and non-normal ground procedures on any aircraft an airline may require me to operate. ***Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree***		
Group	**Mean**	**Std Dev**
Control	5.33	.667
Question 2: I am a well above average pilot. ***Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree***		
Group	**Mean**	**Std Dev**
Control	4.67	.667
Question 3: I can accomplish any required airline training without failing any ground training. ***Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree***		
Group	**Mean**	**Std Dev**
Control	5.00	.000
Question 4: I can accomplish any required airline training without failing any simulator sessions. ***Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree***		
Group	**Mean**	**Std Dev**
Control	6.00	.000

Question 5: I can overcome failed events to ensure I complete the full airline training program (MCC through type-rating training). ***Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree***		
Group	**Mean**	**Std Dev**
Control	4.67	.333

Table 5 below presents data from the experimental group pre and post survey self-efficacy responses.

Table 5

Experimental Group Only (N=5) Self-Efficacy Survey Results (Pre to Post Survey)

Question 1: I can execute normal and non-normal ground procedures on any aircraft an airline may require me to operate. ***Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree***		
Group	**Mean**	**Std Dev**
Experimental	3.60	.812
Question 2: I am a well above average pilot. ***Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree***		
Group	**Mean**	**Std Dev**
Experimental	4.00	.894
Question 3: I can accomplish any required airline training without failing any ground training. ***Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree***		
Group	**Mean**	**Std Dev**
Experimental	4.20	.735
Question 4: I can accomplish any required airline training without failing any simulator sessions. ***Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree***		
Group	**Mean**	**Std Dev**
Experimental	4.40	.812
Question 5: I can overcome failed events to ensure I complete the full airline training program (MCC through type-rating training). ***Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree***		
Group	**Mean**	**Std Dev**
Experimental	5.20	.970

VR Specific Survey Results

Four of the five experimental participants also answered ten additional questions on the use of VR on the post survey (Appendix G), as indicated in Table 6.

Table 6
VR Specific Survey Results (N=4)

<table>
<tr><td colspan="7">Question 1: On average how many minutes did you use the VR equipment prior to a Synthetic Flight Training (SFT) exercise? o<i>pen-ended</i></td></tr>
<tr><td>Student 1:
240 min</td><td>Student 2:
60 min</td><td>Student 3:
60-90 min</td><td>Student 4:
30 min</td><td colspan="3">Student 5:
n/a</td></tr>
<tr><td colspan="7">Question 2: Did you use the VR equipment prior to the Final Assessment (SFT #10)? <i>yes; no</i></td></tr>
<tr><td colspan="3">Yes</td><td colspan="4">No</td></tr>
<tr><td colspan="3">0</td><td colspan="4">Student 1-4: 4</td></tr>
<tr><td colspan="7">Question 3: For approximately how many minutes did you use the VR equipment prior to the Final Assessment? o<i>pen-ended</i></td></tr>
<tr><td>Student 1:
0 min</td><td>Student 2:
0 min</td><td>Student 3:
0 min</td><td>Student 4:
0 min</td><td colspan="3">Student 5:
n/a</td></tr>
<tr><td colspan="7">Question 4: Approximately how many minutes or hours total did you spend preparing for the Final Assessment (include all methods)? o<i>pen-ended</i></td></tr>
<tr><td>Student 1:
48 hours</td><td>Student 2:
4 hours, 40 min</td><td>Student 3:
4 hours</td><td>Student 4:
8 hours</td><td colspan="3">Student 5:
n/a</td></tr>
<tr><td colspan="7">Question 5: Practicing with VR better prepared me for the Final Assessment? <i>Strongly Disagree, Disagree, Somewhat Disagree, Not Agree or Disagree, Somewhat Agree, Agree, Strongly Agree</i></td></tr>
<tr><td>Strongly Disagree</td><td>Disagree</td><td>Somewhat Disagree</td><td>Not Agree or Disagree</td><td>Somewhat Agree</td><td>Agree</td><td>Strongly Agree</td></tr>
<tr><td>Student 3: 1
Student 4: 1</td><td></td><td></td><td></td><td>Student 1: 1
Student 2: 1</td><td></td><td></td></tr>
<tr><td colspan="7">Question 6: How did VR better prepare you for the Final Assessment? (e.g., not-applicable, retention, faster flows, better skill transfer)? o<i>pen-ended</i></td></tr>
<tr><td colspan="7">Student 1: “n/a”</td></tr>
<tr><td colspan="7">Student 2: “Better prepared me through muscle memory skills and scan flows, as well as cockpit familiarization.”</td></tr>
</table>

Student 3: “It didn't really due to the minimal and basic content available on the headset.”
Student 4: “n/a”
Student 5: n/a
Question 7: How many SFT retraining events did you have in the program? o*pen-ended*

Student 1:	Student 2:	Student 3:	Student 4:	Student 5:
0	0	0	0	n/a

Question 8: (For those reporting any use of VR) Using VR better prepared me for simulator sessions, including the Final Assessment, more than just using a paper cockpit representation alone. I never used the paper cockpit representation; *Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree*

Strongly Disagree	**Disagree**	**Somewhat Disagree**	**Not Agree or Disagree**	**Somewhat Agree**	**Agree**	**Strongly Agree**
Student 1: 1 Student 3: 1	Student 4: 1			Student 2: 1		

Question 9: The VR equipment improved the quality of training (e.g., motivation, training device availability, increased skill performance, etc)? o*pen-ended*
Student 1: “Yes, it’s a lighthearted way of learning”
Student 2: “Yes it did improve the quality of training as it provides an alternative method to revision with more interactive use compared to other methods”
Student 3: “It has the potential to do this, but more advanced content must be made available. Motivation, muscle memory would most certainly improve.”
Student 4: “No”
Student 5: n/a
Question 10: I think VR equipment should be incorporated into MCC training because it improved the quality of the training. *yes; no*

Yes	**No**
Student 1: 1 Student 2: 1 Student 3: 1	Student 4: 1

Interview Trends

Interviews were conducted by the researcher for all five of the experimental group participants. Interviews lasted approximately 30 minutes and used the open-ended interview questions in Appendix J. Trends from the interviews are included in Table 7 below. Trends were determined when three of the five participants answered the question similarly. If data is included that affected one or two students it is specifically identified in the table.

Table 7
Interview Trends

Time using VR	
20 minutes - 4 hours	All five participants used the VR ranging from one to three occurrences lasting from 20 minutes to four hours.
Quality of Training	
Motivation	Four interviewees indicated the VR was motivating, but it would be more motivating had they received it prior to the MCC course beginning.
Enjoyment	Four interviewees indicated enjoyment using the VR equipment. One interviewee indicated the HMD was painful while using glasses which negatively affected his enjoyment. All participants were impressed with the graphics and realism of the virtual environment.
Efficiency	All interviewees did not think VR added efficiency to the MCC course as the procedures did not match the Standard Operating Procedures (SOPs) and the inability to navigate the VR quickly to specific events.
Effectiveness	All interviewees did not think VR improved effectiveness of their training as the procedures did not match the SOPs.

Self-Efficacy	
Confidence	Four interviewees indicated marginal to no increase in confidence. However, they indicated it may increase confidence if the VR equipment arrived one month to two weeks before the MCC course started as they could begin using it to become proficient on SOPs as quickly as possible.
Issues	
Wearing glasses while using VR	Both interviewees who wore glasses found the headset difficult to use with their glasses on. One felt he could not use the headset with glasses. When one interviewee took his glasses off, he found he could not focus one of his eyes. Both did not use the VR more than a total of an hour due to the eye glass issue.
Procedures in VR did not match MCC Course Standard Operating Procedures (SOPs)	The VR equipment procedures did not match the MCC course SOPs on all procedures and modules. All students felt the VR would be much more effective if it taught and reinforced the SOPs precisely.
Need access to VR prior to class	All interviewees agreed they needed the VR equipment at least one month to two weeks before the program started. Once the MCC course started interviewees felt there was insufficient time to use the VR to prepare for the next day's SFT.
No fast forward option	All interviewees wanted a fast forward feature to move to specific procedures and modules more helpful to their needs at that moment.
Future VR Use	
Significant future for VR in pilot training programs	All interviewees felt VR will be a component of future pilot training programs. Interviewees overwhelmingly saw the potential of VR to increase the quality of the MCC course.
Pair headsets for crew training	Two interviewees thought the ability to train in VR while paired to another pilot in VR as a flight crew would significantly increase the efficacy of VR.
Watch video of instruments during flying operations	One interviewee thought it would be helpful if the VR could demonstrate certain maneuvers such as an instrument landing system approach.

MCC SFT Analysis

The MCC course gradebooks and archival data provided scores for each pilot that covered the twelve key competencies for all ten SFTs. The 12 key competencies are scored on each of the ten SFTs using a grading scale from one to five. Scores of "1-4" are passing scores, and a score of "5" is unsatisfactory. A student must have a "4" or better on each of the 12 key competencies on SFT #10 (Final Assessment) to complete the MCC Course (see List 3 for scoring criteria).

Table 8 below is the analysis of all SFT scores separated between experimental and control groups. The table combines the scores of all 12 key competencies for each of the ten SFTs for every pilot in the experimental group and compares to the same data for the control group.

Table 8
Combined SFT Scores (N=51)

Group	Mean	Std Dev	T-Test	P-Value
Experiment	3.2585	.35124	1.075	.288
Control	3.1305	.39879	Significance: No	

Table 9 contains analysis of each experimental and control group's SFT scores.

Table 9
SFT Scores, (N=51)

SFT #	Group	Mean	Std Dev	T-Value	P-Value
SFT #1	Experiment	3.7269	.43325	.047	.960
	Control	3.7202	.48408	Significance: No	

SFT #2	Experiment	3.7359	.37703	1.334	.188
	Control	3.5591	.45076	Significance: No	
SFT #3	Experiment	3.5717	.36702	1.130	.264
	Control	3.4342	.40490	Significance: No	
SFT #4	Experiment	3.4500	.44410	1.360	.180
	Control	3.2537	.47713	Significance: No	
SFT #5	Experiment	3.3167	.44677	1.285	.205
	Control	3.1261	.49349	Significance: No	
SFT #6	Experiment	3.2722	.37197	1.661	.103
	Control	3.0316	.50407	Significance: No	
SFT #7	Experiment	3.1217	.38833	1.225	.226
	Control	2.9626	.43357	Significance: No	
SFT #8	Experiment	2.9185	.32868	1.221	.228
	Control	2.7738	.40112	Significance: No	
SFT #9	Experiment	2.7556	.43010	.259	.797
	Control	2.7210	.43391	Significance: No	
SFT #10	Experiment	2.7157	.57782	-.082	.935
	Control	2.7294	.52604	Significance: No	

Table 10 below analyzes the five most pertinent key competencies. All data for Table 10 was generated from student gradebooks and archival data.

Table 10
MCC key competencies of SA, WM, KAP, AMMC, and AMA, (N=51)

Key Competency	Group	Mean	Std Dev	T-Test	P-Value
SA	Experiment	3.3400	.38508	.730	.469
	Control	3.2305	.52202	Significance: No	
WM	Experiment	3.4733	.38631	.190	.240
	Control	3.3086	.47177	Significance: No	
KAP	Experiment	3.4733	.40261	.946	.349
	Control	3.3222	.55786	Significance: No	
AMMC	Experiment	3.1919	.47395	.912	.366
	Control	3.0470	.53067	Significance: No	
AMA	Experiment	3.4119	.43034	1.811	.076
	Control	3.1771	.41550	Significance: No	

Of the 51 student pilots' data that were analyzed only one did not complete the MCC program. The one pilot that failed to graduate did not employ VR in their training. Four of the 51 pilots required at least one retraining event. See Table 11 for retrain events.

Table 11
Retrain Events, (N=51)

Group	Retrain Events	Mean	Std Dev	T-Value	P-Value
Experiment	2	3.2585	.35124	1.075	.288
Control	2	3.1305	.39879	Significance: No	

CHAPTER V

CONCLUSION

The research questions explored in this study include:

1. Can VR increase the average Synthetic Flight Training session scores in an MCC course?
2. Can VR increase scores on the MCC course key competencies of situational awareness, workload management, knowledge and procedures, aircraft management (manual control), and aircraft management (automation)?
3. Can VR increase the score of the MCC course Final Assessment?
4. Does VR increase the quality of training experienced by the students in a typical MCC course?
5. Can VR increase self-efficacy in flying related skills and airline aviation training programs?

The hypothesis for this study is that average session scores, the five key competencies scores, and the Final Assessment score will increase, and the pilots' sense of quality of training and self-efficacy will increase.

The results of the experiment do not prove the hypothesis although some positive outcomes were achieved as noted below for research question 4.[6]

Research Question #1

Can VR increase the average Synthetic Flight Training session scores in an MCC course?

No, the experiment indicated that VR did not increase the SFT session scores. The analysis resulted in no significance (p <.05) between the experimental and control group scores, $t(48) = 1.075$, $p = .288$. The interviews helped explain why the VR did not increase scores for the experimental group. The interviewees stated they only received the VR the first day of class which gave them limited time to use it to prepare for the SFTs. Further once they started the SFTs they only had few hours per day to prepare for the next day's SFT mission. During the last two weeks (i.e., 10 business days), the students must complete the ten SFTs. Therefore, the students could not start preparing for the next SFT until immediately after completing the previous SFT. The interviewees considered this a very busy time and prioritized studying the SOPs for the next day's SFT.

The VR equipment had procedures that did not perfectly match the SOPs. Since the student pilots were required to comply with the SOPs participants felt their limited time was

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[6] In other words, the experiment proved the null hypothesis and did not prove the alternative hypothesis as indicated.

better spent with paper cockpit diagrams following the SOPs precisely versus in the VR. Post-survey and interview data shows that the five participants that used VR only spent one to two hours in the VR the first week (note that one participant used the VR four hours the first week). Most of the students spent two or more hours a night preparing for SFTs over the three-week MCC course. The short duration the participants employed the VR may explain why it was not helpful in increasing scores.

Additionally, all five participants employed the VR in the first week exclusively. One would expect the VR would then have the greatest impact on the first SFT. Not only did they employ the VR just prior to SFT #1, SFT #1 focuses on ground operations which the VR is optimized for. However, as Table 9 illustrates the VR had no significance ($p < .05$) in the first SFT, $t(48) = .047$, $p = .960$. Therefore, the fact VR did not have a significant effect for all ten SFTs combined is logical.

Research Question #2

Can VR increase scores on the MCC course key competencies of situational awareness, workload management, knowledge and procedures, aircraft management (manual control), and aircraft management (automation)?

No, VR did not increase scores significantly on the five key competencies observed ($p < .05$):

Situational Awareness (SA), $t(48) = .730$, $p = .469$

Workload Management (WM), $t(48) = .190$, $p = .240$

Knowledge and Application of Procedures (KAP), $t(48) = .946$, $p = .349$

Aircraft Management, Manual Control (AMMC), *t*(48) = .912, *p* = .366

Aircraft Management, Automation (AMA), *t*(48) = 1.811, *p* = .076

Based on limited VR use participants indicated on the post-survey and interviews, and as stated above under Research Question #1, the results are logical. Of note the five key competencies above were chosen from the total of 12 key competencies as they are areas most germane to the VR software and capabilities.

Research Question #3

Can VR increase the score of the MCC course Final Assessment?

No, VR did not increase scores significantly (p <.05) on the Final Assessment, *t*(48) = -.082, *p* = .935. The considerations from the answers above for Research Question #1 and #2 apply to this question. Therefore, the fact there is not a significant change between groups is logical.

Research Question #4

Does VR increase the quality of training experienced by the students in a typical MCC course?

Yes, VR marginally increased the quality of training experienced by participants. Quality was defined in this experiment as the student's sense of motivation, enjoyment, efficiency, and effectiveness of the training. From the post survey students reported:

"Yes, it's a lighthearted way of learning"

"Yes it did improve the quality of training as it provides an alternative method to revision with more interactive use compared to other methods"

"It has the potential to do this, but more advanced content must be made available. Motivation, muscle memory would most certainly improve."

On participant answered "no".

From the interviews students reported:

Four interviewees indicated enjoyment using the VR equipment. One interviewee indicated the HMD was painful while using glasses which negatively affected his enjoyment. Interviewees did not think VR added efficiency to the MCC course. Interviewees did not think VR improved effectiveness of their training.

The survey and interview data indicates that students did not think the VR they employed was effective or efficient. Students did find the equipment motivating and enjoyable. Students overwhelmingly saw the potential of VR to increase the quality of the MCC course.

Research Question #5

Can VR increase self-efficacy in flying related skills and airline aviation training programs?

The interviews indicate that self-efficacy was not improved by employment of VR. However, all the experimental participants pointed out that had they received the equipment prior to the course it may have contributed to increased confidence prior to the first day of MCC formal training beginning.

Completion and Retrain Events

Only one of the 51 students whose data was analyzed in this research project failed to graduate the MCC program. That pilot did not employ VR in their training. Four of the 51 pilots required at least one retraining event. A retraining event is required because a student failed an SFT mission. Analysis from an independent t-test indicates no significance (p <.05) between the control and experimental groups, $t(48) = 1.075$, $p = .288$. Therefore, VR did not have a significant effect on retrain events.

Conclusions

VR did not significantly improve student outcomes in the MCC course. However, most students did report marginal increases in training quality in terms of enjoyment and motivation.

Outcomes may have been significant had the VR software precisely matched the MCC course SOPs and students received the VR equipment earlier. Following the proper SOPs precisely and in a timely manner is critical in flying and in courses such as MCC. The fact the VR headsets had procedures that did not match the MCC course SOPs precisely was the most critical factor in why participants did not employ the VR more during the experiment. Participants felt they had limited time to prepare for each MCC course event. Therefore, they did not want to use limited preparation time employing VR that had some inaccurate SOPs. Participants did not feel they had enough time once the program started to orient to the VR equipment. Had the equipment arrived earlier it is possible they would have been more comfortable training with it during the MCC course.

It is important to note that VR is not a requirement of the MCC course, and its use is additive to the syllabus. Therefore, students are not mandated to use VR in the program. As noted in Chapter Two, Fussell (2020) used a technology acceptance model to indicate that aviation students are more likely to use VR if it is incorporated effectively into the training program. The fact the VR equipment was additive may have disincentivized students spending time employing VR versus simply studying the SOPs through other methods such as a tablet, binder, book, or paper cockpit diagram.

Future Research

Virtual Reality use in airline training programs should continue to be researched. All experimental participants indicated they think VR will be part of future pilot training programs. All participants were impressed by the VR capabilities. All participants stated they need the VR equipment one month to two weeks prior to the beginning of training. They also stated that the flying procedures must match the training programs SOPs to be effective.

Further research could also analyze data from the other MCC course key competencies of Motivation and Professional Attitude (MPA), Problem Solving and Decision Making (PSDM), Leadership and Teamwork (LT), Briefing (B), Effective Communication (EC), Pilot Monitoring (PM), and Energy Management (EM). VR may prove to affect the outcomes in these areas despite not having software specifically designed to target them. Additionally, as VR equipment becomes more capable it is likely that these key competencies may be targeted by the VR.

Interviews should be used in addition to any quantitative data instruments. Interviews were helpful during this experiment to capture issues and observations that would not have been captured by quantitative instruments alone.

Further research into VR employment in pilot training programs will be useful. This research should ensure the VR equipment is provided to participants one month to two weeks prior to their training program beginning. Every effort should be made to ensure the flying related procedures within the VR matches the SOPs of the training program.

Possibly the most useful research project would be if an airline training program would adopt VR and require the VR software to match the SOPs exactly. A randomized study could be conducted allowing some students to use VR while others use the classic paper cockpit representation.

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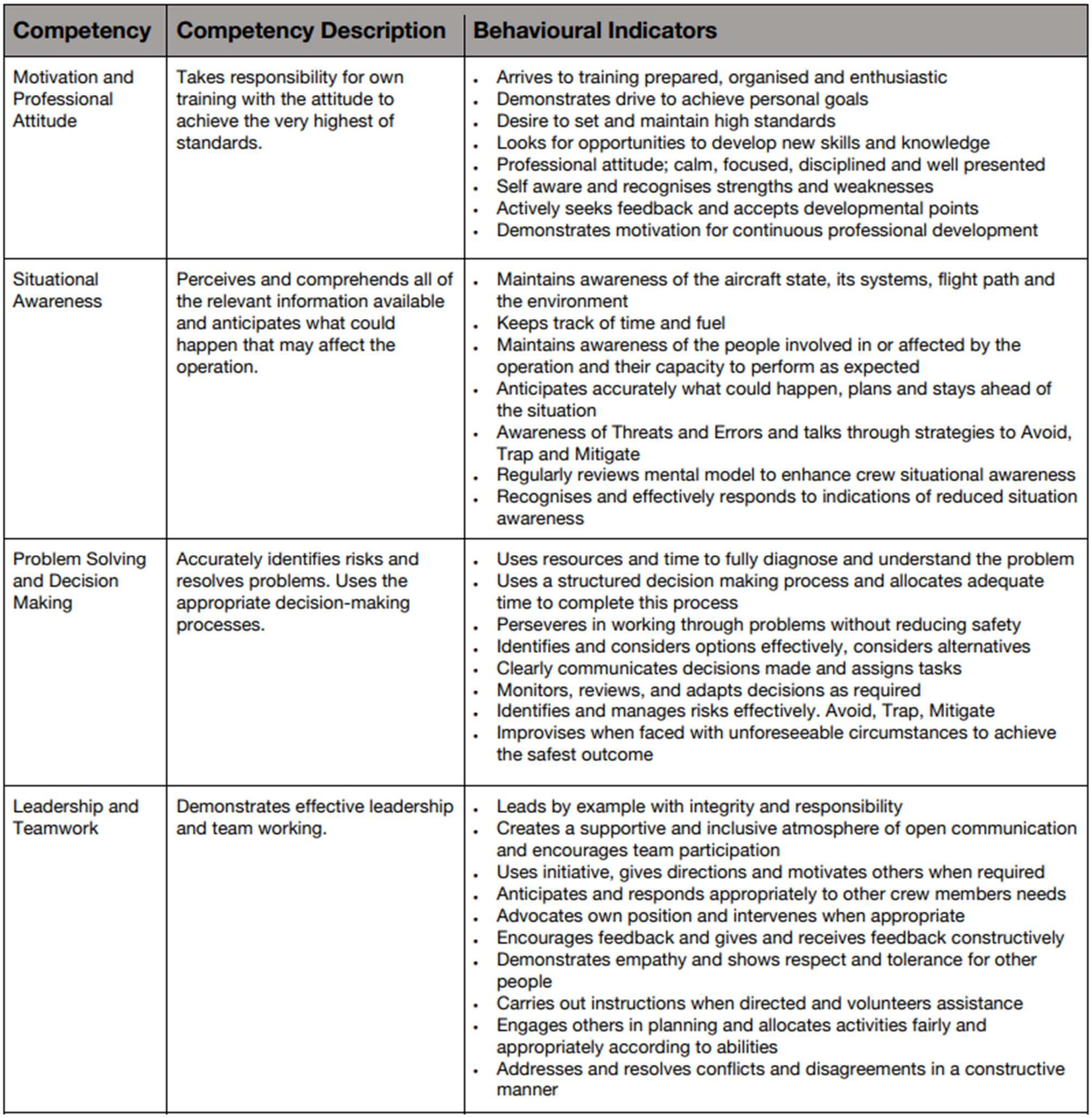
APPENDICES

APPENDIX A

COMPETENCY BEHAVIORAL INDICATORS (VA, 2019)



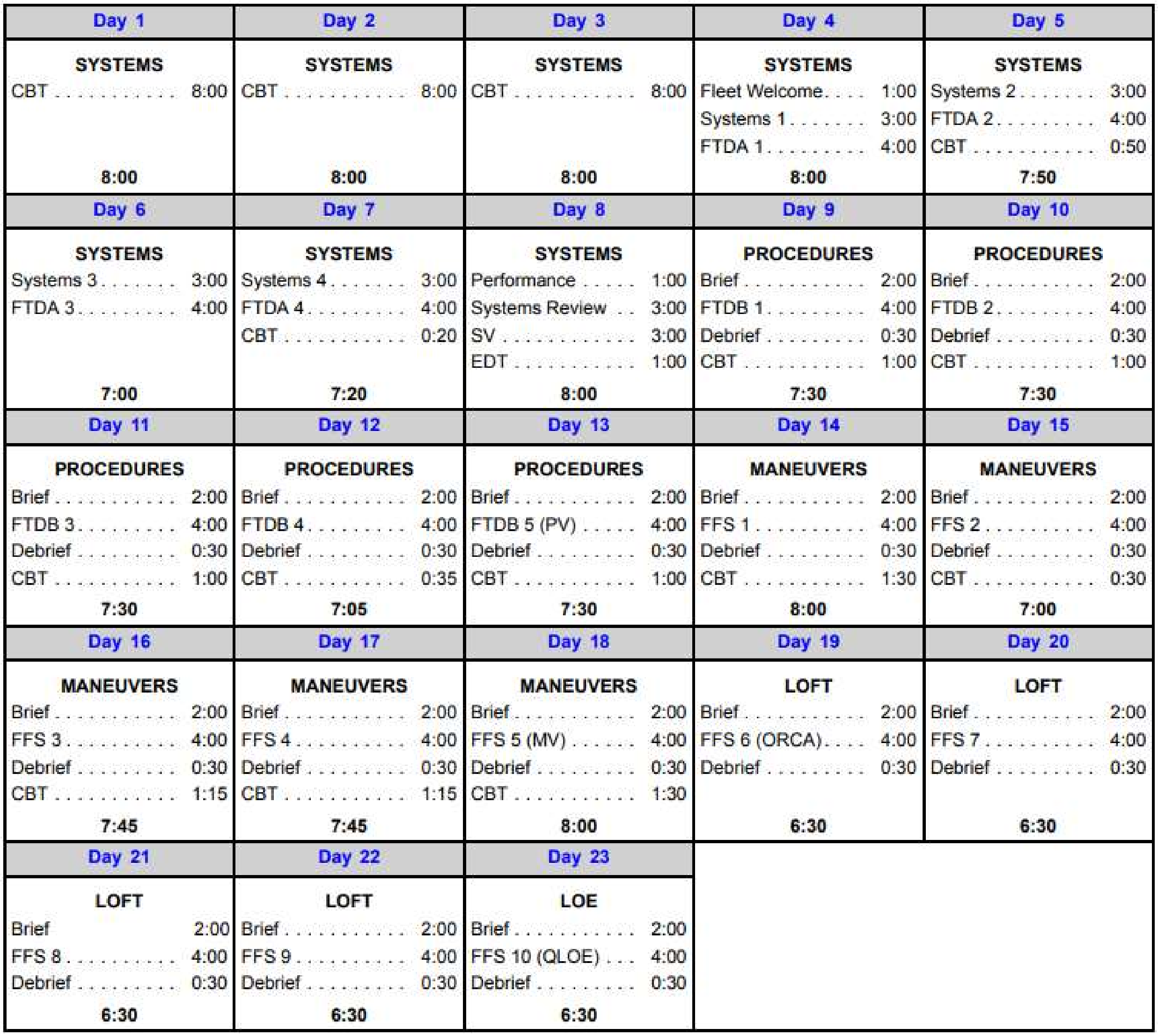
Competency	Competency Description	Behavioural Indicators
Motivation and Professional Attitude	Takes responsibility for own training with the attitude to achieve the very highest of standards.	• Arrives to training prepared, organised and enthusiastic • Demonstrates drive to achieve personal goals • Desire to set and maintain high standards • Looks for opportunities to develop new skills and knowledge • Professional attitude; calm, focused, disciplined and well presented • Self aware and recognises strengths and weaknesses • Actively seeks feedback and accepts developmental points • Demonstrates motivation for continuous professional development
Situational Awareness	Perceives and comprehends all of the relevant information available and anticipates what could happen that may affect the operation.	• Maintains awareness of the aircraft state, its systems, flight path and the environment • Keeps track of time and fuel • Maintains awareness of the people involved in or affected by the operation and their capacity to perform as expected • Anticipates accurately what could happen, plans and stays ahead of the situation • Awareness of Threats and Errors and talks through strategies to Avoid, Trap and Mitigate • Regularly reviews mental model to enhance crew situational awareness • Recognises and effectively responds to indications of reduced situation awareness
Problem Solving and Decision Making	Accurately identifies risks and resolves problems. Uses the appropriate decision-making processes.	• Uses resources and time to fully diagnose and understand the problem • Uses a structured decision making process and allocates adequate time to complete this process • Perseveres in working through problems without reducing safety • Identifies and considers options effectively, considers alternatives • Clearly communicates decisions made and assigns tasks • Monitors, reviews, and adapts decisions as required • Identifies and manages risks effectively. Avoid, Trap, Mitigate • Improvises when faced with unforeseeable circumstances to achieve the safest outcome
Leadership and Teamwork	Demonstrates effective leadership and team working.	• Leads by example with integrity and responsibility • Creates a supportive and inclusive atmosphere of open communication and encourages team participation • Uses initiative, gives directions and motivates others when required • Anticipates and responds appropriately to other crew members needs • Advocates own position and intervenes when appropriate • Encourages feedback and gives and receives feedback constructively • Demonstrates empathy and shows respect and tolerance for other people • Carries out instructions when directed and volunteers assistance • Engages others in planning and allocates activities fairly and appropriately according to abilities • Addresses and resolves conflicts and disagreements in a constructive manner

Workload Management	Manages available resources efficiently to prioritise and perform tasks in a timely manner under all circumstances.	• Remains methodical and focused in task management resisting impulsiveness • Plans, prioritises and schedules tasks effectively prioritising Fly, Navigate, Communicate • Manages time efficiently when carrying out tasks • Offers and accepts assistance, delegates when necessary and asks for help early • Uses all resources available to fulfil task completion • Reviews, monitors and cross-checks actions conscientiously • Manages and recovers from interruptions, distractions, variations and failures effectively • Awareness of stress, overload and fatigue and responds effectively to early signs to reduce workload and conserve capacity
Effective Communication	Demonstrates effective oral, non-verbal and written communications, in normal and non-normal situations.	• Uses appropriate vocabulary, conveying message clearly and accurately and at appropriate times • Checks understanding of important information, resolves ambiguity and seeks clarification • Challenges appropriately with respect, assertiveness and at appropriate points • Influential and supports opinion with facts and information • Listens actively and demonstrates understanding when receiving information • Asks relevant and effective questions • Adheres to standard radiotelephone phraseology and procedures • Uses body language that is consistent with and supports verbal messages
Knowledge and Application of Procedures	Identifies and applies procedures in accordance with published operating instructions and applicable regulations, using the appropriate knowledge.	• Correctly gathers required operational information • Follows SOP's unless a higher degree of safety dictates an appropriate deviation • Identifies and follows all operating instructions in a timely manner • Correctly operates aircraft systems and associated equipment • Demonstrates practical knowledge of aircraft technical systems and limitations • Complies with applicable regulations • Applies relevant procedural knowledge, SOP profiles and Standard Calls • Disciplined in use of checklists, QRH and procedures
Aircraft Management, Manual Control	Controls the aircraft flight path through manual flight, including appropriate use of flight management system(s) and flight guidance systems.	• Controls the aircraft manually with accuracy and smoothness as appropriate to the situation • Detects deviations from the desired aircraft trajectory and takes appropriate action • Contains the aircraft within the normal flight envelope • Controls the aircraft safely using only the relationship between aircraft attitude, speed and thrust • Manages the flight path to achieve optimum operational performance • Maintains the desired flight path during manual flight whilst managing other tasks and distractions • Selects appropriate level and mode of flight guidance systems in a timely manner considering phase of flight and workload • Effectively monitors flight guidance systems including engagement and automatic mode transitions

Aircraft Management, Automation	Controls the aircraft flight path through automation, including appropriate use of flight management system(s) and guidance.	• Controls the aircraft using automation with accuracy and smoothness as appropriate to the situation • Detects deviations from the desired aircraft trajectory and takes appropriate action • Contains the aircraft within the normal flight envelope • Manages the flight path to achieve optimum operational performance • Maintains the desired flight path during flight using automation whilst managing other tasks and distractions • Selects appropriate level and mode of automation in a timely manner considering phase of flight and workload • Effectively monitors automation, including engagement and automatic mode transitions • Maintains FMA awareness throughout the operation with an understanding of the active modes
Briefings	Conducts effective briefings for departures, arrivals and non-normal events.	• Prepares for briefings, gathering information, programming/checking the FMS • Uses appropriate times to conduct briefings • Briefings are interactive, engaging, concise and structured • Emphasis on Threat and Error management • Involves PM and listens to their inputs • Sets effective gates for energy management and to empower PM to intervene • Explains how they are planning to operate aircraft, modes, level of automation, etc • Continues to operate the aircraft safely throughout briefing with appropriate automation and task sharing
Pilot Monitoring	Supports and Monitors Pilot Flying, challenges as appropriate, to enhance flight safety and operational efficiency.	• Maintains an active role throughout the operation • Monitors, verbalises and reviews situation awareness, particularly regarding the tasks of other crew members • Supports the PF by providing input to the tactical (short term) and strategic (long term) plan for the flight • Monitors parameters not immediately apparent to the PF • Monitors activities of the PF • Provides back-up to the PF and intervenes effectively when the PF does not respond to cues or fails to ensure safety • Makes call-outs of deviations from SOPs and/or limitations • Performs tasks as defined by SOPs
Energy Management	Plans and executes successful descent profiles.	• Knows how to calculate the likely track miles • Sets firm profile gates at briefing to enhance descent management awareness and empower PM • Is able to constantly calculate the deviation from the ideal profile • Can select the correct technique to regain the correct profile • Can articulate any deviation - both as PF and PM • Is able to generate options if regaining the profile is in doubt • Knows when & how to trade potential with kinetic energy

APPENDIX B

EXAMPLE TYPE-RATING COURSE SCHEDULE (B737/A320)



Day 1	Day 2	Day 3	Day 4	Day 5
SYSTEMS CBT 8:00 **8:00**	**SYSTEMS** CBT 8:00 **8:00**	**SYSTEMS** CBT 8:00 **8:00**	**SYSTEMS** Fleet Welcome 1:00 Systems 1 3:00 FTDA 1 4:00 **8:00**	**SYSTEMS** Systems 2 3:00 FTDA 2 4:00 CBT 0:50 **7:50**
Day 6	**Day 7**	**Day 8**	**Day 9**	**Day 10**
SYSTEMS Systems 3 3:00 FTDA 3 4:00 **7:00**	**SYSTEMS** Systems 4 3:00 FTDA 4 4:00 CBT 0:20 **7:20**	**SYSTEMS** Performance 1:00 Systems Review 3:00 SV 3:00 EDT 1:00 **8:00**	**PROCEDURES** Brief 2:00 FTDB 1 4:00 Debrief 0:30 CBT 1:00 **7:30**	**PROCEDURES** Brief 2:00 FTDB 2 4:00 Debrief 0:30 CBT 1:00 **7:30**
Day 11	**Day 12**	**Day 13**	**Day 14**	**Day 15**
PROCEDURES Brief 2:00 FTDB 3 4:00 Debrief 0:30 CBT 1:00 **7:30**	**PROCEDURES** Brief 2:00 FTDB 4 4:00 Debrief 0:30 CBT 0:35 **7:05**	**PROCEDURES** Brief 2:00 FTDB 5 (PV) 4:00 Debrief 0:30 CBT 1:00 **7:30**	**MANEUVERS** Brief 2:00 FFS 1 4:00 Debrief 0:30 CBT 1:30 **8:00**	**MANEUVERS** Brief 2:00 FFS 2 4:00 Debrief 0:30 CBT 0:30 **7:00**
Day 16	**Day 17**	**Day 18**	**Day 19**	**Day 20**
MANEUVERS Brief 2:00 FFS 3 4:00 Debrief 0:30 CBT 1:15 **7:45**	**MANEUVERS** Brief 2:00 FFS 4 4:00 Debrief 0:30 CBT 1:15 **7:45**	**MANEUVERS** Brief 2:00 FFS 5 (MV) 4:00 Debrief 0:30 CBT 1:30 **8:00**	**LOFT** Brief 2:00 FFS 6 (ORCA) 4:00 Debrief 0:30 **6:30**	**LOFT** Brief 2:00 FFS 7 4:00 Debrief 0:30 **6:30**
Day 21	**Day 22**	**Day 23**		
LOFT Brief 2:00 FFS 8 4:00 Debrief 0:30 **6:30**	**LOFT** Brief 2:00 FFS 9 4:00 Debrief 0:30 **6:30**	**LOE** Brief 2:00 FFS 10 (QLOE) 4:00 Debrief 0:30 **6:30**		

APPENDIX C

CONSENT FORM

Thank you for agreeing to participate in this study, which will take place from October 2021, through February 28, 2022. This form details the purpose of this study, a description of the involvement required, and your rights as a participant. This study involves research and is being accomplished as part of a dissertation in partial fulfillment for a Doctorate in Education in Applied Educational Studies with the Aviation and Space Specialization at Oklahoma State University.

Researcher Information:

- Matt Johnston (matthew.r.johnston@okstate.edu; 385-234-8226)
- No research assistants will be utilized

The purpose of this study is:

- To gain insight into the efficacy of Virtual Reality (VR) in airline pilot training

The benefits of the research will be:

- To improve test scores and improve simulator efficacy using VR technology
- To introduce VR technology in airline training to increase training efficacy while reducing cost and time in the training programs
- Eventually to minimize students' time in airline pilot training
- Participants are neither expected to experience any adverse effects from VR, nor risk from any aspect of the research
- Participation will not negatively affect students' performance or assessment in the training; refusal to participate will not result in penalty or loss of benefits, and subjects may withdraw without penalty

The methods that will be used to meet this purpose include:

- A pre-survey that is conducted prior to training
- A post survey that is administered after the Final Assessment
- Collection of Synthetic Flight Training Exercise test scores, Final Assessment score, and number of retraining events (if required)
- One interview after the Final Assessment (if required)
- Control groups will not use VR (October and November classes)
- Experimental groups will use VR (December and January classes

You are encouraged to ask questions or raise concerns at any time about the nature of the study, your rights, or the methods I am using. Please contact me at any time at the e-mail address or telephone number listed above. Participants will neither receive compensation nor incur any cost from the study. Participants have the right to not answer questions on the survey or the interview (if applicable).

Should they desire, participants can be provided the findings of the study. The study anticipates that all members of the control group (class without VR) and experimental groups (classes with VR) will participate. The exact class sizes are unknown, but approximately eight to ten students are anticipated per class.

If you are issued VR equipment, please use it at least one time prior to your first Synthetic Flight Training (SFT) mission, Exercise #1. You can use the VR equipment as much, or as little as you want during your training. If you were not issued VR equipment, I request you do not utilize any personal VR equipment that simulates a B737 flight-deck.

If an interview is required, our discussion will be digitally recorded to help me accurately capture your insights in your own words. The recording will only be heard by me for the purpose of this study. If you feel uncomfortable with the recording you may ask that it be turned off at any time.

You also have the right to withdraw from the study at any time. In the event, you choose to withdraw from the study all information you provide (including recording) will be destroyed and omitted from the final paper.

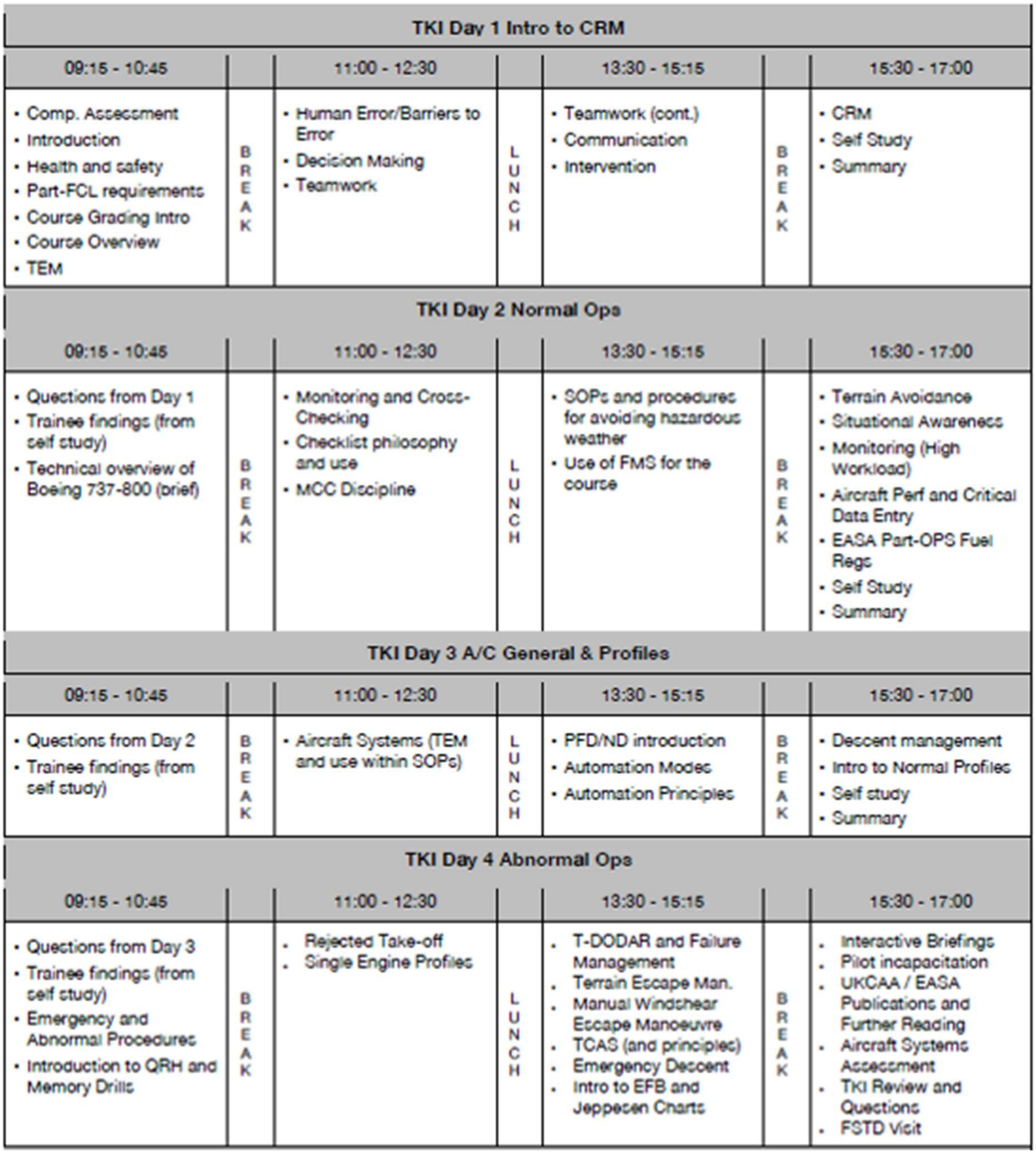
Insights gathered by you and other participants will be used in writing a research report, which may be published. Though direct quotes from you may be used in the paper, your name and other identifying information will be kept anonymous. All data will be kept digitally in my laptop and cloud storage. The computer is protected by industry-accepted anti-virus and firewall software. The computer requires a strong password, only known to me. Once all data is collected and analyzed your name and any other personal information such as an email address will be deleted from all records.

The research team works to ensure confidentiality to the degree permitted by technology. It is possible, although unlikely, that unauthorized individuals could gain access to your responses because you are responding online. However, your participation in the online survey involves risks similar to a person’s everyday use of the internet. If you have concerns, you should consult the survey provider privacy policy at https://www.alchemer.com/privacy/.

Participants will digitally *sign* the consent via an Alchemer prompt.

APPENDIX D

EXAMPLE MCC PROGRAM



TKI Day 1 Intro to CRM

09:15 - 10:45		11:00 - 12:30		13:30 - 15:15		15:30 - 17:00
• Comp. Assessment • Introduction • Health and safety • Part-FCL requirements • Course Grading Intro • Course Overview • TEM	BREAK	• Human Error/Barriers to Error • Decision Making • Teamwork	LUNCH	• Teamwork (cont.) • Communication • Intervention	BREAK	• CRM • Self Study • Summary

TKI Day 2 Normal Ops

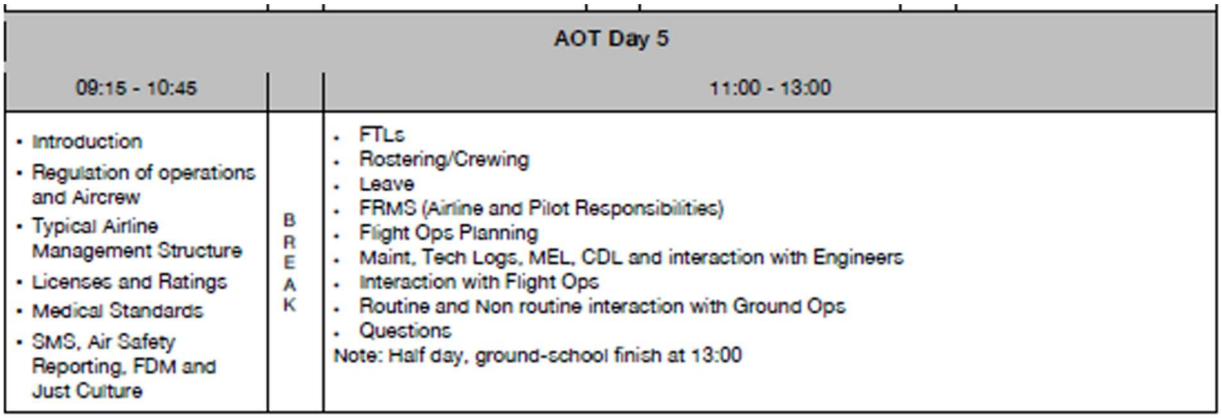
09:15 - 10:45		11:00 - 12:30		13:30 - 15:15		15:30 - 17:00
• Questions from Day 1 • Trainee findings (from self study) • Technical overview of Boeing 737-800 (brief)	BREAK	• Monitoring and Cross-Checking • Checklist philosophy and use • MCC Discipline	LUNCH	• SOPs and procedures for avoiding hazardous weather • Use of FMS for the course	BREAK	• Terrain Avoidance • Situational Awareness • Monitoring (High Workload) • Aircraft Perf and Critical Data Entry • EASA Part-OPS Fuel Regs • Self Study • Summary

TKI Day 3 A/C General & Profiles

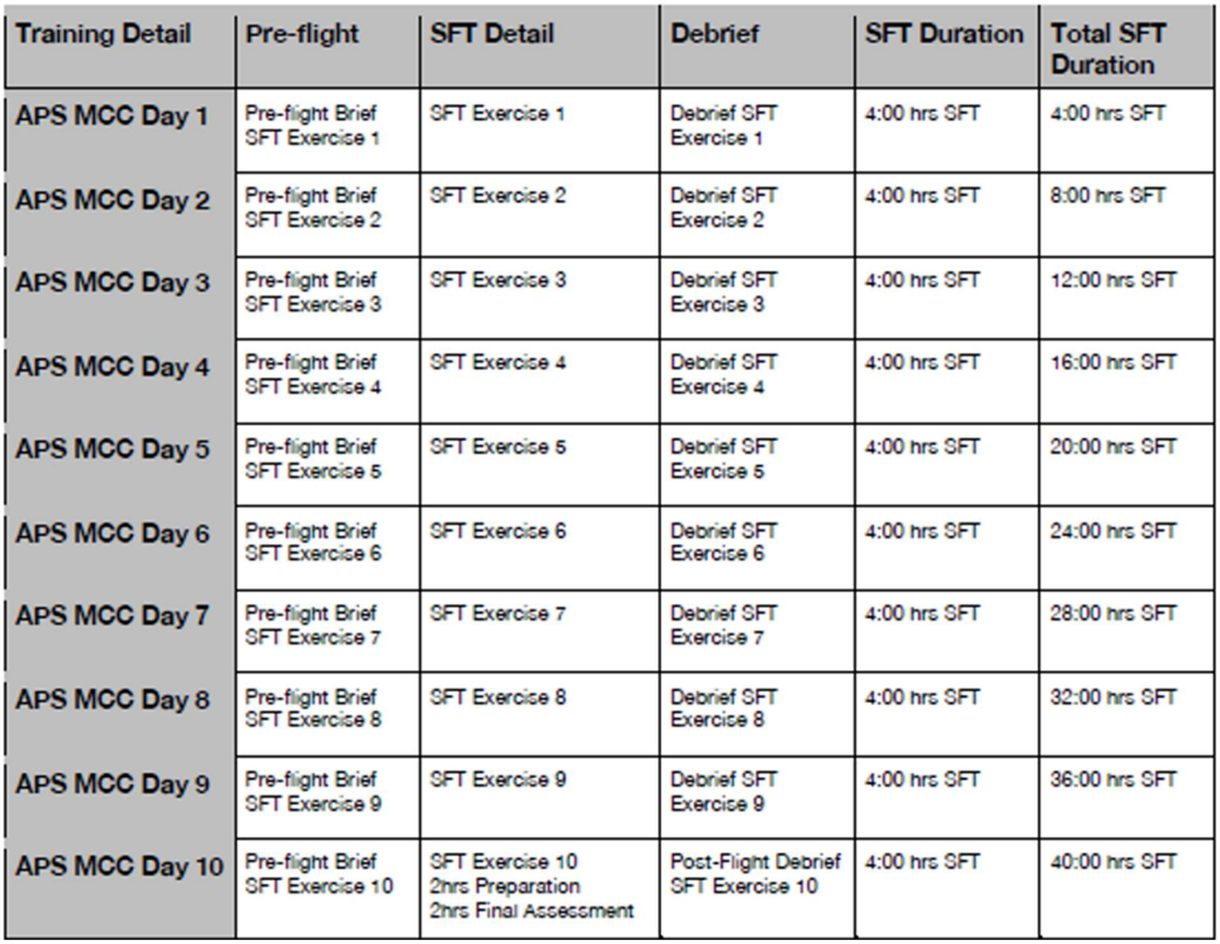
09:15 - 10:45		11:00 - 12:30		13:30 - 15:15		15:30 - 17:00
• Questions from Day 2 • Trainee findings (from self study)	BREAK	• Aircraft Systems (TEM and use within SOPs)	LUNCH	• PFD/ND introduction • Automation Modes • Automation Principles	BREAK	• Descent management • Intro to Normal Profiles • Self study • Summary

TKI Day 4 Abnormal Ops

09:15 - 10:45		11:00 - 12:30		13:30 - 15:15		15:30 - 17:00
• Questions from Day 3 • Trainee findings (from self study) • Emergency and Abnormal Procedures • Introduction to QRH and Memory Drills	BREAK	. Rejected Take-off . Single Engine Profiles	LUNCH	. T-DODAR and Failure Management . Terrain Escape Man. . Manual Windshear Escape Manoeuvre . TCAS (and principles) . Emergency Descent . Intro to EFB and Jeppesen Charts	BREAK	. Interactive Briefings . Pilot incapacitation . UKCAA / EASA Publications and Further Reading . Aircraft Systems Assessment . TKI Review and Questions . FSTD Visit



AOT Day 5		
09:15 - 10:45		11:00 - 13:00
- Introduction - Regulation of operations and Aircrew - Typical Airline Management Structure - Licenses and Ratings - Medical Standards - SMS, Air Safety Reporting, FDM and Just Culture	BREAK	- FTLs - Rostering/Crewing - Leave - FRMS (Airline and Pilot Responsibilities) - Flight Ops Planning - Maint, Tech Logs, MEL, CDL and interaction with Engineers - Interaction with Flight Ops - Routine and Non routine interaction with Ground Ops - Questions Note: Half day, ground-school finish at 13:00



Training Detail	Pre-flight	SFT Detail	Debrief	SFT Duration	Total SFT Duration
APS MCC Day 1	Pre-flight Brief SFT Exercise 1	SFT Exercise 1	Debrief SFT Exercise 1	4:00 hrs SFT	4:00 hrs SFT
APS MCC Day 2	Pre-flight Brief SFT Exercise 2	SFT Exercise 2	Debrief SFT Exercise 2	4:00 hrs SFT	8:00 hrs SFT
APS MCC Day 3	Pre-flight Brief SFT Exercise 3	SFT Exercise 3	Debrief SFT Exercise 3	4:00 hrs SFT	12:00 hrs SFT
APS MCC Day 4	Pre-flight Brief SFT Exercise 4	SFT Exercise 4	Debrief SFT Exercise 4	4:00 hrs SFT	16:00 hrs SFT
APS MCC Day 5	Pre-flight Brief SFT Exercise 5	SFT Exercise 5	Debrief SFT Exercise 5	4:00 hrs SFT	20:00 hrs SFT
APS MCC Day 6	Pre-flight Brief SFT Exercise 6	SFT Exercise 6	Debrief SFT Exercise 6	4:00 hrs SFT	24:00 hrs SFT
APS MCC Day 7	Pre-flight Brief SFT Exercise 7	SFT Exercise 7	Debrief SFT Exercise 7	4:00 hrs SFT	28:00 hrs SFT
APS MCC Day 8	Pre-flight Brief SFT Exercise 8	SFT Exercise 8	Debrief SFT Exercise 8	4:00 hrs SFT	32:00 hrs SFT
APS MCC Day 9	Pre-flight Brief SFT Exercise 9	SFT Exercise 9	Debrief SFT Exercise 9	4:00 hrs SFT	36:00 hrs SFT
APS MCC Day 10	Pre-flight Brief SFT Exercise 10	SFT Exercise 10 2hrs Preparation 2hrs Final Assessment	Post-Flight Debrief SFT Exercise 10	4:00 hrs SFT	40:00 hrs SFT

APPENDIX E

EXAMPLE VR ENVIRONMENT AND EQUIPMENT

APPENDIX F

VIRTUAL REALITY EQUIPMENT SPECIFICATIONS

Hardware: Pico Neo 2 headset with two hand-held controllers for each hand

1. Pico Interactive
    - Neo 2 Eye
    - www.pico-inteactive.com for any changes in specifications

Software: Two software packages

1. SDK Pico Developer Platform (allows for basic headset and controller functionality and to run applications loaded onto the headset)

2. Unity XR Platform (proprietary software)
    - Android Operating System
    - Android Native SDK 1.3.4.

APPENDIX G

EXPERIMENTAL POST SURVEY

1. Full name: *open-ended*
2. On average how many minutes did you use the VR equipment prior to a Synthetic Flight Training (SFT) exercise? *open-ended*
3. Did you use the VR equipment prior to the Final Assessment (SFT #10)? *yes; no*
4. (If yes to #3): For approximately how many minutes did you use the VR equipment prior to the Final Assessment? *open-ended*
5. Approximately how many minutes *total* did you spend preparing for the Final Assessment (include all methods)? *open-ended*
6. Practicing with VR better prepared me for the Final Assessment? *Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree*
7. How did VR better prepare you for the Final Assessment? (e.g., not-applicable, retention, faster flows, better skill transfer)? *open-ended*
8. How many SFT retraining events did you have in the program? *open-ended*
9. (For those reporting any use of VR) Using VR better prepared me for simulator sessions, including the Final Assessment, more than just using a paper cockpit representation alone. *I never used the paper cockpit representation; Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree*

10. The VR equipment improved the quality of training (e.g., motivation, training device availability, increased skill performance, etc)? o*pen-ended*
11. I think VR equipment should be incorporated into MCC training because it improved the quality of the training. *yes; no*
12. I can execute normal and non-normal ground procedures on any aircraft an airline may require me to operate. *Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree*
13. I am a well above average pilot. *Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree*
14. I can accomplish any required airline training without failing any ground training. *Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree*
15. I can accomplish any required airline training without failing any simulator sessions. *Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree*
16. I can overcome failed events to ensure I complete the full airline training program (MCC through type-rating training). *Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree*

APPENDIX H

PRE-SURVEY (CONTROL AND EXPERIMENTAL GROUPS)

1. Full name: *open-ended*
2. Gender Affiliation: *Male, Female, Other*
3. Age: *open-ended*
4. Ethnicity: *White (English or Welsh or Scottish or Northern Irish or British, Irish, Gypsy or Irish Traveler, Any other White background), Mixed/Multiple ethnic groups (White and Black Caribbean or White and Black African or White and Asian or Any other Mixed or Multiple ethnic background), Asian / Asian British (Indian, Pakistani, Bangladeshi, Chinese, Any other Asian background), Black / African / Caribbean / Black British (African, Caribbean, Any other Black or African or Caribbean background), Arab, Other*
5. What is your flying experience in hours: *Less than 200 flying hours, 200-500 flying hours, 500-1500 flying hours, 1500-3000 flying hours, more than 3000 flying hours*
6. Previous flying certifications (select all that apply): *737 type-rated, previous 737 training (but no type-rating), other aircraft type-rating, previous military aircraft commander (pilot in command), previous military flying other than aircraft commander (pilot in command)*
7. What is your previous experience with any type Virtual Reality (VR): *None, Some (less than 5 hours total), Intermediate (More than 5 but less than 20 hours total), Significant (Greater than 20 hours total)*

8. I can execute normal and non-normal ground procedures on any aircraft an airline may require me to operate. *Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree*
9. I am a well above average pilot. *Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree*
10. I can accomplish any required airline training without failing any ground training. *Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree*
11. I can accomplish any required airline training without failing any simulator sessions. *Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree*
12. I can overcome failed events to ensure I complete the full airline training program (Multi-Crew Cooperation Course (MCC) through type-rating training). *Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree*

APPENDIX I

CONTROL POST SURVEY

1. Full name: *open-ended*
2. Did you use any Virtual Reality (VR) equipment prior to the Final Assessment that accurately represented a B737 flight deck? *yes; no*
3. Approximately how many minutes *total* did you spend preparing for the Final Assessment (include all methods)? *open-ended*
4. How many SFT retraining events did you have in the program? *Open-ended*
5. I can execute normal and non-normal ground procedures on any aircraft an airline may require me to operate. *Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree*
6. I am a well above average pilot. *Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree*
7. I can accomplish any required airline training without failing any ground training. *Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree*
8. I can accomplish any required airline training without failing any simulator sessions. *Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree*

9. I can overcome failed events to ensure I complete the full airline training program (MCC through type-rating training). *Strongly Disagree, Disagree, Somewhat Disagree, Not agree or disagree, Somewhat Agree, Agree, Strongly Agree*

APPENDIX J

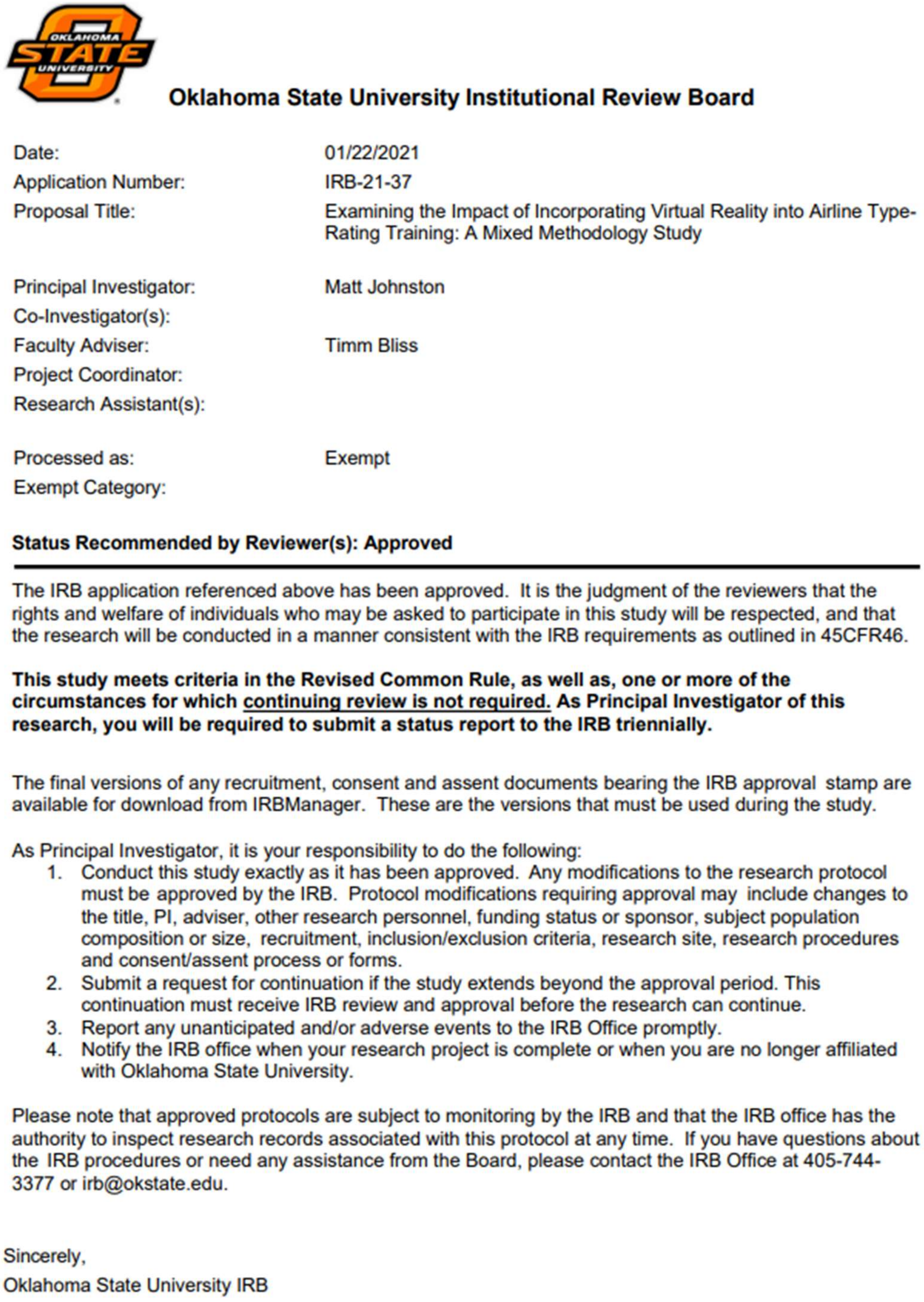
EXPERIMENTAL INTERVIEW GUIDE

1. Full name (open-ended)
2. Did you use the VR equipment?
    a. [prompt] When did you usually use it?
    b. [prompt] How did you usually use it?
    c. [prompt] Why didn't you use it/use it more?
3. Explain your experience with VR?
4. Do you feel VR affected your Synthetic Flight Training (SFT) Exercises?
    a. [prompt] How did VR effect it this way?
5. Does VR have the potential to replace any SFT Exercises?
    a. [prompt] How many?
    b. [prompt] Which ones?
6. What is the relationship between VR and SFT retraining events?
7. How would you describe VR and its effect on the quality of your training?
    a. [prompt] You said * on the survey (reference survey questions #7, #9 and #10, #11).
8. What about your experience with VR was the most helpful?
9. What additional hardware would you want to see included in the VR equipment you used?
    a. [prompt] Would you want data-gloves that provide haptic feedback (e.g., you could grasp a switch and "feel" the switch)?

10. What negative issues did you have with VR?
    a. [prompt] How did these impact your training?
    b. [prompt] Where the issues resolved?
11. What, if any, additional software would you like to see developed (e.g., additional non-normal procedures, or flying profiles)?

APPENDIX K

INSTITUTIONAL REVIEW BOARD APPROVAL



Oklahoma State University Institutional Review Board

Date:	01/22/2021
Application Number:	IRB-21-37
Proposal Title:	Examining the Impact of Incorporating Virtual Reality into Airline Type-Rating Training: A Mixed Methodology Study
Principal Investigator:	Matt Johnston
Co-Investigator(s):	
Faculty Adviser:	Timm Bliss
Project Coordinator:	
Research Assistant(s):	
Processed as:	Exempt
Exempt Category:	

Status Recommended by Reviewer(s): Approved

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in 45CFR46.

This study meets criteria in the Revised Common Rule, as well as, one or more of the circumstances for which continuing review is not required. As Principal Investigator of this research, you will be required to submit a status report to the IRB triennially.

The final versions of any recruitment, consent and assent documents bearing the IRB approval stamp are available for download from IRBManager. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be approved by the IRB. Protocol modifications requiring approval may include changes to the title, PI, adviser, other research personnel, funding status or sponsor, subject population composition or size, recruitment, inclusion/exclusion criteria, research site, research procedures and consent/assent process or forms.
2. Submit a request for continuation if the study extends beyond the approval period. This continuation must receive IRB review and approval before the research can continue.
3. Report any unanticipated and/or adverse events to the IRB Office promptly.
4. Notify the IRB office when your research project is complete or when you are no longer affiliated with Oklahoma State University.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact the IRB Office at 405-744-3377 or irb@okstate.edu.

Sincerely,
Oklahoma State University IRB

VITA

Matthew Roderick Johnston

Candidate for the Degree of

Doctor of Education

Dissertation: EXAMINING THE IMPACT OF INCORPORATING VIRTUAL REALITY INTO AIRLINE PILOT TRAINING: A MIXED METHODOLOGY STUDY

Major Field: Applied Education Studies

Biographical:

Education:

Completed the requirements for the Doctor of Education in Applied Educational Studies at Oklahoma State University, Stillwater, Oklahoma in May, 2022.

Completed the requirements for the Master of Science in National Security Strategy at the National Defense University, Washington, D.C. in 2020.

Completed the requirements for the Master of Arts in National Security and Defense Strategies at the Naval War College, Naval Station Newport, Rhode Island in 2015.

Completed the requirements for the Master of Business Administration at Colorado State University, Fort Collins, Colorado in 2010.

Completed the requirements of Bachelor of Science in Management with Japanese Minor at the United States Air Force Academy in Colorado Springs, Colorado in 2001.

Experience:
Military command; military operations; formal course F-35 and F-16 pilot instructor and evaluator; Combat Air Forces instructor and evaluator; combined and joint operational planning; strategy and policy development, implementation, and assessment; national security; Politico-Military affairs for Russia, Central Europe, South China Seas, Vietnam, Laos, Myanmar, and Singapore; United States Air Force, 1997 to present.