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Birdsong, J. G., Reesman, K. L., Sefton, J. M., & Miller, M. W. (2023). Efficacy of Using Virtual Reality To Support the Training of the Emerging Pilot Workforce. *22nd International Symposium on Aviation Psychology*, 78.
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EFFICACY OF USING VIRTUAL REALITY TO SUPPORT THE TRAINING OF THE EMERGING PILOT WORKFORCE

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Classroom instruction, computer-based training, flight simulation, and aircraft are used to train pilots. New immersive technologies and associated learning methods are used to train military pilots and may have value in civilian pilot training. This paper describes a study to explore the efficacy of using Virtual Reality (VR) Head-mounted Displays (HMDs) to support the training of the emerging pilot workforce. Participants were *ab-initio* civilian pilot students enrolled in a collegiate aviation program. Participants learned commercial aircraft preflight tasks using one of three methods. The control group used a combination of traditional classroom lectures and simulator sessions; one experimental group used VR to augment classroom instruction and simulator training; the other received classroom instruction and used VR to replace simulator training. Participants' performance was evaluated at a partner air carrier. Researchers completed a preliminary data analysis to understand the effectiveness of the training provided with results presented in this paper.

The current 14 CFR Part 121 air carrier pilot workforce comprises four generations: Baby Boomers (born 1946-1964), Generation X (born 1965-1980), Generation Y (born 1981-1996), and Generation Z (born 1997-2012) (FAA, (n.d.) *U.S. Civil Airmen Statistics* & Pew Research Center, n.d.). Baby Boomers will exit the workforce within the next ten years, and Generation X will retire between 2030-2045, leaving an emerging workforce of Generation Y and Z pilots (FAA, (n.d.) *U.S. Civil Airmen Statistics)*.

Current pilot training methods include classroom instruction, computer-based training (CBT), flight simulation, and aircraft training. New immersive virtual reality (VR) technologies have demonstrated value in military pilot training (Lewis & Livingston, 2018; Pennington et al., 2019; McFarland, 2020; & Mishler et al., 2022) and may have value in civilian pilot training, specifically in the development of procedural knowledge, filling a niche between CBT and traditional flight simulation (Bauer & Klingauf, 2008) and supplementing classroom instruction and simulator procedure training activities (Cross et al., 2022).

This research effort evaluates immersive technology's potential human factors, benefits, and limitations for training pre-flight tasks in a transport airplane. This is part of a larger FAA research effort to understand the characteristics of the emerging pilot workforce and various training and checking methods that might be effective for the emerging pilot workforce.

Method

Experimental Design

This effort evaluated interactive, immersive asynchronous eLearning using a VR headset and software to train general Airbus A320 flight deck orientation and operation of systems preflight tasks described in FAA Airline Transport Pilot Airman Certification Standards and FAA Advanced

Qualification Program (AQP) Job Task Listings Terminal Proficiency Objectives (TPOs) and Supporting Proficiency Objectives (SPOs) examples found in FAA Advisory Circular 120-54A Advanced Qualification Program.

The control group used a combination of traditional classroom lectures and simulator sessions in a Flight Deck Solutions Airbus A320 Procedures Trainer to learn system preflight tasks. In contrast, the experimental groups used VR Pilot A320 flight deck procedural trainer software installed on Oculus Meta Quest 2 virtual reality headsets to learn and rehearse tasks in a guided virtual environment. One experimental group used VR to augment classroom and simulator training; the other used VR to augment classroom training and used VR as a replacement for simulator training. The three groups are summarized below.

- Control group: access to traditional classroom training and simulator training.
- Experiment group #1: access to classroom training, simulator training, and VR on a head-worn device to augment baseline classroom and simulator training.
- Experiment group #2: access to classroom training, no simulator training, and VR on a head-worn device as a replacement for simulator training.

Tasks instructions were presented in two modules developed for this project, based on two aircraft preflight checklist procedures, Preliminary Flight Deck Prep (Module 1) and Flight Deck Prep (Module 2), outlined below.

Module 1 TPO is Preliminary Flight Deck Prep and includes 7 SPOs (with 29 subtasks):

1. Aircraft setup (5 subtasks)
2. Batteries, external power (2 subtasks)
3. APU fire test, start (5 subtasks)
4. Cockpit lights (1 subtask)
5. EFB initialization (3 subtasks)
6. Aircraft acceptance (4 subtasks)
7. Before walkaround (9 subtasks)

Module 2 TPO is Flight Deck Prep and includes 5 SPOs (with 46 subtasks):

1. Overhead panels (15 subtasks)
2. Center instrument panel (4 subtasks)
3. Pedestal (12 subtasks)
4. Glare shield (6 subtasks)
5. Lateral console, instrument panel (9 subtasks)

Sample

The population for this study was *ab-initio* civilian pilot students enrolled in the Auburn University School of Aviation, a 14 CFR Part 141, FAA R-ATP approved institution, who have completed their instrument rating as a minimum, are working towards or completing the commercial certificate and multi-engine rating and enrolled in the AVMF 4320 AIRLINE TRANSPORT CATEGORY SYSTEMS AND PROCEDURES capstone course. This course is a 4-credit (3 classroom hours + 1 lab hour) course focusing on Airbus A320 systems and operational procedures and 14 CFR Part 121 air carrier flight and crew management. Procedural content presented in Modules 1 and 2 were not previously taught in this course and were added for this study. AVMF 4320 students are members of the

emerging pilot workforce. They will join the 14 CFR Part 121 air carrier pilot workforce upon reaching as little as 1,000 flight hours, typically within 12-18 months of graduating from Auburn University.

To increase the number of research participants, the study spanned two semesters of AVMF 4320. The baseline control group included Fall semester 2022 AVMF 4320 students. The experimental groups included students from the Spring semester 2023 AVMF 4320 course. Spring AVMF 4320 sim blocks were predesignated (before student signup) for Module 1 and Module 2 instruction methods, either using head-worn VR devices to augment classroom and simulator training (experimental group #1) or classroom with no simulator training and VR head-worn device as a replacement for simulator training (experimental group #3). Participants self-selected their AVMF 4320 simulator schedule based on their academic schedule, not knowing which experimental group they would be assigned to. All students had approximately two weeks to learn Modules 1 and 2 before being evaluated. 26 students opted into the study, beginning with 7 in the control group, 10 in experimental group #1, and 9 in experimental group #2. Four students in experimental group #2 opted not to complete the field test, leaving a total of 22 participants who completed the field test.

Tools

The VR device was the Oculus Meta Quest 2 virtual reality headset, a fully mobile, wireless/untethered, all-in-one VR system (headset and two controllers) that allows the user to train anywhere, anytime. A personal computer (PC) or console was not required. This system is inexpensive to purchase compared to higher-end VR devices and is widely available for approximately $399. The US Navy used an earlier version of this system in their Project Avenger VR study (Mishler et al., 2022). The Meta Quest 2 VR system weighs about four pounds, uses a Fast-Switch LCD Display, has 1832 x 1920 resolution per eye, and supports 60 Hz, 72 Hz, or 90 Hz refresh rates. This system is eyeglass compatible and uses six degrees of freedom tracking. The headset tracks the movement of both head and body, then translates them into VR with realistic precision.

The experimental groups used VRflow software developed by VRpilot. The VRflow A320 provides a 3D virtual flight deck that responds and behaves like a real aircraft (including sounds, lights, screens, etc.) to provide the user with a realistic training environment. VRflow provides “learning” and “exam” modes to guide procedural learning and check if the procedure has been learned correctly. VRflow provides student feedback on procedure performance and shows the time taken to complete the procedure. Training content is stored locally on the VR device and can be transmitted to a learning management system (LMS) with Wi-Fi connectivity or collected manually. VR headsets were managed using the ManageXR platform and “locked down” to prevent other software use on the VR devices. Devices were distributed at the beginning of the AVMF 4320 course, along with a quick start VR user’s guide developed by a graduate student.

The Flight Deck Solutions Airbus A320 Procedures Trainer simulator is a spatially correct, functionally accurate, precise tactile feel flight deck with an instrument panel, glare shield, aisle stand, primary and aft overhead, flight controls shell/interior, and crew/observer seating. The flight deck is integrated with a Q4 Services SupraVue Collimated 10’ dome visual system (Level D compliant), ProsimA320 Aviation Research Professional Suite flight data package, and Lockheed Martin’s Prepar3D Pro Plus imaging system. The trainer uses Brunner control loaded rudders and a sound system with dual 800-watt subwoofers and custom surround sound to simulate accurate and directional wind noises, vibrations, engine sounds, and aerodynamic drag. This A320 procedures trainer is FAA Level 4 compliant but not FAA-certified since Auburn University does not type-certify students in the A320. The simulator is used primarily for human factors training focusing on crew resource management (CRM) using Line Oriented Flight Training (LOFT) scenarios.

Data Collected

Participants took a pretest to measure A320 systems and procedures knowledge and a pretest survey to collect the following information:

1. Demographics
2. Flight experience
3. Career pathway program participation
4. VR experience
5. Gaming experience
6. Inventory of Learning Styles
7. Eyeglasses or contact lenses use.

Control and experimental group participants participated in a modified Line Oriented Simulation (LOS) in a Level 7 Flight Simulation Training Device (FSTD) at a partner 14 CFR Part 121 air carrier using Aircrew Program Designees (APDs) as evaluators. The APDs used grading sheets for each module, developed by the researchers, based on modified AQP grading criteria (2 – not proficient (error not managed), 3 – competent (managed error), 4 – proficient (no errors)) to evaluate individual task proficiency and the overall performance of experimental and control group members. APDs were blind to the training intervention and did not know whether the participants they evaluated were from an experimental or control group. Airbus Original Equipment Manufacturer (OEM) A320 procedures were used to standardize all devices' training and evaluations.

The experimental groups had an early morning LOS and spent the night near the air carrier's training center to minimize fatigue. The control group used one FSTD, and the experimental group used two FSTDs simultaneously for evaluations. APDs initialized the flight deck the same for each participant's LOS, with either a graduate assistant or faculty member familiar with A320 aircraft procedures in the left seat and the research participant sitting in the right seat. Participants performed both checklists alone initially at their own pace. When complete with the checklist, the individual in the left seat read the checklist with challenge and response. As researchers observed, air carrier APDs scored task performance during each participant's LOS. Researchers collected LOS scores from the APDs and recorded the time to task completion.

Following the LOS, participants completed a post-test survey to capture user experience data:

1. Self-confidence in execution (Likert, 1-7)
2. Time (hours) spent studying to feel confident in the procedural ability
3. Perceived difficulty (Likert, 1-7)
4. Intrinsic motivation inventory (Isen & Reeve, 2005)
5. Simulator Sickness Questionnaire (SSQ) (Kennedy, Lane, Berbaum, & Lilienthal, 1993)
6. VR experience questionnaire

Results

Data Analysis

A series of Kruskal-Wallis tests were used to determine if there was a difference in Preliminary Flight Deck Prep and Flight Deck Prep task performance and combined task completion time based on training method (Classroom and Simulator Training, Classroom and Simulator Training with VR to augment, and Classroom with No Simulator Training and VR as a replacement for Simulator Training). Preliminary Flight Deck Prep task performance by training method is shown in Table 1, Flight Deck Prep

task performance by training method is shown in Table 2, and combined task completion time by training method is shown in Table 3.

Table 1

Preliminary Flight Deck Prep Task Performance by Training Method.

Preliminary Flight Deck Prep Task Performance Score	*M*	*SD*	*n*	*df*	*H*	*p*
Classroom and Simulator Training	3.80	.11	7	2	2.81	.246
Classroom, Simulator, and VR Training	3.69	.12	10			
Classroom, No Simulator, and VR Training	3.62	.24	5			

Note: N = 22

Table 2

Flight Deck Prep Task Performance by Training Method.

Flight Deck Prep Task Performance Score	*M*	*SD*	*n*	*df*	*H*	*p*
Classroom and Simulator Training	3.77	.14	7	2	1.31	.519
Classroom, Simulator, and VR Training	3.75	.09	10			
Classroom, No Simulator, and VR Training	3.62	.21	5			

Note: N = 22

Table 3

Combined Task Completion Time by Training Method.

Combined Task Completion Time (Minutes)	*M*	*SD*	*n*	*df*	*H*	*p*
Classroom and Simulator Training	13.27	2.11	7	2	5.54	.063
Classroom, Simulator, and VR Training	15.37	1.65	10			
Classroom, No Simulator, and VR Training	18.39	4.52	5			

Note: N = 22

Discussion

All groups learned the required tasks and had mean scores between the competent and proficient levels. No significant difference was found in Preliminary Flight Deck Preparation task performance based on the training method ($H(2) = 2.81$, $p = .246$), Flight Deck Preparation task performance based on the training method ($H(2) = 1.31$, $p = .591$), or the task completion time ($H(2) = 5.54$, $p = .063$).

Conclusion

Preliminary task performance results indicate that all three types of training were equally effective, suggesting Virtual Reality (VR) Head-mounted Displays (HMDs) may have value in learning commercial aircraft preflight task procedures. Further data analysis, including user experience, is forthcoming.

Acknowledgments

This research is derived from a more extensive research effort sponsored by the Federal Aviation Administration (FAA) through an aviation research grant with the Center of Excellence for Technical Training and Human Performance. The views expressed herein are those of the authors and do not reflect the views of the United States (U.S.) Department of Transportation (DOT), the FAA, or Auburn

University. The authors thank the FAA and our various industry and airline partners for their generous support of this research effort.

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