Spatial Navigation Transfer Evaluation Toolkit

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14. ABSTRACT
The training transfer study focused on a group of student navigators at HS-10 (San Diego, California) preparing for their first operational rotary wing tactical overland flight, aimed at developing and utilizing terrain association skills. In order to assess the training transfer effectiveness of the VEHELO, a set of outcome and process metrics for a spatial terrain association task was specified. As VE training effectiveness has been found to be dependent on individual difference variables such as spatial ability (Waller, 1999), several additional standardized metrics were utilized to assess process measures, including spatial ability (Ekstrom, French, & Harman, 1976), navigation skill (Hegarty, Richardson, Montello, Lovelace, & Subbiah, 2002), workload (Hart & Staveland, 1988), self-efficacy (Scott, 2000), and simulator sickness (Kennedy, Lane, Berbaum, & Lilienthal, 1993). To assess terrain association skill, a test was developed in which participants were asked to correlate out-the-window views with topographical maps and vice versa.

15. SUBJECT TERMS
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Executive Summary

The current effort focused on providing a Transfer of Training (ToT) framework, as this method provides rigor in assessing training transfer from an experimental design perspective (Lathan et al., 2002). The first step was to develop a VE-based spatial knowledge acquisition task with specific training objectives. From this, both *outcome* measures to illustrate performance effects through exposure to VE training and *process* metrics to better understand these effects were developed, and finally, a training transfer study was designed. The goal of this report is to present the research design and a set of performance measures as a toolkit for conducting similar studies. Preliminary results are presented, though no statistical analyses were conducted.

The training transfer study focused on a group of student navigators at HS-10 (San Diego, California) preparing for their first operational rotary wing tactical overland flight, aimed at developing and utilizing terrain association skills. A virtual environment helicopter (VEHELO) was designed to allow practice of these skills. In order to assess the training transfer effectiveness of the VEHELO, a set of outcome and process metrics for a spatial terrain association task (e.g., ability to correlate topographical map features to out-the-window views) was specified (see Table 2). As VE training effectiveness has been found to be dependent on individual difference variables such as spatial ability (Waller, 1999), several additional standardized metrics were utilized to assess process measures, including spatial ability (Ekstrom, French, & Harman, 1976), navigation skill (Hegarty, Richardson, Montello, Lovelace, & Subbiah, 2002), workload (Hart & Staveland, 1988), self-efficacy (Scott, 2000), and simulator sickness (Kennedy, Lane, Berbaum, & Lilienthal, 1993). To assess terrain association skill, a test was developed in which participants were asked to correlate out-the-window views with topographical maps and vice versa. Landmark recognition was assessed by asking participants to watch a video clip of the flight and to identify terrain features they recognized. Global positioning data (GPS) and flight communications were collected during flight.

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Objective

The objective of this study was to assess the effectiveness of spatial knowledge and terrain association transfer from a VE training environment, and to determine how spatial knowledge, developed through navigation training, may influence this transfer of knowledge to the real world. In developing this training transfer framework, both *outcome* measures to illustrate performance effects through exposure to VE training and *process* metrics to better understand these effects were used to evaluate transfer of training.

Background

Stanney, Mourant and Kennedy (1998, p. 330) suggest that: "To justify the use of VE technology for a given task, when compared to alternative approaches, the use of a VE should improve task performance when transferred to the real-world task because the VE system capitalizes on a fundamental and distinctively human sensory, perceptual, information processing, or cognitive capability." Few studies, however, have characterized the types of tasks or training activities for which the unique characteristics of VEs (i.e., egocentric perspective, stereoscopic 3D visualization, real-time interactivity, immersion, multi-sensory feedback) can be leveraged to provide significant gains in human performance, knowledge, or experience (Stanney & Zyda, 2002). One area in which VE has shown training enhancements, though not pervasively so, is that of spatial knowledge acquisition. Darken and Banker (1998) found that a VE could be used to familiarize individuals with unknown environments. In particular, training gains were found for intermediate orienteers, as compared to advanced or beginner orienteers. Waller (1999) found that spatial ability, especially spatial visualization and spatial orientation ability, affected VE transfer effectiveness. Interestingly, users' proficiency with the virtual interface (a joystick) was found to be the most influential factor in determining transferability of spatial knowledge. Taken together, the Darken and Waller studies suggest that while VE training can enhance spatial knowledge of real world environments, both individual and VE system factors may temper this transfer, likely due to finite cognitive resources. Nevertheless, these findings provide impetus for further study of VE transfer-of-training. In particular, it is essential to determine if greater spatial knowledge acquisition can be obtained if one controls for the virtual interface. The current study investigated the effectiveness of VE training to enhance spatial knowledge of terrain landmarks, while removing the need to directly interact with the VE system by using an intermediary (i.e., instructor pilot) to enact navigational commands communicated by a navigator, an interaction termed 'passive navigation.' The study assessed how well the navigator can glean spatial knowledge of terrain from the VE and transfer that to real-world navigation. The study further investigated how spatial ability may influence spatial knowledge acquisition.

Research Design

While there are many methods to assess training transfer, the Transfer of Training (ToT) framework provides, from an experimental design perspective, the greatest rigor in assessing training transfer (Lathan et al., 2002). This method estimates simulator effectiveness as a comparison of two groups of trainees, an experimental group that receives simulator training and a control group that receives conventional training. In the current study, the latter consisted of 'best practices' training.

In this study, the task involved navigating a land-based route while flying in a helicopter. Participants were randomly assigned to one of two training groups, (1)classroom training on 'best practices' for navigation training, or (2) VE training which allowed for navigation practice of a virtual model of the real flight path (Table 1; note: both groups received the same CSAR ground training prior to this experiment). After training, all groups navigated the real world flight path with an instructor pilot.

As best practices training is focused on the development of procedural skills, and current VEs provide interactive practice opportunities, it was hypothesized that groups who received VE training flights would perform the required navigation skills more effectively with lower perceived workload/stress than those who received the best practices training regimen. The key to the effectiveness of VE spatial navigation training may be in the nature in which it couples the human to the training medium. More specifically, the VE forces trainees to turn their heads to achieve views of the terrain being traversed. Chance et al. (1999) has suggested that individuals are better able to maintain orientation when they must turn their head to update their spatial awareness. This *directional cuing effect* has also been demonstrated with auditory localization accuracy, which is enhanced when an observer must visually look in the direction of an auditory target (Jones & Kabanoff, 1975).

An additional hypothesis was that those participants with better spatial orientation and spatial visualization skills would perform better than participants with lower spatial orientation and spatial visualization skills (co-variables), implicating that VE training may be differentially effective, depending on the abilities of the trainee. In addition, it was expected that VE training provided students with an opportunity to synthesize procedural knowledge. Thus, a third hypothesis was that participants in the VE training group would develop better terrain association skills, as the VE provides hands-on practice in correlating map features to out-the-window terrain. It was also hypothesized that those exposed to the VE trainer would result in better navigator process performance.

Table 1. Design of Study

	Best practices	VE	Navigate Real world route
CSAR training plus best practices	X		X
CSAR training plus VE training		X	X

Participants

Three student navigators in the HS-10 training program participated in this study. All students were experienced pilots, and had successfully passed a NATOPS flight (certified to co-pilot helicopter after 16 flights) prior to this study. In addition, all students had completed CSAR ground school on overland navigation training. None, however, had previously been responsible for terrain navigation of a helicopter in flight.

Apparatus

VE HELO

ChrAVE Hardware and Physical Setup. The current ChrAVE system was developed as a practical intermediary step in establishing the viability and usability of embedded trainers. The ChrAVE acts as a laboratory from which to launch research into the psychology and potential of training certain tasks via trainers/simulators. The ChrAVE primitively mocks the navigator's seat and associated controls from the helicopter. It is meant to be rather generic to all helicopter communities.

Platform.

Seat & Flight Controls alignment. The current implementation used a Flight Link Inc. seat and basic helicopter flight controls. These controls mimicked standard multi-axes game port input devices to PCs. Two axes (pitch & roll) were dedicated to the cyclic, one (thrust) to the collective, and one (yaw) to the rudder pedals. Additionally, there was a button on the collective that could be given specific assignments. The flight controls were not used by the navigating pilot during this experiment. They only provided aesthetically realistic obstacles to the task of cockpit management for the navigating pilot (see Figures 1 and 2).

Figure 1. The ChrAVE Platform

Figure 2. ChrAVE Instrument Panel (SGL LCD monitor)

Headgear: Head Mounted Display. The Virtual Research V8 Head Mounted Display (HMD) was selected to be used with this simulator, as it maintains a high standard in performance among professional HMDs, even though its active matrix Liquid Crystal Displays (LCD) have a Video Graphics Array (VGA) pixel resolution of ((640x3)x480). Considering cost versus performance, HMDs of higher resolution were far too costly for this research. The V8 provides a CRT quality image. The V8 allows for interpupillary adjustments as well as eye relief adjustments. The V8's earphones will not be used during this research therefore they will be rotated away from the ears above the headband. Audio will be provided by a surround sound speaker system.

Inputs and outputs for audio, video, and power are handled through an external control box. Red Light Emitting Diodes (LED) indicate 'Power On' and 'Stereo' modes. Standard 15 pin VGA type connectors accept VGA (640 x 480 60Hz) inputs, readily available on today's graphics engines and workstations.

Camera. The camera used in this implementation was an Auto Gain Control (AGC) and Electronic Light Control (ELC) Panasonic with three Charged Couple Devices (CCD), one each for red, green, and blue. The camera was mounted on top of the HMD to capture real images (of navigator's map in hand or flight displays) that were fused with virtual 'out the window' views.

Lens. The camera lens used was a fixed focal length (4mm) lens. It had two adjustment rings, one for focus and the other for aperture f/stop settings. Changing the aperture to a lower f/stop # allowed more light to reach the camera sensors but reduced the depth of field.

Motion Tracker. The IS-600 Mark 2 was used in this implementation. It is a hybrid motion tracker that utilizes inertial and ultrasonic sensing technologies to provide 6-DOF. The Mark 2 provides multimode communication redundancy for inertial and ultrasonic hybrid components. The inertial system is comprised of an InertiaCube™ that is strapped to the user's headgear and tethered by wire to a control unit. It is nearly immune from environmental interference. The ultrasonic system is comprised of SoniDiscs™ placed adjacent to the InertiaCube™ on the user's headgear and an X-bar installed overhead. The SoniDiscs™ chirp an ultrasonic burst when they sense an infrared flash from the X-bar. The X-bar is equipped with microphones on each of four pods. When the X-bar hears the ultrasonic chirp on the four pods the location of the SoniDisc™ is calculated by the control unit. The SoniDiscs™ are susceptible to interference. They require line of sight communication and normal indoor environmental light intensities due to the infrared portion of the system.

Chromakey Bluescreen Matting. A backdrop made of standard entertainment industry chromakey blue cloth panels was constructed in such a fashion so as to surround the mock cockpit from eleven o'clock to four o'clock. Where necessary, chromakey blue tape was used to hide seems.

Lighting. Lighting is by far the most temperamental component to implementing chromakey technology. The chromakey mixer must perceive the chromakey blue backdrop (called the matting) without noise such as being unevenly lit and having shadows. A number of fluorescent lamps were placed about the mock cockpit in such a manner so as to light the matting while not impeding the navigator's view of the matting. An additional hurdle was ensuring that the lamps did not directly shine into the camera lens or the sonic disks. Although the sonic disks are alerted to infra light, the intensity of the fluorescent lamps can create sufficient noise to disrupt proper motion tracking.

This implementation employed four fixtures that were four feet in length and four fixtures that were two feet in length. Each fixture has high output flicker-free ballast that operate on 120 VAC/60Hz. Each fixture also includes a specular reflector, and two lamp barn doors.

Signal Converters, Mixers, and Splitters. A number of signal converters were used in the system. The chromakey mixer used in this implementation requires a CCIR-601 signal as input. Therefore, both the foreground (FG) signal (an RGB signal from the camera) and the background (BG) signal (a VGA signal from the CPU) has to be converted. Furthermore, once the FG and BG signals are mixed, the CCIR-610 output signal has to be converted back to a VGA (640X480) signal for the HMD.

Task

Student navigators were recruited immediately before their first terrain association flight in their curriculum (which followed CSAR ground school). For their first flight, students were asked to utilize terrain and man made features to facilitate passive navigation of a helicopter. The flight lasted approximately 4 hours, although the course of interest for this study included only the first 45 minutes of the overall route.

Measures

The following section describes the measures for the current study. Table 2 delineates measures that were collected and the time at which each was administered.. A brief description of each measure follows.

Table 2. Experimental design and dependent measures.

Dependent measure	**Training Session 1 (VE / best practices)**		**Training Session 2 (VE / best practices)**		**Operational Flight**
Individual difference measures	Pre-exposure	Post-exposure	Pre-exposure	Post-exposure	Post-flight
Spatial Orientation	X				
Spatial Visualization	X				
Navigation Skill questionnaire	X				
Process measures					
Flight communications					X
Workload questionnaire	X			X	X
Self-Efficacy	X			X	X
Simulator Sickness	X (VE group only)	X (VE group only)	X (VE group only)	X (VE group only)	
Outcome Measures					
Landmark recognition test					X
Terrain Association Task	X			X	X
GPS data					X

***Spatial Orientation Test*:** The ETS Spatial Orientation Test was completed by each participant as a trait measure of spatial orientation ability.

Spatial Visualization Test: The ETS Spatial Visualization Test was completed by each participant as a trait measure of spatial visualization ability.

Workload questionnaire: This questionnaire assessed the current stress state of the student navigator in relation to performing terrain navigation.

Self-Efficacy Questionnaire: A self-efficacy questionnaire assessed students' confidence in performing a set of tasks related to terrain navigation (Scott, 2000).

Simulator Sickness Questionnaire (SSQ): The SSQ was used to assess any sickness symptoms experienced during VE exposure. The SSQ consists of a checklist of 26 symptoms, each of which is related in terms of degree of severity (none, slight, moderate, severe). A weighted scoring procedure is used to obtain a global score reflecting the overall discomfort level known as the Total Severity (TS) score. The SSQ also provides scores on three subscales representing separable but somewhat correlated dimensions of simulator sickness (i.e., Nausea [N], Oculomotor Disturbances [O], and Disorientation [D]).

Navigation Skill Questionnaire/Santa Barbara Questionnaire: This questionnaire assessed general navigation skill via self-report.

Instructor Questionnaire. Instructors were given a short questionnaire to assess the student's performance and use of best practices in flight.

Course Review Interview. Participants were provided with actual GPS track data from their real world flight and their intended route of flight, and asked to describe times during the course of the mission that they were off course. Students were encouraged to justify each time their flight path differed from the intended flight path by more than 1000m.

Terrain Association Task. Participants were presented with 10 'out-the-window' views, each of which was coupled with three distinct maps. Students were asked to match the out-the-window view with one of the three maps (a point on each map denoted the location of the out-the-window view). Students were then presented with 10 maps,each of which was coupled with three distinct out-the-window views. Again, students were asked to match the map to the appropriate out-the-window view. New stimuli (maps and out-the-window views) were used each time the test was administered.

VE Video Review. Participants were presented with a video clip illustrating the course that they flew, and asked to note any landmarks they recognized from their flight. (Note: future forms of this evaluation may consider the use of utilizing the VE as a dynamic method of assessing spatial memory, rather than passive video).

Additional Dependent Measures

1) Time that checkpoints were recognized in the real world
2) Number of errors that were made in navigating
3) Number of times that Navigators were warned that they were off course (level 1 warning)

4) Number of times that the Navigators were shown where they were (in the VE, shown a GPS track of where they were vs. the planned route; in the RW, instructor pilot provided verbal direction of where they were).
5) Navigator communications (online recording of cockpit conversation; measures of navigation process)
6) Instructor questionnaires
    a. % of time that the student spent heads up vs. heads down
    b. Scaled use of best practices
    c. Rank order of the performance (from GPS tracks) of all participants
    d. Use of landmarks assessment

Method

Three participants were randomly placed into either 'best practices' training (review of best practices e.g. map management, team performance, scanning skills, etc.) or VEHELO training (which allowed practice using a virtual model of the real route). After training, all participants navigated a real world flight with an instructor pilot. Best practices training focused on summarizing procedural skills, while VEHELO training allowed for consolidation of this knowledge via interactive practice opportunities. It was thus hypothesized that individuals who received VEHELO training would develop better terrain association skills and perform navigation skills more effectively with lower workload than those who received the best practices training. A second hypothesis was that participants with better spatial ability would perform better than participants with lower levels of spatial skills.

Results

Data collection is ongoing, and no statistical analyses were completed due to the low number of participants (N = 3). Individual results are presented below for spatial ability, self-efficacy, workload, and landmark recognition. Due to ongoing modifications of the terrain association test, those data are not included. Other data collected (e.g. GPS and flight communication data) are currently being analyzed.

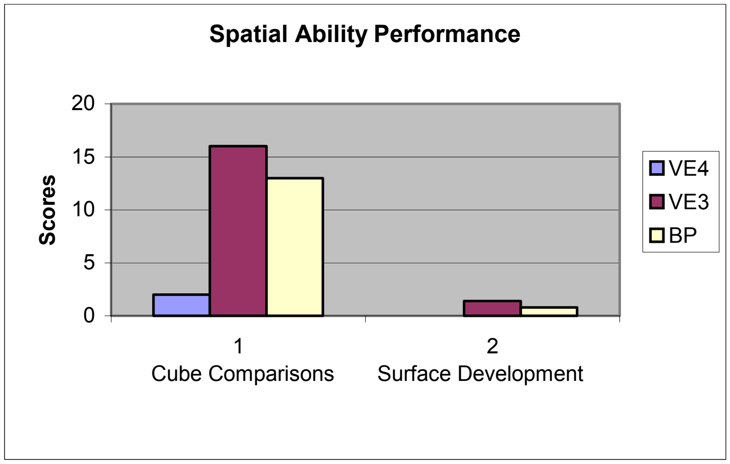


Figure 1: Spatial Ability

Figure 1 shows that spatial ability differed across the participants, with one participant from the VE training group having lower spatial ability. The impact of this on flight performance (assessed via GPS and communications) will be examined.

Figure 2 shows that after training and real world flight, self-efficacy increased, regardless of training method. Figure 3 illustrates how workload decreased post training, but increased slightly for the best practices participant post-flight. Figure 4 illustrates performance on the landmark recognition test. As shown, the best practices participant recalled the most terrain features. This may be explained by the nature of the best practices condition, as the trainee was instructed to mentally simulate navigating the route by calling out the landmarks.

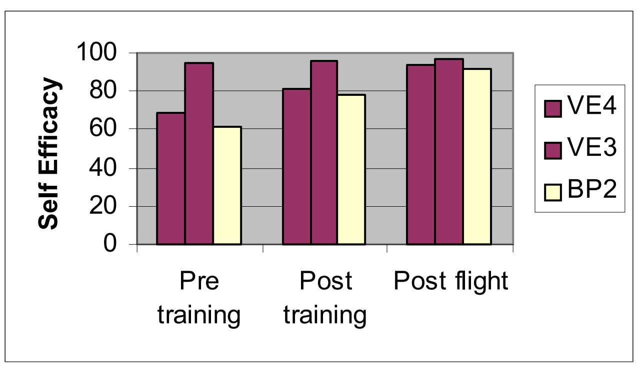
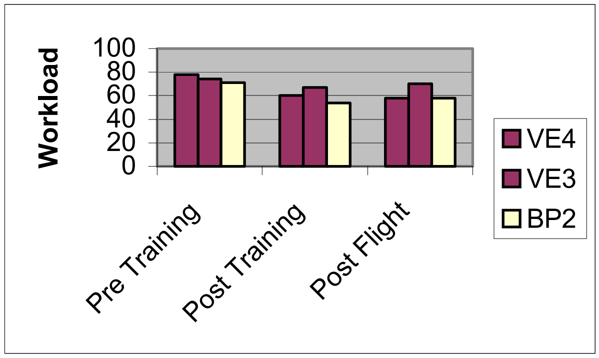


Figure 2: Self-Efficacy Ratings



*Lower scores indicate decreases in workload

Figure 3. Subjective Workload ratings

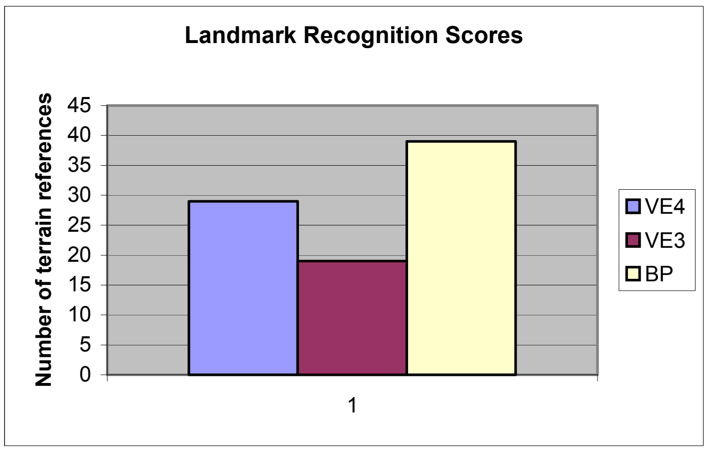


Figure 4. Landmark Recognition Performance

Discussion

Given the paucity of ToT studies in operational environments, this effort focused on the development of a transfer framework. First, an examination of VE capabilities and interviews with subject matter experts were used to derive training objectives. This process indicated the VEHELO would best be used to supplement training for terrain navigation. Next, training objectives were used to develop process and outcome measures that would evaluate changes in performance due to training. Finally, a transfer of training study was designed and implemented at HS-10. Ongoing data collection and future analyses will illustrate the impact of VE training on performance measures. Taken together, the results of this study may shed light on the training transfer effectiveness of VE training, as well as provide insights into why enhancements, if any, are realized via VE training.

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Appendix A: Experimental Protocol

Experiment Day 1

During CSAR training, participants were briefed on the experimental plan, and asked to sign an informed consent. Participants also completed a biographical data form, the Spatial Orientation Test, Spatial Visualization Test, Navigation Skill Questionnaire, the Terrain Association Test and the workload, and self-efficacy questionnaires at this time.. Participants were then given time for map preparation (following standard HS-10 protocol concerning time allotted). This prepared chart was used for VE flight (for those exposed) as well as real world flight. An instructor pilot later assessed the quality of each map (above average, average, below average or unsatisfactory), and results were given to experimenters (this information was not entered in the student's flight jacket). Participants were then given a map preparation questionnaire (e.g. to assess whether the map was built or borrowed).

Experiment Day 2

VEHELO training condition

Participants who were randomly selected for VEHELO exposure were given training on how to use the VE through a warm-up/practice period in the VE to familiarize themselves with the system. Participants were then exposed to the VE (which modeled the area in which the initial route of flight occurred) through one 45-minute session, and asked to navigate through the area hitting set checkpoints throughout the flight. The same instructor pilot flew the VEHELO for all students.

During VE exposure, students were given a verbal warning when they are 1000 meters off course. If students continued off course after 30 seconds, they were shown their current location on their map and instructed to get back on course. If they continued off course for 30 seconds, the session was paused, and the navigator was placed at the last checkpoint (note, the session was not paused for any participants during training).

Simulator sickness measures were taken pre and post VE exposure. Dependent measures taken during VE flight included position data (GPS), self-reported positioning (recorded every 2 minutes and at each checkpoint), and communications data (online recording of cockpit conversation).

Best Practices training condition

Participants were instructed on a number of best practices during map preparation (e.g. finger tracing, changing the map orientation, or learning the map outside-to-in; see Appendix J). This best practices session lasted 45 minutes.

Experiment Day 3

VEHELO training condition

Participants in the VE condition had a second 45-minute training session. Before and after VE exposure, participants were asked to complete the simulator sickness questionnaire. The same dependent measures taken during their first VE flight were again recorded.

Best Practices training condition

Participants in the Best Practices condition had a second 45-minute training session.

Measures completed after both training regimens

Both groups completed the following measures: the workload measure, the self-efficacy questionnaire, and Terrain Association Test.

Experiment Day 4

Real World Flight

Prior to flight (after pre-brief session), participants were given an instruction sheet describing how to operate the data recorder (communication recorder and GPS recorder); this sheet described how data was to be collected for perceived position in space (recorded every 2 minutes by student navigator). In-flight dependent measures collected included position data (GPS), self-reported positioning (recorded every 2 minutes and at each checkpoint), and communications data (online recording of cockpit conversation).

At the completion of flight, student navigators returned the GPS and communication recorders to experimenters. Instructor pilots were given a ‘best practices’ questionnaire to rate student’s process performance. Experimenters developed position maps from GPS.

Post-flight debrief

During the post-flight brief, participants were asked to complete a workload measure, the self-efficacy questionnaire, Terrain Association Test, a VE Video Review (trainees will call out landmarks that they remember from flight), and a Course Review (see above for descriptions).

Appendix B: PARTICIPANT CONSENT FORM

1. **Introduction.** You are invited to participate in a transfer of training study evaluating terrain association skills during helicopter navigation. With information gathered from you and other participants, we hope to discover insight on the effectiveness of this training system. We ask you to read and sign this form if you agree to participate in the study. Please ask any questions you may have before signing.

2. **Background Information.** The Naval Postgraduate School MOVES Institute is conducting this study.

3. **Procedures.** If you agree to participate in this study, the researcher will explain the tasks in detail. There will be two training sessions, each 45 minutes in duration, during which you will be expected to accomplish a number of tasks related to terrain association navigation. In addition, you will be asked to complete a number of questionnaires.

4. **Compensation.** No tangible reward will be given. A copy of the results will be available to you at the conclusion of the experiment.

5. **Confidentiality.** The records of this study will be kept confidential. No information will be publicly accessible which could identify you as a participant.

6. **Voluntary Nature of the Study.** If you agree to participate, you are free to withdraw from the study at any time without prejudice. You will be provided a copy of this form for your records.

7. **Points of Contact.** If you have any further questions or comments after the completion of the study, you may contact the research supervisor, Dr. Rudolph P. Darken (831) 656-7588 darken@nps.navy.mil or the NPS Flight Surgeon, (831) 656-2660.

8. **Statement of Consent.** I have read the above information. I have asked all questions and have had my questions answered. I agree to participate in this study.

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Participant's Signature Date

-- ---------------------------

Researcher's Signature Date

Appendix C: MINIMAL RISK CONSENT STATEMENT

NAVAL POSTGRADUATE SCHOOL, MONTEREY, CA 93943
MINIMAL RISK CONSENT STATEMENT

<u>Participant: VOLUNTARY CONSENT TO BE A RESEARCH PARTICIPANT IN: Team Performance In a Virtual Environment</u>

1. I have read, understand and been provided "Information for Participants" that provides the details of the below acknowledgments.

2. I understand that this project involves research. An explanation of the purposes of the research, a description of procedures to be used, identification of experimental procedures, and the extended duration of my participation have been provided to me.

3. I understand that this project does not involve more than minimal risk. I have been informed of any reasonably foreseeable risks or discomforts to me.

4. I have been informed of any benefits to me or to others that may reasonably be expected from the research.

5. I have signed a statement describing the extent to which confidentiality of records identifying me will be maintained.

6. I have been informed of any compensation and/or medical treatments available if injury occurs and if so, what they consist of, or where further information may be obtained.

7. I understand that my participation in this project is voluntary, refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled. I also understand that I may discontinue participation at any time without penalty or loss of benefits to which I am otherwise entitled.

8. I understand that the individual to contact should I need answers to pertinent questions about the research is Professor Rudy Darken, Principal Investigator, and about my rights as a research participant or concerning a research related injury is the Modeling Virtual Environments and Simulation Chairman. A discussion of the elements of this project and my consent has taken place.

Medical Monitor: Flight Surgeon, Naval Postgraduate School
MOVES Chair, Principal Investigator: R. Darken x7588

____
Signature of Principal Investigator Date

____
Signature of Volunteer Date

____
Signature of Witness Date

Appendix D: PRIVACY ACT STATMENT

NAVAL POSTGRADUATE SCHOOL, MONTEREY, CA 93943
PRIVACY ACT STATEMENT

1. Purpose: Performance data will be collected to enhance knowledge, and to develop tests, procedures, and equipment to improve the development of Virtual Environments for training.

2. Use: Performance data will be used for statistical analysis by the Departments of the Navy and Defense, and other U.S. Government agencies, provided this use is compatible with the purpose for which the information was collected. Use of the information may be granted to legitimate non-government agencies or individuals by the Naval Postgraduate School in accordance with the provisions of the Freedom of Information Act.

3. Disclosure/Confidentiality:

   a. I have been assured that my privacy will be safeguarded. I will be assigned a control or code number which thereafter will be the only identifying entry on any of the research records. The Principal Investigator will maintain the cross-reference between name and control number. It will be decoded only when beneficial to me or if some circumstances, which are not apparent at this time, would make it clear that decoding would enhance the value of the research data. In all cases, the provisions of the Privacy Act Statement will be honored.

   b. I understand that a record of the information contained in this Consent Statement or derived from the experiment described herein will be retained permanently at the Naval Postgraduate School or by higher authority. I voluntarily agree to its disclosure to agencies or individuals indicated in paragraph 2 and I have been informed that failure to agree to such disclosure may negate the purpose for which the experiment was conducted.

   c. I also understand that disclosure of the requested information, including my Social Security Number, is voluntary.

____

Signature of Volunteer   Name, Grade/Rank (if applicable)   DOB   SSN   Date

Appendix E: WORKLOAD SURVEY

Here we are interested in examining the experiences that you think that you will have during the mission. In the most general sense, we are examining the sense of "workload" experienced during the mission(s).

Workload is a difficult concept to define precisely. The factors that influence your experience of workload may come from several factors. This survey is divided into four sections which will serve to assess workload. As two sections deal with assessing perceptions of your workload and two sections deal with assessing your perception of workload, please read the instructions for each section carefully before completing.

SECTION 1: Pre flight workload

Instructions: Place an X on each scale at the point that best represents **how much workload you think that you will experience during the mission**. Marks must be placed inside the box, not on the lines.

1. Mental Demand:
How much mental and perceptual activity did the mission require of you (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)?

Low Medium High

2. Physical Demand:
How much physical activity did the mission require of you (e.g., pushing, pulling, turning, controlling, activating, etc.)? This refers to you not your soldier.

Low Medium High

3. Temporal Demand:
How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred?

Low Medium High

4. Performance:
How successful do you think you were in accomplishing the goals of the task? How satisfied were you with your performance in accomplishing these goals?

Bad Average Good

5. Effort:
How hard did you have to work (mentally and physically) to accomplish your level of performance?

Low Medium High

6. Frustration:
How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

Low Medium High

SECTION 2: Post Flight workload

Instructions: Place an X on each scale at the point that best represents **the level of workload you experienced during the mission**. The X must be placed within the box, not on the line.

1. Mental Demand:

How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.) by the team during your last mission?

Low Medium High

2. Physical Demand:

How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.) by the team during the last mission?

Low Medium High

3. Temporal Demand:

How much time pressure did your team feel due to the rate or pace at which the tasks or task elements occurred?

Low Medium High

4. Performance:

How successful do you think your team was in accomplishing the goals of the task?

Bad Average Good

5. Effort:

How hard did the team have to work (mentally and physically) to accomplish its level of performance?

Low Medium High

6. Frustration:

How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did the team feel during the task?

Low Medium High

Appendix F: Self Efficacy HELO Questionnaire

Name: ___________________________

This questionnaire lists different activities associated with performing helicopter navigation from the planning phase to execution phase. With the assumptions described below, please rate how confident you are that you can perform these tasks for the actual mission. We are not interested in your confidence levels for performing the simulated version of this task, just your confidence in performing the real mission. It is also important that you rate how confident you are that you can perform these tasks <u>as of now</u>, in this very moment. Finally, it is important that you rate what you CAN DO as opposed to what you are willing to do.

For the next questions assume the following:

Assume the pilot has been given specific mission objectives and constraints to include aircraft configuration, crew load, area of operation, and mission support.

First primary objective is to complete the planning phase of the task. This involves acquiring maps, aerial photos, intelligence data, etc. that will be used for planning flight paths, spider routes, and assumed accuracy and location of assumed threats.

Rate your degree of confidence under the column CAN DO NOW by recording a number from 0 to 100 using the scale given below.

CAN YOU DO THIS NOW?

0	10	20	30	40	50	60	70	80	90	100
Certain can't do it					**Moderately certain can do it**					**Certain can do it**

CAN DO NOW?

1. Conduct a map study.	
2. Conduct a legend study (e.g. determine elevation scale, contour interval, vegetation types, cultural features, populous areas, magnetic variation)	
3. Locate and plot threats, area of interest, current flight hazards, SAFE areas and threat areas	
4. Analyze terrain features using the prominent recognizable checkpoints method	
5. Analyze terrain features using the prominent limiting features method	
6. Analyze terrain features using the prominent guiding features method	
7. Select navigation points for primary and secondary ingress and egress routes	
8. Calculate distance, time and fuel for ingress and egress routes	
9. Calculate mission timeline	
10. Prepare in flight guides (e.g. kneeboard cards, annotated maps)	

For the next questions assume the following:

Assume successful completion of planning phase tasks and all associated objectives. The second primary objective is to prepare the cockpit for the actual flight. This begins with the pre-flight preparation, and concludes with the aircraft in the air beginning the overland navigation component.

CAN YOU DO THIS NOW?

0	10	20	30	40	50	60	70	80	90	100
Certain can't do it					Moderately certain can do it					Certain can do it

CAN DO NOW?

11. Conduct navigation to the initial point	
12. Identify the ingress point on map	
13. Identify features to aid identifying initial point	
14. Scan field of view for navigation aids	
15. Locate navigation aids	
16. Positively identify initial point	
17. Estimate arrival time at initial point	
18. Adjust speed to arrive at ingress point on time	
19. Adjust course to overfly initial point	
20. Use visual aids to identify ingress point	
21. Verify ingress point with cockpit navigation aids	

For the next questions assume the following:

Assume successful completion of all preceding tasks and associated objectives. The last primary objective is the actual in-flight navigation component. Because we make no assumptions as to the length and duration of the flight, nor do we assume anything about the terrain in question, we assume a simple repeated procedure for each pre-planned leg of the flight. For each leg, the navigating pilot will conduct a number of sub-tasks involving orientation to the environment and self-location. Communication to the PAC (pilot-at-controls) is included. If disorientation occurs (or even if it is believed to have occurred), the sub-goal Execute-Magellan-procedure is entered which involves re-orienting and getting back on route.

CAN YOU DO THIS NOW?

0	10	20	30	40	50	60	70	80	90	100
Certain can't do it					Moderately certain can do it					Certain can do it

CAN DO <u>NOW</u>?

22. Navigate to next waypoint	
23. Direct flying pilot to predetermined heading by using the landmark method	
24. Direct flying pilot to predetermined heading by using the clock position method	
25. Direct flying pilot to predetermined heading by using the turn & rollout calls method	
26. Adjust navigation needle to new course	
27. Adjust timing using the late arrival method with low confidence in navigation solution method	
28. Adjust timing using the late arrival method with high confidence in navigation solution method	
29. Adjust timing using the early arrival method	
30. Verify PAC proceeding correctly	
31. Making corrections for ground speed	
32. Check on track progress	
33. Correct heading	
34. Determine aircraft position	
35. Scan heading & track	
36. Align map with aircraft track	
37. Analyze terrain within field of view	
38. Assess if salient navigation cues are in view	
39. Match navigation feature with map representation	
40. Use the positive match method (estimate distance and bearing to feature, estimate position on map based and	

distance and bearing to feature, update position on map)	
41. Assess if there is a possible correlating feature in view method (estimate map representation of correlating feature, compare feature with map, compare map with feature to verify.)	
42. Use positive match with correlating feature method to get back on track(estimate distance and bearing to feature, estimate position on map based and distance and bearing to feature, update position on map)	
43. If no positive match of correlating feature method, ability to use time-distance-heading to maintain track (fly time-distance-heading, update aircraft position based on time distance heading, update continue analyzing and comparing until found or lost.)	
44. Ability to determine if lost	
45. When terrain features are located, the ability to use the major deviation method (determining new course to route, treating current position as new waypoint, and executing navigation to the waypoint)	
46. If have no cues, the ability to query crew for salient cues	
47. If no cues reported by crew, ability to use the Magellan procedure	
48. Ability to maintain orientation	
49. Ability to follow hand rail method	
50. Use the Visible intermediate navigation point method	
51. Use the Proceed through ambiguous area method	
52. Use the Time distance heading method	
53. Use the Confess method	
54. Use the wingman method	
55. Use the RESCORT/RESCAP method	
56. Use the Orbit method	
57. Use the NOE method	
58. Use the hover method	
59. Use the land method	
60. Use the climb method	

The following lists some other types of activities. Again, for these, please rate how confident you are that you can do them <u>as of now</u> under the column CAN DO. It is important that you rate what you CAN DO as opposed to what you are willing to do.

	CAN DO <u>NOW</u>?
23. Function competently as department head of a ship.	_______
24. Function competently as the XO of a ship.	_______
25. Negotiate a take-off maneuver in a F-14 jet.	_______
26. Function competently as the CO of a ship.	_______
27. Land a helicopter on a landing pad.	_______

Appendix G: SANTA BARBARA SENSE-OF-DIRECTION SCALE

Name: Today's Date:________________

This questionnaire consists of several statements about your spatial and navigational abilities, preferences, and experiences. After each statement, you should mark one of the circles on the scale to indicate your level of agreement with the statement. Circle "strongly agree" if you strongly agree that the statement applies to you, "strongly disagree" if you strongly disagree, or some number in between if your agreement is intermediate. Circle "Neutral" if you neither agree nor disagree.

1. I am very good at giving directions.

O	O	O	O	O	O	O
Strongly Agree			Neutral			Strongly Disagree

2. I have a poor memory for where I left things.

O	O	O	O	O	O	O
Strongly Agree			Neutral			Strongly Disagree

3. I am very good at judging distances.

O	O	O	O	O	O	O
Strongly Agree			Neutral			Strongly Disagree

4. My "sense of direction" is very good.

O	O	O	O	O	O	O
Strongly Agree			Neutral			Strongly Disagree

5. I tend to think of my environment in terms of cardinal directions (N, S, E, W).

O	O	O	O	O	O	O
Strongly Agree			Neutral			Strongly Disagree

6. I very easily get lost in a new city.

O	O	O	O	O	O	O
Strongly Agree			Neutral			Strongly Disagree

7. I enjoy reading maps.

O	O	O	O	O	O	O
Strongly Agree			Neutral			Strongly Disagree

8. I have trouble understanding directions.

O	O	O	O	O	O	O
Strongly Agree			Neutral			Strongly Disagree

9. I am very good at reading maps.

O	O	O	O	O	O	O
Strongly Agree			Neutral			Strongly Disagree

10. I don't remember routes very well while riding as a passenger in a car.

O	O	O	O	O	O	O
Strongly Agree			Neutral			Strongly Disagree

11. I don't enjoy giving directions.

O	O	O	O	O	O	O
Strongly Agree			Neutral			Strongly Disagree

12. It's not important to me to know where I am.

O	O	O	O	O	O	O
Strongly Agree			Neutral			Strongly Disagree

13. I usually let someone else do the navigational planning for long trips.

O	O	O	O	O	O	O
Strongly Agree			Neutral			Strongly Disagree

14. I can usually remember a new route after I have traveled it only once.

O	O	O	O	O	O	O
Strongly Agree			Neutral			Strongly Disagree

15. I don't have a very good "mental map" of my environment.

O	O	O	O	O	O	O
Strongly Agree			Neutral			Strongly Disagree

Figure Caption

Figure 1. Example of a city question from Study 7.

Pretend you are at Denver, CO, Facing Miami, FL.
Draw an arrow pointing toward Dallas TX.

Appendix H: Terrain Association Evaluation

Terrain association is the skill of correlating map features to out the window views and vice versa. For this evaluation, we will ask you to match map views to out-the-window views.

For the first half of the evaluation, you will be presented with a map and asked to identify which out-the-window view corresponds to the map. Indicate which of the 3 views is the correct answer on the answer sheet. The second half of the test will present you with an out-the-window view, and you will be asked to identify which map corresponds with the out-the-window view. Indicate which of the 3 maps is the correct answer on your answer sheet. There are 20 items, so please work as quickly and accurately as you can, but do not sacrifice accuracy for time.

Please note that when you select an answer, the program will automatically direct you to the next item.

Do you have any questions? Please tell the evaluator that you are ready to begin.

Subject Name _______________-

Appendix I: SSQ

Directions: Rate your experience of the following (i.e. right now I feel…)

1. General discomfort	None ____	Slight____	Moderate____	Severe____
2. Fatigue	None ____	Slight____	Moderate____	Severe____
3. Headache	None ____	Slight____	Moderate____	Severe____
4. Eyestrain	None ____	Slight____	Moderate____	Severe____
5. Difficulty focusing	None ____	Slight____	Moderate____	Severe____
6. Increased salivation	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 Head	None ____	Slight____	Moderate____	Severe____
11. Blurred Vision	None ____	Slight____	Moderate____	Severe____
12. Dizzy (eyes open)	None ____	Slight____	Moderate____	Severe____
13. Dizzy (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____

Appendix J: Best Practices (MaP TeNS)

MaP TeNS

10 Best Practices: Key Points to Remember

MaP TeNS

- *Map Management*: Physically manipulate your map to decrease workload
- *Prioritization*: Aviate, navigate, communicate
- *Team Performance*: Use your team to be a another set of eyes
- *Navigation backup / Map Use*: Use control points and DR from planning to backup your navigation
- *Scanning*: Don't get tunnel vision

List of 10 Best Practices:

Map management

1. Orient the map in the direction of travel
   - Hold map in position that facilitates rapid transition from inside to outside scan (not down on the lap)
   - Refold the map as you go along to follow the route

Prioritization

2. Prioritize tasks (aviate, navigate, communicate)
   - Focus on avoiding obstacles, fuel, altitude, etc. first (terrain collision avoidance)
   - Look out the window and on map for terrain features
   - Communicate with ground control

Team Performance

3. Provide clear, timely direction to PAC

- Use terrain or clock references to provide direction instead of course headings

  Best – fly to saddle to left of peak at your 2 o'clock
  Good – turn to 2 o'clock
  Good – come right, … roll out
  Weak – turn to 095

4. Keep crew informed of navigation picture: location, expected hazards & navigation features, confidence in navigation solution

- Provide situation updates (e.g. heading, legs, timing, hazards)
- Use voice inflection (and direct comms) to let others know confidence in navigation solution

5. Prompt crew for features/hazards that should be in their view

- Ask crew for backup with terrain features (e.g. use crewmembers as extra eyes)
- Listen and acknowledge if crew notes a terrain feature

Navigation Backup best practices

6. Use intermediate checkpoints and checking features to verify navigation and judge along-track progress

- In map planning, identify salient features to use as intermediate points
- In flight, use intermediate points as a way to continually assess current location
- In map planning, identify checking features to use as navigation backup
- In flight, use checking features to assess if you are off course

7. Use elevation as identifying feature when possible

- In map planning, use elevation to help identify key features
- In flight, use elevation to assess relative orientation

8. Back up terrain association with dead reckoning (time, distance, heading)

- Verbalize when approaching checkpoint, call out time and distance to turn, direction of turns and heading as backup to terrain association

Scanning best practices

9. Divide scan appropriately: proportion of time scanning OTW and map

- When looking within the cockpit, perform an instrument scan, evaluate time, distance, and heading and check map for mental list of things you should be seeing
    - o Determine upcoming terrain features direct attention to what you are most uncertain of

10 Scan complete FOV

- Keep your head moving to avoid tunnel vision (e.g. don't fixate on instruments or terrain features)

Appendix K: Mental Simulation Review of Course

- Map review:
  - Have them tell us checkpoints, intermediate checkpoints, limiting features, hazards in review
  - Time to complete: 15 minutes
- Mental simulation:
  - Have students mentally follow the route and call out landmarks, hazards, intermediate checkpoints etc. as they would expect to see them
  - Provide backup to terrain with timing, distance and heading information
  - Move the map around to match what they're looking for (direction of travel)
  - Refold map to follow the route
  - Time to complete twice: 30 minutes

Note: they are also practicing the best practices of keeping the crew informed and prompting the crew for visual cues by stating the landmarks/hazards aloud

Appendix L: Instructor Questionnaire (Post Flight)

Instructor Name ______________

Student Navigator on your flight _________________

Date / Time of flight ___________________

Post Flight Questions (Instructor Pilot)

Please Mark an "X" along the scale below each question. Note that we are only interested in the outbound route (e.g. the first 45 minutes of the flight). We are specifically interested in the student's ability to perform Terrain Association and their use of best practices.

1. How often did the student navigator use terrain association to navigate the route?

   0% 25% 50% 75% 100%

   (of the route) (of the route)

   |____|

2. How much time did the student navigator spend in a 'heads-up' position versus a 'heads-down' position?

   0% 25% 50% 75% 100%

   (of the time) (of the time)

   |____|

3. How often did the student navigator reference absolute heading (from instrument panel) along the route?

   0% 25% 50% 75% 100%

   (of the time) (of the time)

   |____|

4. How often did the student navigator prompt/query for visual features from other crew members?

   0% 25% 50% 75% 100%

   (of the time) (of the time)

   |____|

5. How often was the student navigator ‘on route’?

0% (of the time)	25%	50%	75%	100% (of the time)

|____|

6. How often was the student navigator ‘on time’?

0% (of the time)	25%	50%	75%	100% (of the time)

|____|

7. How would you rate this student’s overall navigation performance?

1 (best ever)	3 (average)	5 (very poor)

|____|

8. How would you rate this student’s map?

1 (best ever)	3 (average)	5 (very poor)

|____|

9. How often did the student orient their map in the direction of travel?

0% (of the time)	25%	50%	75%	100% (of the time)

|____|

10. Did the student provide clear and timely direction to the pilot?

0% (of the time)	25%	50%	75%	100% (of the time)

|____|

11. How often did the student keep the crew informed about location, expected hazards and navigation features?

0% (of the time)	25%	50%	75%	100% (of the time)

|____|

12. How often did the student prompt the crew for location, hazards and navigation features?

0% 25% 50% 75% 100%
(of the time) (of the time)
|____|

13. How often did the student make reference to intermediate checkpoints when appropriate?

0% 25% 50% 75% 100%
(of the time) (of the time)
|____|

14. How often did the student use checking features, where needed?

0% 25% 50% 75% 100%
(of the time) (of the time)
|____|

15. How often did the student use elevation as an identifying feature when appropriate?

0% 25% 50% 75% 100%
(of the time) (of the time)
|____|

16. How often did the student scan his complete FOV?

0% 25% 50% 75% 100%
(of the time) (of the time)
|____|

Appendix M: Course Review

Participants will be provided with actual GPS track data from the real world flight and the planned route and asked to identify landmarks for each leg and to describe times during the course of the mission that they were off course.

Appendix N: Number of Terrain Association References in Course Review

Student:
Experimenter:

Leg 1:	
Leg 2:	
Leg 3:	
Leg 4:	
Leg 5:	
Leg 6:	
Leg 7:	
Leg 8:	
Leg 9:	