

Cover Page for ClinicalTrials.gov

Study Protocol

Effects of Simulator Motion Fidelity on Pilot Performance while using a Mixed-Reality Headset

NCT07129876

May 14, 2025

1. Title

Effects of simulator motion fidelity on pilot performance while using a mixed-reality headset.

2. Organizations and Study Location(s)

This research will be performed in the Simulation Research & Development Branch (Code AFS) at NASA Ames Research Center (ARC). Data collection will be conducted in the Vertical Motion Simulator (VMS) in building N-243 at ARC. A signed ARC476 form is attached to this submission.

3. Investigators

Principal Investigator: Peter M. T. Zaal, Ph.D. (Metis Technology Solutions, Inc.)

Co-Investigator and Simulator Operator: Matt L. Blanken (NASA Ames Research Center)

Co-Investigator and Simulator Operator: Sam P. Orth (Symvionics, Inc.)

Co-Investigator and Simulator Operator: Supreethi V. Penmetcha (NASA Ames Research Center)

4. Purpose

The purpose of this research is to investigate how different levels of simulator motion fidelity affect pilot performance in two different flight tasks while using a head mounted display (or mixed-reality headset) for out-the-window (OTW) visuals. Three levels of motion fidelity will be studied: 1) no motion, 2) small hexapod motion, and 3) one-to-one vehicle motion.

5. Background

This is a ground-based study.

Virtual reality (VR) technologies have been a topic of research for decades. In fact, one of the first VR head mounted displays (HMD) was developed at NASA Ames Research Center in 1985 [1]. In addition, there is a rich history of training astronauts with VR at NASA Johnson Space Center [2]. In the last decade, virtual- and mixed-reality (MR) technologies have seen major advancements and are now readily available to consumers due to products from major technology companies. Furthermore, VR and MR are increasingly used in flight simulators and training devices for pilot training, and training facilities are keen on increasing the use, due to the lower cost and smaller footprint of HMD systems compared to conventional visual systems.

Even though VR/MR technologies have improved significantly in recent years, and issues including eye fatigue have been greatly reduced by implementing technologies such as eye tracking and foveated rendering, limitations like reduced visual acuity remain. In addition, the implications of using VR/MR for pilot training are still largely unknown as research is limited. Specific gaps in knowledge include:

1. The effects of VR/MR on pilot wellbeing and, in turn, the quality of training, are largely unknown. For example, nausea and other discomfort are experienced significantly more using HMDs compared to conventional visual systems.

2. The effects of the quality of the visual cues are still largely unknown. This includes characteristics such as brightness, resolution, and field of view. Research on these characteristics in the context of pilot performance have been investigated for conventional displays, but results might not directly transfer to HMDs.
3. Guidelines for the fidelity of physical motion needed with VR/MR and the synchronization of HMD visuals with physical motion for effective pilot training have not been researched.

The last two gaps in knowledge are specifically important in the training of skill-based tasks, like manually flying an aircraft, where the quality and synchronization of visual and motion cues affect performance [3]. Due to these gaps in knowledge, very limited regulatory standards for using VR/MR in training programs currently exist, which limits the use of the technology for training. Regulations that do exist focus on helicopter simulation and use conventional visual systems as the norm [4]. In addition, in cases where HMD technologies can be used for training, the quality of the training could potentially be reduced compared to the current standards due to our lack of knowledge.

This experiment will add data to gap 3 and will provide the first insights into motion fidelity requirements in VR/MR simulation.

6. Why Human Research is Required

The goal of this study is to determine differences in pilot performance between different simulator motion conditions while wearing an HMD for displaying OTW visuals. Pilot performance effects can only be investigated using human subjects in an experimental setting, as no accurate computational models of human behavior and performance under these conditions exist.

7. Conflict of Interest

Do any of the participating study investigators or other research personnel (or their immediate family/significant other) have a financial and/or intellectual property interest in the sponsor or products used with this project?

____ Yes ☒ No

8. Plan of Study

8.1 Protocol Overview

The aim of this study is to determine the effects of simulator motion fidelity on pilot performance in two demanding piloting tasks while wearing a mixed-reality headset for OTW visuals. Pilots will be exposed to mixed-reality visuals (Figure 1) meaning that the virtual OTW visual scene will be overlaid on an image of the real simulator cockpit and head down displays (HDD). Figure 2 shows an example of a location in the virtual OTW scene that will be displayed

in the headset. Pilots will fly two tasks in this experiment: 1) a roll-lateral sidestep maneuver, and 2) a precision landing.

In task 1, the roll-lateral sidestep maneuver will be from one landing pad to a second landing pad (gray/white areas in Figure 2) of a vertiport on the Fifth & Mission Parking Garage in San Francisco. The vertiport is in a San Francisco visual database surrounded by buildings with high-resolution textures. Pilots are instructed to stay at a constant altitude. A positioning sight will be placed in the visual scene at each landing pad to allow pilots to determine their positioning error precisely. Pilots will be provided with lateral position and time criteria for desired and adequate performance. Pilots will be instructed to press an event marker on their control inceptor when they acquire the station-keeping point at the landing pad. Turbulence will be used to make the task more difficult. This task will be similar to the roll-lateral experiment described by Schroeder [5] that was also performed in the VMS.

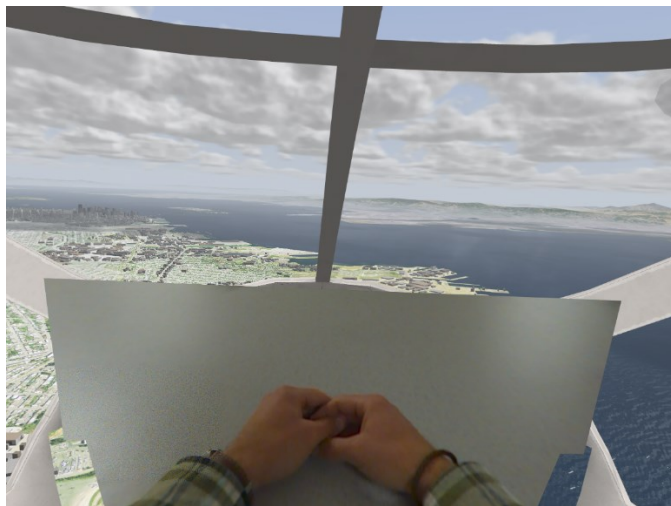


Figure 1 Example of the mixed-reality visuals showing the virtual out-the-window scene and a passthrough of the real environment.

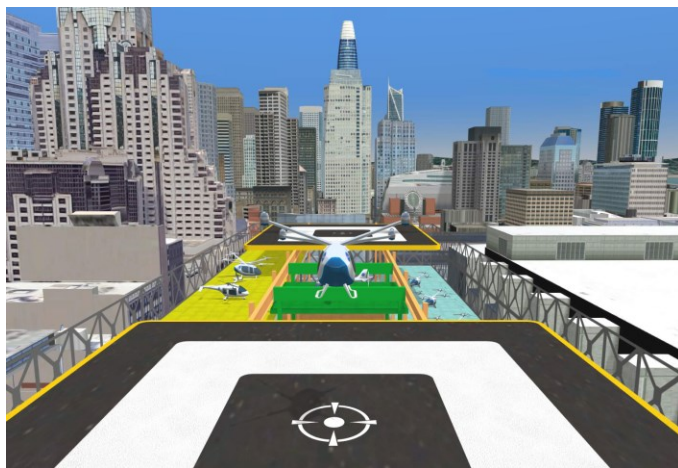


Figure 2 Virtual out-the-window scene showing the Fifth & Mission Parking Garage with vertiport in San Francisco.

In task 2, pilots will perform a landing at the same vertiport in San Francisco that is used in task 1. The task will start from level flight from a position that allows for a standard approach and landing. Landing position and time criteria for desired and adequate performance will be communicated to the pilots. Pilots will press an event marker on the control inceptor when they acquire the desired reference point on the landing pad. Turbulence will be introduced to make the task more difficult.

Pilots will receive the informed consent form and a Motion Sickness Susceptibility Questionnaire (MSSQ) via email first. They will be asked to fill out the MSSQ at home and return it to the PI before being scheduled and coming to the VMS. On the day of the experiment, participants will first receive a briefing and walkaround of the facility before providing their informed consent (60 minutes). Next, they will take a seat in the simulator cab where seat and headset adjustments will be made first to make sure the experiment can be performed comfortably. This is followed by the first data-collection session in which one of the tasks is flown (45 minutes). Both tasks will be flown under three motion fidelity conditions described in Section 8.3 below. Three repetitions of each motion condition will be flown for both tasks, after completing three training runs, for a total of 12 runs per task. A 30-minute break is scheduled after the first data-collection session. The second session in which the other task is flown will commence after the break (45 minutes). Finally, pilots will be debriefed and can ask any remaining questions (30 minutes).

Pilot performance in each task will be determined by several outcome-based variables, including the error between desired and actual aircraft position and attitude at specified locations, the intensity of control inputs, and task completion time. Pilots will also complete a motion fidelity rating [5] and a Simulator Sickness Questionnaire (SSQ) [6] at the end of each run (see Appendix A).

Hypothesis: Pilot performance and subjective motion ratings will be significantly different between the different simulator motion fidelity conditions.

Before data analysis, all data will be averaged over the three repetitions of each condition. A one-way repeated-measures Multivariate Analysis of Variance (MANOVA) will be used on the data from each task to determine statistically significant effects. If test assumptions are not met (e.g., homogeneity of covariance matrices), corrections or appropriate alternate tests will be used. Any reporting of the statistical results will include the F statistic (or equivalent for alternate tests), degrees of freedom, probability values, and effect sizes.

Based on previous studies investigating the effects of motion fidelity on pilot performance, it is expected that pilot performance will be lower without simulator motion or with small-hexapod motion compared to one-to-one vehicle motion [3]. Control intensity will show the opposite trend; that is, will be higher without simulator motion and will decrease with higher motion fidelity.

8.2 Equipment

Data collection will take place in the VMS (<https://www.nasa.gov/simlabs/vms>), the largest vertical motion simulator in the world. The VMS provides motion in all three rotational and all three translational degrees-of-freedom. Its vertical and lateral motion range are 60 ft and 40 ft, respectively. This study will use the Rotorcraft Cab (R-Cab) with a single seat. Two sidesticks, positioned on the left and right sides of the seat, will be used for controlling a lift-plus-cruise electrical vertical takeoff and landing (eVTOL) vehicle (Figure 3). The vehicle accelerations will drive the motion system of the simulator. HDDs will be positioned in front of the pilot providing primary flight and navigation information.



Figure 3 Visual presentation of the simulated lift-plus-cruise electrical vertical takeoff and landing vehicle.

OTW visuals will be provided by a Varjo XR-4 mixed-reality headset worn on the pilot's head (Figure 4). The Varjo XR-4 (<https://varjo.com/products/xr-4-secure-edition/>) has a 4K mini-LED display per eye. The headset has a 120° x 105° field of view delivering full binocular range vision, and 200 nits of brightness and 1:10000 contrast ratio. 20-megapixel cameras on the outside of the headset facilitate mixed-reality simulation setups where real-world elements such as cockpits and HDDs can be merged with virtual content. The headset also features a built-in eye tracker with 200 Hz eye tracking to allow for foveated rendering; that is, the scene will be rendered at a higher resolution around where a user is looking. The weight of the headset is 1021 grams.



Figure 4 Varjo XR-4 mixed-reality headset.

An ART SMARTTRACK Dual-Camera Tracking Solution will be installed in the simulator cab for determining the location of the mixed-reality headset in the 3D environment. Pilots will not have to interact with the tracking system.

Pilots will wear David Clark noise-canceling headsets at all times allowing for direct communication with simulator operators.

8.3 Stimuli

The principal stimulus and independent variable in this experiment is the motion of the VMS cabin with three levels: 1) no motion, 2) small-hexapod motion, and 3) one-to-one vehicle motion. Pilots will not be told which motion condition will be present during any of the simulation runs to make sure pilots are not preconditioned. A visual presentation of the type of motion system the three levels of motion fidelity represent is provided in Figure 5. Note that all motion conditions will be flown in the VMS with its large motion system as depicted in Figure 5(c), but the motion settings will be different for each motion fidelity level. For the no-motion condition, the simulator motion system is turned on, and pilots and simulation operators will follow the same procedures as during a run with motion; however, the simulator will not move during the task.

Mixed-reality visuals will be provided by the Varjo XR-4 mixed-reality headset as described above. Background sound in the form of powertrain noise will be provided by speakers in the simulator cab but no other specific aural stimuli will be used.



(a) No motion.



(b) Small hexapod motion.



(c) One-to-one vehicle motion.

Figure 5 Visual presentation of the three motion fidelity conditions in the experiment.

8.4 Prior to Runs

Pilots local to NASA Ames will be recruited for the experiment with an email announcement sent by the PI. The email announcement will include a recruitment flyer with the following requirements for participation:

1. Be 18 years or older.
2. Be in general good health.
3. Have normal or corrected to normal vision.
4. Not have claustrophobia.
5. Not be susceptible to motion sickness.

Individuals who confirm by email that they would like to participate and meet the study inclusion/exclusion criteria posted in the recruitment flyer will be contacted by the PI and will be offered to discuss the study protocol in more detail via telephone or Teams. If they remain interested in participating in the study, the pilots will be emailed an electronic copy of the consent form and a short form Motion Sickness Susceptibility Questionnaire (MSSQ) [7]. Pilots are asked to return the completed MSSQ to the PI via email. The pilot's MSSQ score will serve as confirmation of their self-identified susceptibility to motion sickness as confirmed in their response to the inclusion/exclusion criteria. At this time, pilots will also be given a schedule with open time slots to schedule their participation.

On the day of the experiment, pilots will receive an experiment briefing in the pilot ready room adjacent to the VMS. The briefing will include an explanation of the post-run questionnaires. Pilots will be encouraged to discuss the protocol and details of the study with the investigators. They will also be provided the opportunity to view the VMS facility and the R-Cab prior to reconfirming their informed consent by physically signing their informed consent form. Pilots will also be asked to complete a short demographics questionnaire. Before data collection starts, pilots will receive a safety walkaround by the simulator motion operator.

8.5 Experiment Design

This experiment will collect prospective data from participants (outcome-based performance metrics and questionnaire responses) obtained consequent to experimental manipulation in the form of different simulator motion fidelity conditions.

The study has a within-subjects repeated-measures design, with each participant performing two tasks under three levels of the independent variable: motion fidelity. Tasks will be completed consecutively. The order of the tasks will be randomized for each pilot. The order of the simulator motion fidelity conditions for each task will be randomized using a Latin square design (independent variable level vs repetition).

Every task will start with a training session consisting of three training runs to make pilots familiar with the task criteria and procedures. The training runs will all be flown with one-to-one motion (Figure 5(c)). After training, each motion condition will be repeated three times for a total of nine measurement runs.

8.6 Data Protection

All participant data will be coded using a code assigned to each participant prior to data collection. Therefore, no stored test data will contain identifiable information. A datasheet linking participant names with their codes will be stored on the Principal Investigator's password-protected NASA computer. All test data will be collected, stored, and analyzed on password-protected NASA computers protected per NASA data security procedures. If a participant withdraws from the experiment or is not able to complete the experiment, their non-identifiable run data will be preserved but will not be used in the data analysis.

Only aggregate summary data or coded raw data will ever be shared or made public for any subsequent analyses or for publication. The results of the research or any resulting statistics will not be made available in a form that could indirectly identify individuals (e.g., age will be used, not birth dates).

All stated precautions will be taken to protect confidentiality, but there remains a small risk that confidentiality could be breached.

9. Proposed Test Schedule

The study is currently planned to run from May 19 to June 2, 2025. Participants will complete the experiment in no more than 3.5 hours, including the briefing and breaks between sessions. This means two participants can participate on one day, the first in the morning, and the second in the afternoon. The cadence of participant testing will depend on pilot availability which means no pilot or only one pilot will be tested on some days. Pilots' sessions will be scheduled so that only one test participant will be present at a time.

10. Practical Aspects of Safety and Ethical Conduct

This study is minimal risk.

The VMS has been used in many piloted simulation experiments and training. The simulator is rated for human occupancy and contains many levels of safety. For every simulation, standard operating procedures, including all safety procedures, are always followed. In case of motion sickness or any other discomfort, the participant can stop the simulation at any time either by requesting so verbally or by the push of a button in the simulator cab. Note that pilots still have visibility in the cab and can see the control inceptors and their hands since the HMD is used in a mixed-reality mode, allowing them to easily locate any buttons. In addition, the PI, simulator engineer, and motion operator can stop the simulation if necessary. Because on-site medical monitoring has not been required for prior VMS studies, the Medical Monitor will instead be available on call during testing days.

The range of motion conditions in this experiment has been used in previous VMS studies with standard OTW visuals without participants experiencing any significant motion sickness. However, since VR visuals are known to have an increased chance of inducing motion sickness, pilots will fill out the SSQ at the end of each run to determine their level of motion sickness. In addition, pilots will be instructed to terminate the session if they feel overly uncomfortable due to motion sickness or any other reason. Sickness bags are available in the simulator cab.

If participants experience motion sickness during the experiment, they will be instructed to remain at the facility for no less than 30 minutes following the last simulation run to ensure that there are no significant post-exposure symptoms.

11. Number, Source, and Pertinent Characteristics of Participants

The study population will consist of helicopter pilots and does not include astronauts. Data will be required from up to 10 participants to complete the full protocol. Up to 15 participants may be recruited to allow for any dropouts.

G*Power version 3.1 was used to calculate the sample size for the proposed study. Effect sizes (determined by the partial eta squared, η_p^2) in previous work [8, 9] were often well above 0.14 which is a benchmark for a large effect size [10, 11]. To be conservative, an effect size of $\eta_p^2 = 0.14$ (which corresponds to an effect size $f = \sqrt{\eta_p^2 / (1 - \eta_p^2)} = 0.4$ as used by G*Power) was chosen to calculate the required sample size [11]. The correlation amongst dependent measures in previous similar research was not reported; however, it is known that the different performance metrics used in this study are highly correlated. For example, if overall performance, as indicated by several performance metrics, increases with higher fidelity motion, control intensity decreases [3]. For this reason, the correlation between measures was assumed to be 0.7 in the power analysis. Using a probability of making a Type I error $\alpha = 0.05$, and a probability of making a Type II error $\beta = 0.2$ (that is, a power of 0.8), the required total sample size is calculated to be 10 (Figure 6).

Participants should be in general good health and have normal or corrected to normal vision. There are no restrictions for age (other than being 18 years or older) and sex. The MSSQ will be used to evaluate susceptibility to motion sickness. Pilots that have a higher susceptibility to motion sickness will be discouraged from participating. Because each pilot will be seated alone

in the closed VMS cabin, with an internal volume comparable to a small aircraft cockpit, we will exclude pilots who self-identify as having claustrophobia from the study.

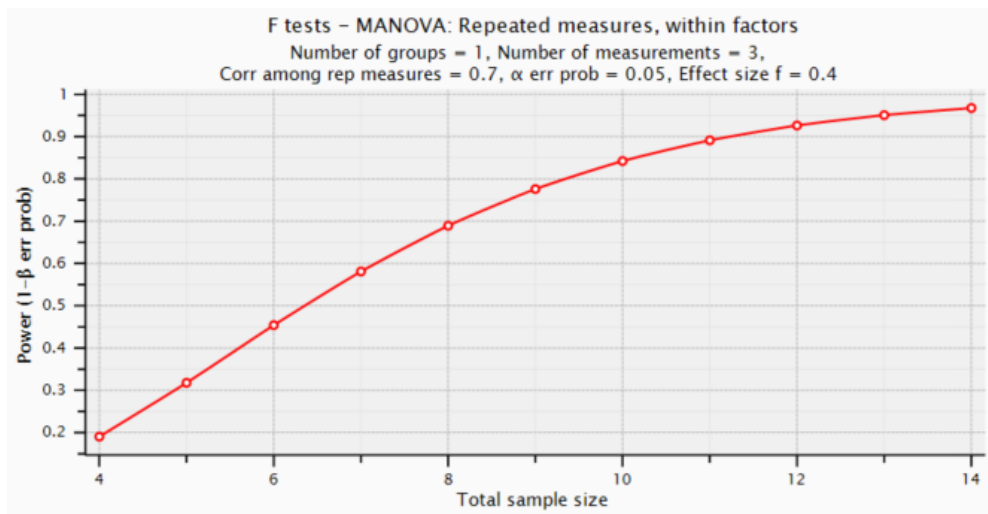


Figure 6 Relationship between sample size and statistical power.

12. Benefits of Participation

No benefits will accrue to the individual participant. Participants' data will help inform the use of simulator motion in future simulation studies and training with mixed-reality headsets.

13. Possible Inconveniences, Discomfort, Pain, and Risks to the Participants

There is a small risk of some degree of motion sickness, including a risk of vomiting, in this study due to the use of VR visuals with simulator motion. Otherwise, the experimental procedures are non-invasive, and should not cause pain or other discomfort, or risk to participants.

There is a risk that terminating a study run due to motion sickness may cause some embarrassment or emotional discomfort.

There is a small risk of claustrophobia.

There is very small risk of VMS malfunction.

Although all stated precautions will be taken to protect confidentiality, there remains a small risk that confidentiality could be breached. A breach of confidentiality may cause some embarrassment or emotional discomfort depending on achieved task performance and experienced motion sickness during the experiment.

Currently there are no known risks to a pregnant female and a fetus for this protocol. However, unknown adverse fetal events may occur, even in the absence of maternal symptoms.

14. Measures Taken to Minimize Discomfort and Risks

In case of motion sickness or any other discomfort (including claustrophobia), the participant can stop the simulation at any time either by requesting so verbally or by the push of a button on the inceptor. In addition, the investigators, simulator engineer, and motion operator can stop the simulation when necessary.

To reduce the risk and severity of motion sickness the following measures are taken to limit the duration and magnitude of nauseogenic stimuli: 1) being susceptible to motion sickness is an exclusion criterion in the recruitment flyer (pilots must self-identify as not being susceptible and confirm with the PI), 2) participants will be instructed to request that the simulated flight session be terminated when they start to feel nauseous, and 3) the SSQ responses will be monitored by the investigators and the study will be terminated if there is an indication of increasing motion sickness.

The risk of claustrophobia is mitigated by using being claustrophobic as an exclusion criterion in the recruitment flyer. Pilots must self-identify as not being claustrophobic and confirm with the PI. Further, should unanticipated claustrophobia be discovered once onboard the VMS, participants are instructed to ask immediately to be released from the cabin and stop participation in the study.

During the informed consent process, participants will be briefed by the investigator on all anticipated risks and discomforts that may occur during the study. Participants will be informed that they may talk with the PI or Medical Monitor at any time during the study. The participant will be informed that they can discontinue any activity including responding to questionnaires if it causes any discomfort. Participants will also be informed that they are free to withdraw from the experiment at any time for any reason, regardless of whether they choose to reveal the reason.

The investigators have completed ethics training and is aware of the need to make individuals feel comfortable and of the importance of maintaining discretion when discussing potentially embarrassing information. If participants experience any emotional discomfort or embarrassment, they will be encouraged to inform the investigators.

The VMS has been used in many pilot evaluation studies in the past. The VMS's standard operating procedures (SOP), including all safety procedures, are always followed for all motion simulations. Further, the simulator engineer and motion operator can stop the simulation whenever necessary.

15. Conditions of Withdrawal from the Experiment

Participation is voluntary. Participants will be informed in the study description provided for informed consent that they are free to withdraw from the experiment at any time for any reason, whether or not they choose to reveal the reason. Participants will not be penalized or disadvantaged in any way for such a withdrawal.

16. Remuneration for Participants

Helicopter pilots local to NASA Ames will be recruited for the experiment. If pilots participate during normal work hours, they must ask for permission from their supervisor. Pilots will not receive any remuneration for their participation in the experiment.

17. Compensation in the Event of Injury

In the event of injury or illness resulting from this study and calling for immediate action or attention, NASA will provide, or cause to be provided, the necessary treatment. If eligible for Workers' Compensation benefits while participating in this study, participants cannot sue their employer because the law makes Workers' Compensation their only remedy against their employer. Participants may have other remedies against other persons or organizations, depending on the circumstances of the injury. NASA will pay for any claims of injury, loss of life or property damage to the extent required by Federal Employees Compensation Act or the Federal Tort Claims Act.

18. Consent Process

Pilots who confirm by email that they meet the screening criteria in the recruitment flyer will be provided a copy of the informed consent form and the MSSQ. After sending back their filled out MSSQ, the MSSQ score will allow for an extra confirmation of their motion sickness susceptibility. Next, if pilots still meet all the screening criteria, they will be invited to the VMS building to participate in the experiment.

The experiment session will start in the pilot-ready room adjacent to the VMS, where, after a briefing, pilots will be encouraged to discuss the protocol and details of the study with the investigator. They will also be provided the opportunity to view the VMS facility and the simulator cab prior to providing their informed consent.

As a final step before starting data collection, pilots provide their informed consent. Informed consent will be obtained in person by the PI.

Participants are free to withdraw their consent at any stage of the study, whether they are on board the VMS or in between study sessions. In withdrawing their consent, participants will stop any involvement in the study and their data will not be used in any analyses.

19. References

- [1] "A New Continent of Ideas," *Spinoff* 1990, pp. 88-91, 1 January 1990.
- [2] A. D. Garcia, J. Schlueter and E. Paddock, "Training Astronauts using Hardware-in-the-Loop Simulations and Virtual Reality," in *Proceedings of the AIAA Scitech 2020 Forum*, Orlando, 2020.
- [3] J. A. Schroeder and P. R. Grant, "Pilot Behavioral Observations in Motion Flight Simulation," in *AIAA Guidance, Navigation, and Control Conference and Exhibit (August 2-5, 2010)*, 2010.

- [4] EASA, "FSTD Special Conditions for the use of Head Mounted Displays (HMD) combined with a motion platform with reduced envelope," European Union Aviation Safety Agency (EASA), 2023.
- [5] J. A. Schroeder, "Helicopter Flight Simulation Motion Platform Requirements," National Aeronautics and Space Administration, NASA/TP-1999-208766, Moffett Field, 1999.
- [6] R. S. Kennedy, N. E. Lane, K. S. Berbaum and M. G. Lilienthal, "Simulator Sickness Questionnaire: An Enhanced Method for Quantifying Simulator Sickness," *The International Journal of Aviation Psychology*, vol. 3, no. 3, pp. 203-220, 1993.
- [7] J. F. Golding, "Predicting Individual Differences in Motion Sickness Susceptibility by Questionnaire," *Personality and Individual Differences*, vol. 41, no. 2, pp. 237-248, 2006.
- [8] F. M. Nieuwenhuizen, K. A. Beykirch, M. Mulder and H. H. Bulthoff, "Identification of Pilot Control Behavior in a Roll-Lateral Helicopter Hover Task," in *AIAA Modeling and Simulation Technologies Conference and Exhibit*, Hilton Head, 2007.
- [9] P. M. T. Zaal, J. A. Schroeder and W. W. Chung, "Objective Motion Cueing Criteria for Commercial Transport Simulators," in *AIAA Modeling and Simulation Technologies Conference (June, 2018)*, 2018.
- [10] D. Lakens, "Calculating and Reporting Effect Sizes to Facilitate Cumulative Science: A Practical Primer for t-tests and ANOVAs," *Frontiers in Psychology*, vol. 4, pp. 1-12, 2013.
- [11] J. Cohen, *Statistical Power Analysis for the Behavioral Sciences*, New Jersey: Lawrence Erlbaum Associates, Inc., 1988.

Appendix A: Post-Run Questionnaires

Pilots will fill out the motion fidelity ratings scale and Simulator Sickness Questionnaire (SSQ) provided below at the end of each run.

Fidelity rating	Definition
High	Motion sensations are like those of flight
Medium	Motion sensations are noticeably different from flight, but not objectionable
Low	Motion sensations are noticeably different from flight and are objectionable

Figure 7 Motion fidelity rating scale.

(circle severity of each symptom below)

1. General discomfort	None	Slight	Moderate	Severe
2. Fatigue	None	Slight	Moderate	Severe
3. Headache	None	Slight	Moderate	Severe
4. Eye strain	None	Slight	Moderate	Severe
5. Difficulty focusing	None	Slight	Moderate	Severe
6. Salivation increasing	None	Slight	Moderate	Severe
7. Sweating	None	Slight	Moderate	Severe
8. Nausea	None	Slight	Moderate	Severe
9. Difficulty concentrating	None	Slight	Moderate	Severe
10. Fullness of the Head	None	Slight	Moderate	Severe
11. Blurred vision	None	Slight	Moderate	Severe
12. Dizziness with eyes open	None	Slight	Moderate	Severe
13. Dizziness with eyes closed	None	Slight	Moderate	Severe
14. Vertigo	None	Slight	Moderate	Severe
15. Stomach awareness	None	Slight	Moderate	Severe
16. Burping	None	Slight	Moderate	Severe

Figure 8 Simulator Sickness Questionnaire.

Appendix B: Motion Sickness Susceptibility Questionnaire

Pilots will fill out the Motion Sickness Susceptibility Questionnaire below before the start of the experiment.

	Not applicable - never travelled	Never felt sick	Rarely felt sick	Sometimes felt sick	Frequently felt sick
Your CHILDHOOD Experience Only (before 12 years of age), for each of the following types of transport or entertainment please indicate:					
1. As a CHILD (before age 12), how often you Felt Sick or Nauseated (tick boxes):					
Cars					
Buses or Coaches					
Trains					
Aircraft					
Small Boats					
Ships, e.g., Channel Ferries					
Swings in playgrounds					
Roundabouts in playgrounds					
Big Dippers, Funfair Rides					
	t	0	1	2	3
Your Experience over the LAST 10 YEARS (approximately), for each of the following types of transport or entertainment please indicate:					
2. Over the LAST 10 YEARS , how often you Felt Sick or Nauseated (tick boxes):					
Cars					
Buses or Coaches					
Trains					
Aircraft					
Small Boats					
Ships, e.g., Channel Ferries					
Swings in playgrounds					
Roundabouts in playgrounds					
Big Dippers, Funfair Rides					
	t	0	1	2	3

Source: Adapted from Golding JF. Predicting individual differences in motion sickness susceptibility by questionnaire. *Pers Individ Dif* 2006;41:237–248.⁴⁸

Note: This questionnaire is designed to find out how susceptible to motion sickness you are, and what sorts of motion are most effective in causing that sickness. Sickness here means feeling queasy or nauseated or actually vomiting.

Figure 9 Motion Sickness Susceptibility Questionnaire.