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AN EXPLORATION OF SIMULATOR SICKNESS IN THE MH-60G OPERATIONAL FLIGHT TRAINER, AN ADVANCED WIDE FIELD-OF-VIEW HELICOPTER TRAINER

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A simulator sickness research effort was undertaken as an important addition to the Qualification Operational Test and Evaluation (QOT&E) for the MH-60G Operational Flight Trainer (OFT). The primary impetus for the experiment was the configuration of the device (wide field of view and limited motion) and pilot reports of simulator sickness symptoms during device development. The authors assessed (a) post-flight simulator sickness symptoms, (b) prolonged simulator sickness symptoms, and (c) the effects of simulator sickness on the training provided in the MH-60G OFT. Despite limitations of the experimental design and the small sample size, some interesting trends were found. Post-flight simulator sickness symptoms occurred across all types of missions, with greater frequency on more visually dependent scenarios. Only two crewmembers did not report any symptoms. Pilots consistently changed control inputs to lessen the effects of simulator sickness symptoms. Finally, the occurrence of prolonged simulator sickness symptoms was comparatively infrequent. The authors concluded that increased attention must be channeled toward simulator sickness to better understand its origins and effects on training.

14. SUBJECT TERMS

Flight simulators; MH-60G; Mission scenarios; Operational flight trainer; OFT; Post-flight simulator sickness symptoms; Prolonged aftereffects; Qualification Operational Test and Evaluation; QOT&E; Simulator sickness; Simulators; Trainers; Training

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PREFACE

This project was performed for the Aircrew Training Research Division of the Armstrong Laboratory (AL/HRA) by the University of Dayton Research Institute (UDRI) in cooperation with the Air Force Operational Test and Evaluation Center (AFOTEC) for the period November 1993 to October 1994. The research is part of the AL/HRA program to provide behavioral research support to the Air Force Special Operations Forces (AFSOF) through a research partnership with the Kirtland Air Force Base flying training and advanced simulation communities. The results of the current research effort are intended to provide information on the occurrence of simulator sickness symptoms in the MH-60G Operational Flight Trainer and their potential impact on the training provided in this device.

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AN EXPLORATION OF SIMULATOR SICKNESS IN THE MH-60G OPERATIONAL FLIGHT TRAINER AN ADVANCED WIDE FIELD-OF-VIEW HELICOPTER TRAINER

INTRODUCTION

The use of simulation for aircrew training has been embraced in both the military and private sectors (Bartlett, 1989; Goldberg, D'Amico, & Williams, 1980; Grier, 1990; Pate, 1992; Shirts, 1992; Solomon, 1993; Willigies, 1973). In the military, Department of Defense (DoD) budget cuts and force reductions have fostered the search for alternate, more cost-effective and efficient means of training aircrews. High fidelity simulation has risen to the occasion (Reed, 1993; Selix, 1993). The advent of high fidelity simulation and its continuing evolution provides aircrew training in areas that receive little training in the aircraft due to cost (e.g., field exercises) or safety (e.g., emergency procedures).

High fidelity simulation and the realization of its training potential also breeds excitement and acceptance among its users, both crewmembers and instructors. However, a host of issues accompany simulator training. Some of the issues relate to other areas of training, such as defining training requirements (Campbell, 1971; Tannenbaum & Yukl, 1992), or determining optimal procedures for training (Caro, 1973; Hopkins, 1973; Vestewig, Bergsneider, & Richardson, 1991). Other issues are specific to aircrew training using high fidelity simulation. For example, one specific byproduct of high fidelity visual systems is simulator sickness. Simulator sickness generally speaking is "psychophysiological disturbances, visual illusions and sickness following the use of flight simulators" (Frank, Kennedy, Kellogg, & McCauley, 1983, p. 2). The reported symptoms include: eyestrain, blurred vision, difficulty focusing, headaches, sweating, unusual fatigue, nausea, stomach awareness, spatial disorientation, and others (Kellogg & Gillingham, 1986; Kennedy, Dutton, Lilienthal, Ricard, & Frank, 1984; Ungs, 1987). The Navy has had a rather profound and ongoing interest in simulator sickness since the first reported incidence over forty years ago (Kennedy et al., 1984). In 1975 when the Advanced Simulator for Pilot Training (ASPT) and the Simulator for Air-to-Air Combat (SAAC) became operational, the United States Air Force (USAF) experienced increased reports of motion-like sickness. As a result, USAF attention to simulator sickness grew (Kellogg & Gillingham, 1986).

One possible reason for the increase in USAF reports of motion-like sickness is that the ASPT and the SAAC both had wide fields-of-view (FOV). While it is "doubtful that there is any single causal factor for simulator sickness" (Frank et al., 1983, p. 5), researchers have explained and noted various elements that are more likely to induce simulator sickness over others. Some

of the more frequently recognized aspects of the simulator that contribute to the report of simulator sickness are: detail of visual scene, content of visual scene, range of FOV, and the combination of wide FOVs and a six-degree-of-freedom motion base (Kennedy, et al., 1992; McCauley, Hettinger, Sharkey, & Sinacori, 1990). The report and incidence of simulator sickness is also affected by other factors outside of the simulator. These other factors include pilot's age and experience, type of mission scenario, crew position, frequency and duration of exposure to simulator training, and type of aircraft simulated (Frank et al., 1983; Kellogg & Gillingham, 1986). Research has shown that helicopter simulators with wide FOVs are likely candidates for invoking simulator sickness (Kennedy, Lilienthal, Berbaum, Baltzley, & McCauley, 1989). For this reason and an accumulation of anecdotal reports by the second author, the present research was initiated. Wide FOVs, highly detailed imagery, and motion-based systems are becoming the norm rather than the exception. Thus, simulator sickness and its effects have an increased relevance to training and aviation communities: "If flight simulation engineering continues to outdistance human factors engineering, the problem [simulator sickness] may worsen." (p. 10)

MOTION

Since motion has been noted as a key factor in the report of simulator sickness, it is important to explore relevant literature and findings regarding the training value of motion platforms. As with many areas of simulator fidelity, there is a rather large body of contradictory evidence concerning the training advantages incurred by increasing the fidelity of motion bases.

Ricard and Parrish (1984) examined the effects of motion cues on pilot performance of a helicopter hover. They looked at three types of motion cues (in order of increasing fidelity): fixed base, fixed base with g-seat, and a moving base with a six-degree-of-freedom motion platform. The subjects averaged eight and a half years of flying experience. The only task Ricard and Parrish examined was hovering a specific distance beside a destroyer-class ship, using the Visual Motion Simulator at NASA Langley Research Center. The primary indicator of performance was the Vector Combination of Errors (VCE), accounting for factors like position of the helicopter in relation to the ship, aircraft roll, lateral movements of the cyclic, etc. Ricard and Parrish found that pilot performance improved in an incremental fashion from fixed-base to g-seat to moving base. They argued that the greater range of motion in the moving base condition helped to regulate helicopter hover. They did not make any sweeping generalizations about the benefits of motion. Instead, they recommended platform motion for similar steady state control tasks, suggesting further research on how motion contributes to pilot performance on other tasks.

Gray and Fuller (1977), in an exploration of the capabilities of the ASPT, found that a six-degree-of-freedom motion platform was not a factor in increasing the skill level of pilots exposed to simulator training. There were 24 subjects in the study. The subjects were all recent undergraduate pilot training graduates preparing for fighter aircraft assignments. Several independent variables were explored, but the only one of interest here was presence or absence of motion and its effect on pilot performance. The tasks trained were low and high angle bombing. The dependent measures of pilot performance included bomb delivery accuracy and instructor pilot performance ratings. The control group received training in the classroom and the aircraft, whereas the experimental groups received either a combination of classroom and no motion simulation (E_1) or a combination of classroom and motion simulation training (E_2). Gray and Fuller did not find an effect of motion on pilot performance. "The results of the study show unequivocally that the six-degree-of-freedom motion platform did not enhance the training value of the simulator." (p. 90)

Koonce (1974) confuses things further in an examination of three types of motion on training. His central question was whether "the predictive validity of ground-based simulator pilot performance measures vary as a function of simulator motion conditions" (p. 15). There were 30 pilots with multi-engine and instrument ratings. Training took place on the Singer-Link General Aviator Trainer (GAT-2) under three different motion conditions: no motion, sustained motion, and washout motion. Sustained motion was more basic than washout motion, "when operating in this mode as the pilot enter[ed] a banked turn, the simulator cab was angularly displaced in the direction of the turn and maintain[ed] that tilt until...the pilot [brought] the aircraft back to wings level flight" (p. 25). Washout motion provided the same acceleration motion cues as sustainment motion; however, when making turns, the cab returned to the steady state. Two checkrides were performed in the Piper Aztec, a twin-engine aircraft, and two in the simulator. Pilots received training on ten maneuvers; five were considered representative of maneuvers <u>not</u> done with reference to out-of-the-window visual cues, and five that <u>were</u> done with the same references. Two trained observers scored the checkrides according to various criterion levels. In between-group comparisons of performances in the simulator and the aircraft, some interesting differences emerged. In the simulator checkrides, both of the motion groups outperformed the no-motion group. But in the aircraft checkrides, the no-motion trained group marginally outperformed the two motion groups. "Simulator motion tend[ed] to increase the subjects' acceptance of the device, lower performance error scores, and reduce workload on the

subjects . . . but the differential effects of motion on the simulator performance [did] not transfer to the performance in the aircraft." (p. 87)

High fidelity motion systems appear to have questionable value. Table 1 lists only a small portion of the literature on motion-based simulator systems. The studies listed are, however, representative of the inconclusive findings regarding the benefits of motion. The scales are fairly well balanced in terms of the number of studies that report training benefits from motion cues and those that do not report those benefits.

Table 1. Simulators and Motion: The Effects of Motion on Training Effectiveness

Training Benefit	No Training Benefit
Gerathewohl (1979)	Gray & Fuller (1977)
Jacobs (1975)	Horey (1992)
Pohlmann & Reed (1973)	Koonce (1974)
Ricard & Parrish (1984)	Nataupsky, Waag, Weyer, McFadden, & McDowell (1979)
Ryan, Scott, & Browning (1978)	Woodruff, Smith, Fuller, & Weyer (1976)

There have been attempts to reconcile these findings by incorporating other variables into the training and motion equation (Caro, 1973; 1979; Cohen, 1970). Caro (1979) stressed particular training objectives and how they might be affected by motion: "For what training is motion needed?" (p. 493). Whereas, Caro (1977; 1979) and Cohen (1970) both discussed different types of motion, maneuver motion and disturbance motion, and how they may affect training. Maneuver motion is a function of a pilot's actions in the cockpit (e.g., turns) and disturbance motion is a function of factors not in the pilot's control (e.g., turbulence, system failures). Caro (1979) argued that maneuver motion may be redundant with other cues and, therefore, may not add to the training value of the device, but disturbance motion may add to training by providing cues not otherwise available.

Semple, et al. (1981) brought up additional variables that should be considered in order to truly examine the contribution, or lack thereof, of motion platforms. Their analyses included: training objectives, experience levels of trainees, visual environments provided, type of aircraft, and their interactions. For example, visual cues may provide more information and may be more primary than motion, causing motion cues to be redundant. Helicopter pilots, however, may be more dependent on motion cues despite high fidelity motion systems due to the unstable

environment associated with helicopters. Any of these factors could contribute to the discrepant findings surrounding the training benefits of motion.

Another element that may interact with motion and the training effectiveness of a device is the incidence of simulator sickness brought on by the device. Horey (1992), in his test of the 2F120 Operational Flight Trainer (OFT) under three different motion conditions (full, restricted, and none) for the CH-53E helicopter, found that only one task (tail rotor failure/separation) was adversely affected by the reduced motion conditions. In fact, in his conclusions, he discussed the possible disadvantages of motion. Performance for the motion groups "may have actually been reduced or degraded below the performance of the no-motion group because of the motion itself . . . it is also possible that motion does not contribute to learning of certain tasks and in some cases may inhibit learning" (p. 212). Additionally, he found that there was no difference between the incidence of simulator sickness for the full, restricted, or no-motion conditions.

We explored pilot opinion on motion-based platforms in reference to both simulator sickness and effects on training. The MH-60G OFT has a one-degree-of-freedom motion base. We examined whether this type of extremely limited motion base, in conjunction with a medium fidelity visual system, resulted in simulator sickness symptoms. We also explored pilot opinion about addition of a six-degree-of-freedom motion platform on the device's training effectiveness and their opinions about its addition on the incidence of simulator sickness symptoms.

THE OFT, SIMULATOR SICKNESS, AND TRAINING

The 58th Special Operations Wing (SOW), Kirtland Air Force Base (AFB), New Mexico, is acquiring a nonmotion-based MH-60G PAVE HAWK OFT. The MH-60G OFT is designed to replicate the configuration and operation of the PAVE HAWK aircraft. It is a nonmotion-based, helicopter procedures trainer that uses a PT 2000 Image Generator (IG) and a Crossview Visual Display System. This medium fidelity visual system provides a 150 deg horizontal X 40 deg vertical symmetrical FOV about the 0 deg azimuth. In addition to the front display, there are two chin windows, one for each pilot tuned to each individual pilot eyepoint (Figure 1). Image processing is provided by the IG at a 50 Hz update rate. In the case of scene overload, the update rate drops to 25 Hz. Transport delay, i.e., the measured time from when a control input is made to a flight control surface to when the simulator displays that input, is 86 ms. The OFT is on a static platform, although control loading provides vibrations to the pilots' seats via vertical oscillation (one-degree-of-freedom seat shakers) inputs to simulate rotor malfunctions. The OFT will be integrated into the mission qualification PAVE HAWK curriculum which uses a mix of training devices in addition to the actual aircraft.

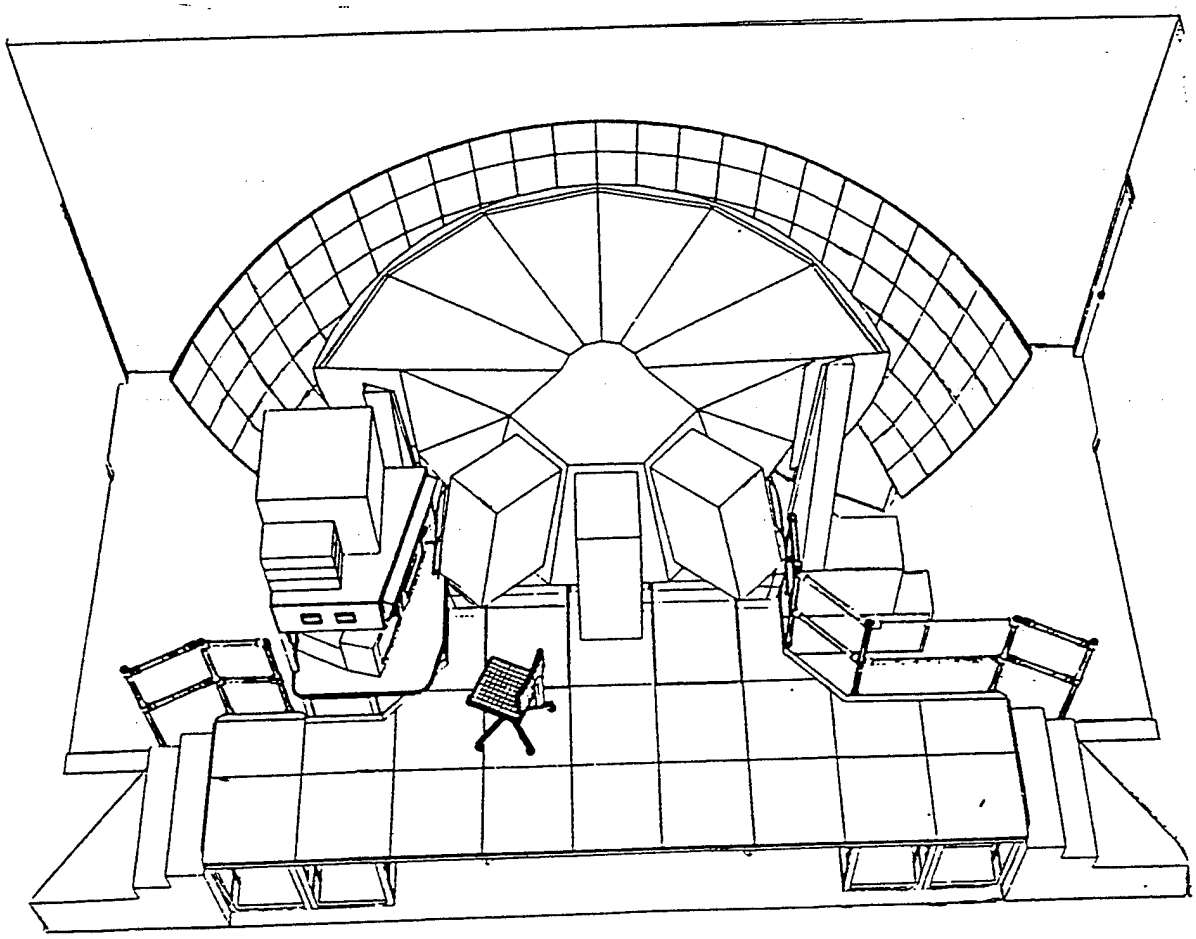

Figure 1

The MH-60G Operational Flight Trainer, A View from Above

During initial acquisition and in-plant development of the MH-60G OFT, the authors noticed several crewmembers reporting symptoms of nausea, imbalance, and eye fatigue, which are symptomatic of simulator sickness. The authors then began researching simulator sickness and discovered little USAF analysis in this area. However, as mentioned above, the U.S. Navy has been exploring this issue for a number of years (Kennedy et al., 1984; 1989), and some indications are that as many as 35% of aircrew members are measurably affected by exposure to simulated flight (Kellogg, Castore, & Coward, 1980).

The authors have t hree primary reasons for their interest in simulator sickness and the MH-60G OFT:

1. Simulator sickness may reduce aircrew confidence in the training provided by the device.

2. Simulator sickness may reduce the training frequency with which aircrews use the device.

3. Simulator sickness may lead to safety problems.

All of these effect the quality of the training that a simulator can provide. If trainees believe that a simulator is not comparable to the aircraft in one way, they may lose confidence that other aspects of the simulator will be comparable to the aircraft. In extreme cases, if simulator sickness symptoms are severe enough, simulator sessions may be forced to stop (Martin, 1992; Warner, Serfoss, Baruch, & Hubbard, 1993), arresting training altogether. In terms of safety, there have been reports (e.g., Kennedy et al., 1984, or Ungs, 1987) of the late onset of simulator sickness symptoms like blurred vision, loss of balance, extreme fatigue, etc. These symptoms can lead to problems in later flights, or simply driving home from training (Kennedy et al., 1984). Also in reference to safety, accommodations made for simulator sickness in the simulator may interfere (negatively transfer) with flying the aircraft. Kennedy et al. (1984) reported anecdotal evidence of one pilot's difficulty landing a helicopter which was attributed to an adjustment made to reduce the effects of a simulator sickness symptom that had previously occurred in a simulator training session.

Although these safety issues are highly significant, they tend to be rather extreme consequences of the more severe and rare simulator sickness symptoms. More commonly observed symptoms are, dizziness, nausea, spatial disorientation, eyestrain, and mild fatigue. As a result, our main interest is the extent to which these symptoms will be manifest with this newly acquired device and their impact on the training provided.

Controlled experiments have been cited as a key component in determining the origins and training implications of simulator sickness, however, there are few simulators available solely for the sake of research (McCauley et al., 1990). Therefore, data must be collected where possible. This often means that data are collected at operational units along with other exercises, which is the rationale behind this work. This simulator sickness experiment was run in conjunction with the Qualification Operational Test and Evaluation (QOT&E) of the MH-60G OFT. The two-week QOT&E examined five mission profiles:

1. Instruments (SI),
2. Emergency Procedures (EPs),
3. Remote Operations (SR),
4. Low-Level Day Tactical (DT), and
5. Low-Level Night Tactical (NT).

Succinctly, the QOT&E was designed to test whether the MH-60G OFT met the training requirements for which it was procured and built.

METHODS

Subjects.

Thirteen crewmembers participated in this experiment; nine pilots and four flight engineers (FEs). Three pilots participated in both weeks of the test. The pilots ranged in flying hour experience from 350 to 15,327[1] total hr with an average of 4,225.2 (Mdn = 2,750). The FEs ranged in flying hour experience from 1,650 to 3,750 hr with an average of 2,700 (Mdn = 2,700). One FE failed to report this information.

USAF active duty and reserve units supplied crewmembers. The backgrounds of the crewmembers were variable. There were instructors from the formal school, participants from Operation Southern Watch (troops that remained in Saudi Arabia following Desert Storm), individuals involved with the acquisition and development of the device, and a flight examiner for the Air Education and Training Command (AETC).

Materials

The MH-60G OFT. The MH-60G OFT was designed to simulate all day, dusk, and night visual operations including tactical, night vision goggle (NVG), and air refueling (AR). The OFT incorporates the MH-60G aircraft instrument panel with use of forward looking infrared (FLIR),

[1] This pilot had mostly commercial jet time.

and uses converted Compuscene V visual data bases for its PT 2000 Crossview visual system. The OFT will provide training to Air Force Special Operations Forces (AFSOF) and search and rescue (SAR) pilots and copilots; FEs will receive training during emergency procedure rides. The OFT will provide training for initial mission qualification, refresher training, and basic mission rehearsal. The trainer is required to be in service 12 hours per day, five days per week.

The Mission Scenarios. The MH-60G OFT is required to provide the training capability for the following types of missions: airland, search and rescue, inflight refueling, day/night low-level tactical, overwater operations, emergency/transition/instrument procedures, and formation flight. For the QOT&E and the adjunct simulator sickness experiment, five sorties (mission scenarios) were used to test the MH-60G OFT's effectiveness for training these skills. A brief description of each follows:

1. Instruments (SI). Basic instrument procedures such as tactical air navigation (TACAN), Very High Frequency (VHF) omnidirectional ranging (VOR) procedures, instrument landing system (ILS), air surveillance radar (ASR), and some precision approach radar (PAR) procedures were covered. Instrument takeoffs, instrument flight rules (IFR) navigation, and fuel management were also highlighted during this scenario.

2. Remote Operations (SR). Procedures for performing takeoffs and landings to austere and unprepared surfaces were practiced. Some tactical navigation procedures and engine malfunctions were also taught.

3. Emergency Procedures (EP). Various EPs were performed as a lead-in to the aircraft missions. They were broken down into ground and in-flight emergencies.

4. Day Tactical (DT)/Night Tactical (NT). The fourth and fifth scenarios were the day and night tactical missions where ingress, egress, landing zone (LZ), formation, air refueling (AR), and shipboard operations were performed.

Sortie length was somewhat variable, but all were at least three hours. Each scenario began with takeoff, and finished with landing; crews were not asked to begin or end scenarios midflight. The day and night tactical scenarios were the only sorties that could be classified as predominantly low level. (See Appendix A for a complete listing of the tasks performed in each scenario.) Time was allotted between each sortie for minor repairs (e.g., light bulb replacements or seat adjustments). Any safety problems that arose were dealt with immediately (e.g., one pilot moved to the instructor operator station (IOS) in the middle of a sortie due to difficulties tolerating simulator sickness symptoms). Simulator sickness was examined for each sortie type.

Questionnaires. Simulator sickness data were collected via three questionnaires (Appendix B). Two information pages were also used: a written introduction sheet which explained the essential elements of the simulator sickness experiment, and an informed consent form (also see Appendix B).

The written introduction of the experiment included a brief description of the experiment's nature, purpose, and procedures, as well as the requirements of the participants. There was some concern about the reliability of self-report data, that is, many crewmembers may feel that having simulator sickness symptoms would reflect poorly on their performance and therefore be reluctant to report any symptoms. The introduction to the experiment assured participants that the data collected were confidential and solely for the purpose of research.

The informed consent form acknowledged that participation was voluntary, that information collected was confidential, and that nothing regarding the experiment would go on the participants' permanent records. An important caveat was added to this informed consent form requiring participants to refrain from flying the actual aircraft for 12 hours after flying the simulator to prevent any potential safety problems if simulator sickness symptoms did occur.

The three main simulator sickness questionnaires were a Motion History Questionnaire, a Post-Flight Questionnaire, and a Prolonged Side Effects Questionnaire. These questionnaires were developed by the authors specifically for this effort based on information found in the literature (Kennedy et al., 1984; 1989; 1992). The primary difference between our questionnaires and existing means of assessing simulator sickness was that our questionnaires were slightly more open-ended. Due to the small sample size (driven by the number of crews provided for the (QOT&E) and the fact that responses were solicited from each participant on multiple occasions throughout the week (repeated measures), this approach seemed the most appropriate.

The Motion History Questionnaire was designed to obtain information on crewmember history, assessing whether participants had motion sickness problems in the past, their experience with flight simulators, and their recent health.

The Post-Flight Questionnaire was designed to assess basic information about the simulator session just completed (e.g., duration, type), whether or not the participant experienced any simulator sickness symptoms as a result of the mission or features of the simulator, and if so, the impact of these symptoms on the crewmember's performance and/or the training provided. The Post-Flight Questionnaire contained a symptom checklist made up of ten common simulator sickness symptoms which, if present, we felt would have the greatest impact on training. The list was followed by an open-ended question to account for crewmembers who

may have experienced other symptoms not present on the list. We did not assess the severity of the symptoms. The primary interest was presence of simulator sickness symptoms and whether or not these symptoms caused the pilots to change their flying behavior.

Finally, the Prolonged Side Effects Questionnaire was designed to assess whether the mission profiles or the simulator induced delayed physiological symptoms from a few to several hours after the simulator training session. It included a checklist of eight symptoms (vertigo, visual illusions, visual flashbacks, faintness, change of appetite, stomach disorders, sensory confusion, and vomiting), as well as space for listing and explaining any other symptoms. This questionnaire also assessed whether any accommodations for the symptoms were made by participants, and what they were doing at the time of symptom onset.

Procedure.

This experiment was conducted in conjunction with the QOT&E for the MH-60G OFT. The QOT&E took 10 days, 12 hr per day. Each crew flew one 3-4 hr mission per day.

Prior to each team's first simulator session, they were given a short briefing that emphasized their responsibilities for the QOT&E. During this initial briefing, teams were provided with information about the simulator sickness experiment. Researchers were available during these briefings to answer any questions the participants had about the experiment and the use of the information obtained. Participants then signed the statement of informed consent and filled out the Motion History Questionnaire. Both of these documents were completed once by each participant.

For the first session, participants filled out the Post-Flight Simulator Sickness Questionnaire. During the remainder of the QOT&E, each participant responded to the two remaining simulator sickness questionnaires--one before and one after each of their simulator sessions. The Post-Flight Simulator Sickness Questionnaire, which assessed individual responses to the simulator session just flown, was administered immediately following the crews' simulator sorties. The Prolonged Side Effects questionnaire was administered prior to simulator flights; it assessed delayed onset of simulator sickness symptoms from the previous day's simulator session. Participants were reminded to be as candid as possible and to complete the questionnaires even if symptoms were not present on given days to maintain data continuity.

RESULTS

The following is an account of the simulator sickness experiment. It does not include the results of the QOT&E.

The QOT&E for the MH-60G OFT provided 15 sorties per week for two weeks. Due to a simulator malfunction, one sortie was canceled the first week. Additionally, complete sets of data, including both post-flight and delayed onset simulator sickness symptoms, could only be collected for simulator sessions held on days 1 through 4. Thus, total number of sorties used for the simulator sickness analyses was 23 (3 sorties x 4 days x 2 wk 1 malfunction). Three crews flew sorties each week, either as a "full" crew (2 pilots and an FE) or with just a pilot and a copilot. There were three pilots who participated in both weeks of the QOT&E. Due to the small sample size, use of self-report data, and the inherent randomization problems of overlaying an experiment onto an existing project, rigid statistical analysis of any effect was difficult. However, the descriptive analyses that follow indicate some interesting trends involving variables that influence simulator sickness, its occurrence in the MH-60G OFT, and possible effects on training.

Post-Flight Simulator Sickness. The post-flight questionnaire assessed, among many things, presence of 10 simulator sickness symptoms. The symptoms reported and the frequency with which each occurred appears in Table 2. The most common symptom was stomach awareness. Although nausea was third in terms of frequency of occurrence, only one pilot was sick enough to remove himself from his seat and continue the sortie from the IOS. It is important to note these symptoms occurred in 8 out of 9 pilots, and 2 out of 3 FEs, meaning the symptoms reported were distributed across participants and not peculiar to one or two individuals.

Table 2. Post-Flight Simulator Sickness Symptoms Reported and Their Frequency

Symptom	Frequency
Stomach Awareness	25
Dizziness	15
Nausea	8
Fatigue	7
Sweating	6
Difficulty Focusing	5
Eyestrain	3
Difficulty Concentrating	3
Blurred Vision	2
Headache	2

A gross measure of the level of simulator sickness caused by this device is overall frequency of symptom occurrence over the course of the 8 days, or the 23 simulation sorties

addressed (i.e., the sum of column two in Table 2). The total number of symptom occurrences was 76 (essentially equivalent amounts each week; week 1 = 37 and week 2 = 39). This is an average of 3.3 symptoms per sortie.

There were various types of scenarios used; past work has demonstrated that the type of maneuvers being flown and scenario profiles can affect the incidence of simulator sickness (Warner et al., 1993). Our data depicted in Table 3 suggest this as well.

Table 3. Number of Post-Flight Simulator Sickness Symptoms Reported by Scenario Type.

	EP	SI	SR	DT	NT
Raw Frequencies	23	11	16	18	8
Weighted Means	4.6	2.2	3.2	4.5	2.0
	(n = 5)	(n = 5)	(n = 5)	(n = 4)	(n = 4)

The trend depicted in Table 3 implies crewmember reliance on the visual scene to perform mission tasks was an influential factor in the onset of simulator sickness. For three mission scenarios (SR, DT, and EPs) where crewmembers relied heavily on the out-of-the-window view, the report of simulator sickness symptoms was markedly higher than for the SI and NT mission scenarios which did not require that crewmembers rely as much on the out-of-the-window view.

Additional support for this trend was found in the analysis of question #10 on the Post-Flight Questionnaire: "Compared to symptoms experienced under the same conditions during flight in the actual aircraft, would you describe your symptoms, if any, that you experienced during simulator flight as being, less symptomatic, same as the aircraft, or more symptomatic?" There were 61 potential responses to this question, 4 questions were left unanswered by participants, leaving 57 responses for analysis. Of these 57 responses, 31 responses were "more symptomatic," 16 were "same as aircraft," and 10 were "less symptomatic." This pattern becomes even more descriptive by removing the two individuals that did not report any simulator sickness symptoms. The proportion changes a bit: 31 "more symptomatic," 13 "same as aircraft," and 7 "less symptomatic." Further, of the 7 "less symptomatic" responses, only one followed a visually dependent scenario (DT). The other 6 responses of 'less symptomatic' came

following either SI scenarios (4) or NT scenarios (2). A similar, although not quite as pronounced, pattern emerges from the 13 "same as aircraft" responses: 4 followed NT scenarios, 3 followed SI scenarios, and the remaining 6 followed SR and EP scenarios (3 from each). Finally, the breakdown of the 31 "more symptomatic" responses clearly reflects this pattern: 23 came from missions scenarios that were highly dependent on the out-of-the-window cues (10 following EP scenarios, 6 following DT scenarios, and 7 following SR scenarios), and of the remaining 8, 5 followed SI scenarios and 3 followed NT scenarios.

It appears again, based on the above response patterns, that crewmember dependence on the out-of-the-window view is a key factor in the onset of simulator sickness symptoms. Both the number of symptoms reported by crewmembers and their own comparisons of their symptoms in the aircraft versus the MH-60G OFT reflect a relationship between a crewmember's use of visual cues and the onset of simulator sickness symptoms.

Continuing to look at the data from a gross level, one can also see a trend in terms of adaptation as it relates to simulator sickness. Adaptation is growing accustomed to the effects of the simulator over time (Kennedy et al., 1989; McCauley, 1984). Table 4 illustrates this trend for both week 1 and week 2; the number of symptoms essentially decreasing from day 1 to day 4.

Table 4. Number of Post-Flight Simulator Sickness Symptoms Reported by Day of the Week.

	Day 1	Day 2	Day 3	Day 4
Week 1	13	9	11	2
Week 2*	10	4	7	4

*Note: The totals from week 2 exclude the symptoms reported by the three pilots who also participated in week one.

Another potentially relevant factor in the onset of simulator sickness symptoms is the time of day of the simulator sortie. In Table 5, symptom occurrence is separated by time of day and scenario type. It is difficult to discern a pattern from each individual cell in this table because varying numbers of crewmembers are associated with each. However, the averages calculated for each time of day illustrate a slight trend. The number of symptoms reported increases as the day progresses. Anecdotal information, instructor accounts, and direct observation of other simulator training support this finding which could have implications for training and syllabus development.

Table 5. Number of Post-Flight Simulator Sickness Symptoms Reported By Scenario Type and Time of Day.

	SI	SR	EP	DT	NT	Total	Average
7-11:00 a.m.	5	4	6	5	2	22(22)*	1.0
11-3:00 p.m.	2	3	17	7	2	31(23)*	1.35
3-7:00 p.m.	4	9	/	6	4	23(16)*	1.44

*Note: Numbers within parentheses represent number of inputs used for each row

Some research has indicated that three highly influential factors in inducing simulator sickness are wide FOVs, motion-base platforms, and crew position with FEs being particularly susceptible (Frank et al., 1983). If these were the primary factors involved, one could surmise that the incidence of simulator sickness would be greater for FEs than pilots in the MH-60G OFT. However, the average number of symptoms reported by FEs was less than one per flight ($\bar{X}$ = .6, n = 4), compared to an average of 1.4 (n = 9) for pilots. This suggests other factors may be equally influential as FOV, motion base, and crew position in the occurrence of simulator sickness symptoms, for example, level of involvement. The configuration of the MH-60G OFT cockpit requires the FE to look over the shoulders of the pilots rather than being seated between them as in many aircraft and other simulators. The somewhat displaced FE may not feel as integrally involved in the mission, perhaps not focusing as intently on the visual scene as the pilots or as the FE would in a simulator with a center FE seat. The FE's position in this simulator may reduce the sense of flight realism and involvement, making the FE more of a "backseater" in this device than in the aircraft,. "Backseaters" tend to have a reduced incidence of simulator sickness symptoms (McCauley, 1984).

A critical question on the post-flight questionnaire was whether pilots adjusted their control inputs during simulator flight to deal with the simulator sickness symptoms that may have occurred. This question was essential to this experiment because of its training

implications. If pilots modify their control inputs, the required skills are not being practiced. In the extreme case of the novice pilot, skills learned in the simulator may not be appropriate in the aircraft; this is a condition known as "negative training." It requires further training, time, and money to correct the improper habits formed in the simulator. Six out of nine pilots reported modifying their control inputs at some point during their participation to attempt to alleviate simulator sickness discomfort,. These modifications ranged from slight such as, "slowed control inputs" to more extreme adjustments such as, "transferred controls" or "closed my eyes during rapid aircraft movements."

Pilots' verbatim verbal responses regarding control input changes appear in Appendix C. No apparent pattern emerged; that is, pilots reported changing control inputs on all types of missions across all levels of flight experience. The two pilots with considerably higher aircraft flying time (6,450 hr and 15,327 hr) most consistently reported changing their control inputs. The pilot with 15,327 hr modified his control inputs in each of his eight sorties; and the pilot with 6,450 hr modified his control inputs in each of his four sorties. For training purposes, record of these control modifications should be kept to determine when they occur and to attempt to prevent potential safety hazards in the actual aircraft by knowing when hazardous control modifications could be made in the aircraft. Also, attempts should be made to coach students about flying the simulator as if it were an aircraft versus flying the simulator. That is, crewmembers should not make modifications in appropriate flying techniques just to accommodate the idiosyncrasies of the simulator.

Motion History Questionnaire: Predisposing Factors. The motion history questionnaire was designed to assess whether there were any crewmember characteristics predisposing them to the onset of simulator sickness symptoms in this device. Any definitive statement about the crewmember characteristics that facilitate the occurrence of simulator sickness symptoms in this device are difficult to make. In fact, two previously demonstrated correlated factors with simulator sickness, prior incidence of motion sickness and number of flying hours in the aircraft (Kennedy et al., 1984), showed little relationship to the occurrence of simulator sickness in the MH-60G OFT.

In Table 6, the participants' data are separated by total number of flying hours. Across the three levels of flying experience, the average number of reported symptoms is virtually the same, and the percentage of crewmembers within each level that reported symptoms is very high.

Table 6. Number of Post-Flight Simulator Sickness Symptoms Reported by Number of Flying Hours .

Number of Hours	0 to 2,500	2,500-3,000	3,000 and Above
Number of Crewmembers	4(+1)	3	5(+2)*
Number of Symptoms	23	13	32
Percent of Crewmembers Who Reported Symptoms	100	66	86
Average Number Per Crewmember	4.6	4.33	4.57

*Note: The numbers in the parentheses represent crewmembers who participated in the experiment both weeks. Also note that one crewmember's data were missing regarding number of hours flown.

The authors felt obliged to pursue this issue further due to the abundance of literature that suggests and demonstrates that flying experience and simulator sickness symptoms are highly related (McCauley, 1984; Warner et al., 1993). Communications with training experts implied that the relevant flying experience in terms of simulator sickness may be aircraft specific. That is, in this case, the number of flying hours crewmembers have spent in the MH-60G aircraft may be more related to the simulator sickness symptoms reported in the MH-60G OFT than their overall number of flying hours. This further analysis is even more perplexing than the analysis associated with the total number of flying hours.

Table 7 depicts the number of symptoms reported by the number of hours solely in the MH-60G. The trend is the opposite of what the literature predicts. More MH-60G flight hours are associated with fewer post-flight simulator sickness symptoms. The authors recommend a degree of skepticism, however, when reviewing this table. The notion of "experience" seems to be unduly confounded because the two pilots with an abundance of flying time (15,327 and 6,450 hr) had 300 hr or less in the MH-60G.

Table 7. Number of Post-Flight Simulator Sickness Symptoms Reported by Number of Flying Hours in the MH-60G.

Number of Hours	0-300	301-400	401-700	701+
Number of Crewmembers	4(+1)	3	2(+1)	3(+1)*
Number of Symptoms	39	11	16	7
Percent of Crewmembers Who Reported Symptoms	100	100	100	33
Average Number Per Crewmember	7.8	3.67	5.3	1.75

*Note: The numbers in parentheses represent crewmembers who participated in the experiment both weeks. Also note that one crewmember's data were missing regarding number of hours flown.

Finally, acknowledged past history of motion-related sickness, either in another simulator or other motion environments has also been previously associated with reports of simulator sickness (Kennedy et al., 1992). In this situation, the difference, although in the right direction is minimal. The average number of symptoms reported by crewmembers with a past history of motion sickness was 5.43 ; those who did not report past motion sickness averaged 4.63 symptoms .

Prolonged Simulator Sickness Symptoms. The total number reported of prolonged symptoms was 32, less than half the number of post- flight simulator sickness symptoms. Table 8 lists the prolonged simulator sickness symptoms and their frequency of occurrence. Within this experiment, the occurrence of prolonged simulator sickness symptoms seems more rare than post-flight simulator sickness symptoms. Yet, the fact that any prolonged side effects occurred is cause for concern and further exploration.

Nearly all participants (85%) reported multiple post-flight simulator sickness symptoms over the course of the experiment,. In terms of prolonged simulator sickness symptoms, five participants reported having no symptoms, four participants reported one symptom, and only four participants reported two or more symptoms (approximately 30%). These four participants did not seem to have any commonalities: one was an FE; three were pilots; two wore glasses, two did not; one had high aircraft flying time (3,000 or more), one medium (2,500 to 3,000) and one low (2,500 or less); two had past occurrences of motion sickness and two did not. The only commonality established was that they all had previous experience with visual flight simulators. However, so did the rest of the participants.

Table 8. Prolonged Simulator Sickness Symptoms Reported and Their Frequency.

Symptom	Frequency
*Fatigue	9
Sensory Confusion	7
Stomach Discomfort	6
Vertigo	6
Visual Flashbacks	2
Visual Illusions	2
Appetite Change	0
Faintness	0

*Note: This symptom was not listed on the questionnaire checklist, but it was a consistent response to question #3 on the Prolonged Side Effects questionnaire.

Although a critical element in making progress in the area of simulator sickness (e.g., finding causal factors, prevention, etc.) is to assess larger sample sizes with more variability among the participants, an interesting correlation was found with the existing data. Prolonged simulator sickness symptoms were highly correlated with post-flight simulator sickness symptoms ($r = .828$). At the risk of stating the obvious, and for emphasis, it seems that the more post-flight simulator sickness symptoms one has, the more prolonged side effects one will also have. Recognition of this by students and trainers has implications for scheduling and safety.

DISCUSSION

The central thrust of this research was to assess the incidence of simulator sickness and the impact, if any, of reported simulator sickness symptoms on the training provided by the MH-60G OFT. In this regard various findings were relevant: (a) nearly all participants reported symptoms, (b) pilots tended to change control inputs during simulator sorties, (c) frequency of reported symptoms differed depending on the type of scenario and time of day, (d) participants reported prolonged side effects after using the device, (e) post-flight simulator sickness symptoms and prolonged simulator sickness symptoms were highly correlated, and (f) there was a reduction of reported symptoms over the course of each week of the QOT&E (adaptation).

Training: Central Aspects and Recommendations

Skills. Control modifications included behaviors such as pilots closing their eyes and surrendering control of the aircraft. These are rather drastic findings both in terms of simulator training and flight safety. These pilot modifications should be examined and monitored more

when the aircrews return to the aircraft?). There are also various measures that can be used to alleviate or reduce symptoms by instructors or simulator operators, perhaps before pilots initiate their own "cures." These include: removing scene content from the screen at the end of a flight, avoiding random use of the reset button, avoiding prolonged exposure, etc. (Kennedy et al., 1984).

The observation that different mission scenarios evoke different simulator sickness levels is also quite critical from a training perspective. Aircrews can be forewarned that certain scenarios cause more simulator sickness problems than others. This may reduce their anxiety, lessen or even eliminate simulator sickness symptoms when or if symptoms occur. Dobie, May, Fisher, and Bologna (1990) demonstrated that providing aircrews with knowledge of simulator sickness symptoms prior to simulator training decreased the number and severity of the symptoms, thereby minimizing training disruptions.

Scheduling and Syllabus Development. Findings (c) and (d) are perhaps most critical for scheduling and syllabus development. For example, we found evidence that morning simulator sorties were associated with fewer reported simulator sickness symptoms. It may be important from a training effectiveness and user acceptance point of view to try to schedule most of the MH-60G OFT training sessions for the morning. The authors realize from a budget and logistical perspective, this suggestion may not be feasible.

The fact that the number of symptoms crewmembers report lessens over time could also be addressed in syllabus development. That is, training could be segmented such that simulator training is provided in segments, or a few sessions in a row, before crews return to the aircraft.

Safety. Although not central to this experiment, a few words can be said about safety and the MH-60G OFT. As already mentioned the control input issue is highly relevant to safety, monitoring these changes in pilot inputs and their effects on actual aircraft flight is critical. Another issue relevant to safety is the onset of prolonged side effects due to simulator use. The number of reported prolonged simulator sickness symptoms was less than reported post-flight symptoms, however, there were still quite a few prolonged side effects reported.

Two factors of apparent importance with respect to prolonged side effects and safety are the time course of symptom onset and the tasks being performed during symptom onset. The time course of the prolonged sickness symptoms and the tasks being performed during symptom onset did not lend themselves to any sweeping generalizations, however, they should be noted because some recommendations can be made based on our findings. The time course

for prolonged simulator sickness symptom onset varied from one hour to 18 hours after simulator flights with the mode being one to one-and-a-half hours.

The tasks that were being performed during symptom onset were variable as well, including things like: office work, eating, sitting, "normal living," etc. Two subjects reported visual illusions and flashbacks while driving. Taken together, these findings suggest potential scheduling accommodations that could prevent safety hazards. For example, given that most individuals experienced prolonged symptoms from one to two hours after the training session, their general duties could be restricted for this duration following simulator sessions. Additionally, AF crewmember flying duties could be restricted for 24 hours after simulator sessions, similar to restrictions required by other aerospace systems (Ungs, 1987). This would perhaps accommodate outliers who experience prolonged side effects up to 18 (or more) hours after their simulator sortie. Prolonged simulator side effects could also be addressed on an individual basis. The high correlation between post-flight simulator sickness symptoms and prolonged symptoms could be further investigated and perhaps eventually used to determine which crewmembers will be more likely to experience prolonged simulator sickness symptoms and these individuals could be "detained" accordingly following simulator training.

Motion

Another aspect explored in this study was pilot opinion about the addition of a motion platform to the MH-60G OFT. Motion bases on aviation simulators are typically six-degree-of-freedom platforms that enable the device to rotate along all axes of flight. Although not prohibitive, their cost is a significant percentage of total system acquisition. Current DoD acquisition strategy demands the lowest cost for the greatest utilization. If pilots are able to train effectively without these platforms, acquisition dollars would be saved not only up front, but also in follow-on maintenance requirements.

There were various opinions about the value of a motion base, seemingly dependent on the type of scenario flown (e.g., motion was consistently viewed as unnecessary for the SI scenario). When crewmembers were asked about the addition that a motion platform would make to training versus the reduction of simulator sickness symptoms, our findings were counterintuitive. Many crewmembers responded that a motion platform would help training by giving them more "seat of the pants" feel, yet, it would probably increase the occurrence of simulator sickness symptoms. We did not ask participants to explain the reasons for their responses, however; perhaps this response pattern supports the conflict theory of motion sickness (McCauley, 1984). The crewmembers may think that motion adds realism to simulator

flight, and is therefore attractive, but the slight delay between control inputs and the resulting motion causes simulator sickness problems. A delay that is not consciously recognized, except for their opinions that removing motion may help to alleviate simulator sickness symptoms. Additionally, none of the pilots implicated the lack of a motion base with specific training deficiencies of the device. Empirical support for some of these opinions can be found in Horey (1992). He demonstrated that transfer of training to the aircraft from three types of motion-based simulators (full, restricted, and none) was essentially the same. Thus, the level of flight realism may be sacrificed by not having a motion base. Most, if not all of the tasks were still sufficiently performed and trained without it.

The tradeoffs associated with not having a motion base must be thoroughly examined before deciding to acquire high fidelity, nonmotion-based aircraft simulators. For instance, certain vibrations associated with specific engine, propeller, and rotor malfunctions can only be simulated with some type of motion base. Whether this type of procedure would be better trained in the aircraft, which may be, and in most cases is, more costly, or is worth the investment that motion requires for a ground-based training device necessitates further investigation.

General Conclusions

The authors make two main recommendations based on this research.

1. With regard to training using this device or training using high fidelity visual simulators in general, simulator sickness symptoms and their potential occurrence should be highlighted and explained prior to aircrew training in a simulator. As mentioned, Dobie et al. (1990) have shown that this is one effective means of reducing the symptoms and their disruptive effects. As a part of this acknowledgement, aircrews should be informed of the factors that tend to be involved and the events that are more likely to induce symptoms. Additionally, those crewmembers who regularly report simulator sickness symptoms should limit their subsequent activities for safety.

2. Simulator sickness data should be collected continuously throughout the lifecycle of this device and other devices, similar to the Navy's efforts (Kennedy et al., 1992). Collecting data continuously will provide a means of determining the contributing factors to simulator sickness more precisely and formally, as well as determining its effects on training. If some aspect is cited fairly often as promoting simulator sickness, attempts can be made to change either the hardware or the method of using the device to prevent symptom occurrence or to lessen symptom severity. For example, this was done during training sessions using the MH-53J

Weapon System Trainer/Mission Rehearsal System (WST/MRS). Although rigorous data collection has not occurred, anecdotal accounts suggest that the use of position freeze can aggravate simulator sickness symptoms. Instructors acknowledge this problem and try to minimize the use of position freeze during training sessions.

The main thrust of this research was to assess indications of simulator sickness in the MH-60G OFT. Although small sample sizes do not lend themselves to inferential statistical analysis, in this case, even with the small sample size, there was evidence for simulator sickness symptoms across most of the participants which warrants further study of this phenomenon. The 58th SOW has a technologically advanced procedures trainer that fits quite well within their formal school curriculum. We would like to encourage them to examine simulator sickness onset in the MH-60G OFT more completely in order to eventually lessen any impact it has on training and to increase user acceptance of the device.

REFERENCES

Bartlett, G. T. (1989). Preparing the Army's surrogate battlefields. Signal, 43, 23-28.

Campbell, J. P. (1971). Personnel training and development. Annual Review of Psychology, 22, 565-602.

Caro, P. W. (1973). Aircraft simulators and pilot training. Human Factors, 15, 502-509.

Caro, P. W. (1979). The relationship between flight simulator motion and training requirements. Human Factors, 21, 493-501.

Caro, P. W. (March, 1977). Some Factors Influencing Air Force Simulator Effectiveness. Alexandria, VA: Human Resources Research Organization.

Cohen, E. (1970). Is motion needed in flight simulators used for training? Human Factors, 12, 75-79.

Dobie, T. G., May, J. G., Fisher, W. D., & Bologna, N. B. (October, 1990). An Evaluation of Cognitive-Behavioral Therapy for Training Resistance to Visually-Induced Motion Sickness. New Orleans, LA: Naval Biodynamics Laboratory.

Frank, L., Kennedy, R. S., Kellogg, R. S., & McCauley, M. E. (April, 1983). Simulator Sickness: A Reaction to a Transform Perceptual World. I. Scope of the Problem. Orlando, FL: Naval Training Equipment Center.

Gerathewohl, S. (December, 1979). Fidelity of Simulation and Transfer of Training: A Review of the Problem. Washington, D.C.: Federal Aviation Administration.

Goldberg, J., D'Amico, A., & Williams, K. (December, 1980). Transfer of Training from Low to High Fidelity Shiphandling Simulators. Kings Point, NY: National Maritime Research Center.

Gray, T. H., & Fuller, R. R. (1977). Simulator training and platform motion in air-to surface weapon delivery training. Proceedings of the 10th NTEC/Industry Conference. Orlando, FL..

Grier, P. (1990). Three tracks for simulation: New options are coming in mission rehearsal, networking, and training. Air Force Magazine, 73, 40-43.

Hopkins, C. O. (1973). How much should you pay for that box? Human Factors, 17, 533-541.

Horey, J. D. (1992). Estimating the impact of restricting simulated motion on transfer of training rotary wing aircraft. Proceedings of the 14th Interservice/Industry Training Systems and Education Conference. San Antonio, TX.

Jacobs, R. S. (August, 1975). Simulator Motion as a Factor in Flight Simulator Training Effectiveness. Urbana, IL: Illinois University.

Kellogg, R. S., Castore, C., & Coward, R. (1980). Psychophysiological effects of training in a full vision simulator. Preprints of the 51st Annual Meeting of the Aerospace Medicine Assoc. Alexandria, VA: Aerospace Medical Association.

Kellogg, R. S., & Gillingham K. K. (1986). United States Air Force experience with simulator sickness, research and training. Proceedings of the Human Factors Society - 30th Annual Meeting.

Kennedy, R. S., Berbaum, K. S., Allgood, G.O., Lane, N.E., Lilienthal, M. G., & Baltzley, D. R. (1992). Etiological significance of equipment features and pilot history in simulator sickness. AGARD Conference Proceedings, No. 433: Motion Cues in Flight Simulation and Simulator Induced Sickness. France: Advisory Group for Aerospace Research & Development.

Kennedy, R. S., Dutton, B., Lilienthal, M. G., Ricard, G. L., & Frank, L. H. (1984). Simulator sickness: Incidence of simulator aftereffects in Navy flight trainers. Proceedings of the Twenty Second Annual Symposium Safe Association. Las Vegas, NV: Safe Association.

Kennedy, R. S., Lilienthal, M. G., Berbaum, K. S., Baltzley, D. R., & McCauley, M. E. (1989). Simulator sickness in U.S. Navy flight simulators. Aviation, Space, and Environmental Medicine, 60, 10-16.

Koonce, J. M. (April, 1974). Effects of Ground-Based Aircraft Simulator Motion Conditions Upon Prediction of Pilot Proficiency (Parts 1 and 2). Savoy, IL: Aviation Research Laboratory.

Martin, E. A. (1992). An evaluation of dome display suitability for side-by-side crewmember viewing. Proceedings of the 14th Interservice/Industry Training Systems and Education Conference. San Antonio, TX.

McCauley, M. E., Ed. (1984). Research issues in simulator sickness: Proceedings of a workshop. Washington DC: National Academy Press.

McCauley, M. E., Hettinger, L., Sharkey, T., & Sinacori, J. (1990). The effects of simulator visual-motion asynchrony on simulator induced sickness. AIAA Flight Simulation Technologies Conference and Exhibit. Dayton, OH.

Nataupsky, M., Waag, W.L.; Weyer, D.C., McFadden, R.W., & McDowell, E. (1979). Platform motion contributions to simulator training effectiveness: Study III--Interaction of motion with Field-of-view (AFHRL-TR-79-25, AD A078426). Williams AFB, AZ: Air Force Human Resources Laboratory, Operations Training Division.

Pate, H. C. (1992). Simulation and training. U.S. Army Aviation Digest, 92, 29-32.

Pohlman, L. D., & Reed, J. C. (1978). Air-to-air combat skills: Contribution of platform motion to initial training (AFHRL-TR-78-53, AD A062738). Williams AFB, AZ: Air Force Human Resources Laboratory, Operations Training Division.

Reed, E. T. (1993). U.S. Air Force helicopter training high fidelity simulation providing advanced mission training and rehearsal. Proceedings of the 15th Interservice/Industry Training Systems and Education Conference. Orlando, FL.

Ricard, G. L. & Parrish, R. V. (1984). Pilot differences and motion cuing effects in simulated helicopter hover. Human Factors, 26, 249-256.

Ryan, L. E., Scott, P. G., & Browning, R. F. (September, 1978). The Effects of Simulator Landing Practice and the Contribution of Motion Simulation to P-3 Pilot Training. Orlando, FL: Training Analysis Evaluation Group.

Semple, C. A., Hennessy, R. T., Sanders, M. S., Cross, B. K., Beith, B. H., & McCauley, M. E. (January, 1981). Aircrew Training Devices: Fidelity Features. Wright-Patterson AFB, OH: Logistics and Technical Training Division.

Selix, G. (1993). Evolution of a training program: the effects of simulation on the MH-53J PAVE LOW combat crew qualification course. Proceedings of the 15th Interservice/Industry Training Systems and Education Conference. Orlando, FL.

Shirts, G. R. (1992). Ten secrets of successful simulations. Training, 29, 79-83.

Solomon, C. M. (1993). Simulation training builds teams through experience. Personnel Journal, 72, 100-108.

Tannenbaum, S. I. & Yukl, G. (1992). Training and development in work organizations. Annual Review of Psychology, 43, 399-441.

Ungs, T. J. (1987). Simulator induced syndrome: Evidence for long term simulator aftereffects. Proceedings of the Human Factors Society - 31st Annual Meeting.

Vestewig, R., Bergsneider, C., & Richardson, S. (1991). Reconfigurable Simulators for Special Operations Forces Mission Rehearsal. Proceedings of the 13th Interservice/Industry Training Systems and Education Conference. Orlando, FL.

Warner, H. D., Serfoss, G. L., Baruch, T. M., & Hubbard, D. C. (1993). Flight simulator-induced sickness and visual displays Evaluation (AL/HR-TR-1993-0056, AD A267019). Williams AFB, AZ: Armstrong Laboratory, Aircrew Training Research Division.

Willigies, B. H. & Roscoe, S. N. (1973). Synthetic flight training revisited. Human Factors, 15, 543-560.

Woodruff, R., R.; Smith, J.F.; Fuller, Jr., J.R.; & Weyer, D.C. (1976). Full mission simulation in undergraduate pilot training: An exploratory study (AFHRL-TR-76-84, AD A039267). Williams AFB, AZ: Air Force Human Resources Laboratory, Flying Training Division.

APPENDIX A

CRITICAL TASK LISTING FOR EACH SCENARIO

Instruments

1. Instrument Takeoff
2. Instrument Flight Rules (IFR) Navigation
3. Fuel Management
4. ASR/PAR/No Gyro
5. ILS/LOC/BC
6. VOR/VOR Holding
7. TACAN/TACAN Holding
8. Arcing
9. Fix-to-Fix Procedures
10. Procedure Turn
11. Circling Approach
12. Missed Approach

Remote Operations

1. Engine Start/Shutdown
2. Normal Takeoff
3. Normal Approach
4. Marginal Power Takeoff
5. Marginal Power Approach
6. Hot/Hung Start
7. Single-Engine Failure Hover
8. Tactical Navigation Procedures
9. Weather (WX) Radar Interface
10. Visual Search Patterns
11. Pilot Locator System Search
12. Power Available Check
13. Remote Site Evaluation
14. Water Operations Procedures

Emergency Procedures (EPs)

1. Engine Start/Shutdown
2. Normal Takeoff
3. Normal Approach
4. Marginal Power Takeoff
5. Marginal Power Approach
6. APU Malfunction
7. Engine Fire on Ground
8. Starter Malfunctions
9. Post-Shutdown Fire
10. Engine Malfunctions
11. ECU Malfunctions
12. Fuel Malfunctions
13. Transmission Malfunctions
14. Hydraulic Malfunctions
15. AFCS Malfunctions
16. Stabilator Malfunctions
17. Tail Rotor Malfunctions
18. Dual Engine Fail/Autorotation

Day and Night Tactical (DT/NT)

1. Terrain Flight Masking
2. Communication Codes
3. IFF/Have Quick
4. Low-Level EPs
5. Landing Zone (LZ) Authentication
6. Tactical Approach/Land/AIE/T/O
7. Single-Ship Landing Zone Operations
8. Lead/Wing
9. Night Vision Goggle (NVG) Fail/Malfunction
10. Go-Around/Abort
11. Formation Positions
12. Join Up/Crossover/LD Change
13. Minimum Light/Communications Out (A/R)
14. Rec Low Rendezvous/Join Up
15. Right/Left Hose/Crossover
16. Breakaway/Lost Visibility Procedures
17. Aerial Refueling Emergencies
18. Shipboard Operations Patterns
19. Shipboard Landing/Takeoff

APPENDIX B

INFORMATION SHEET,

INFORMED CONSENT FORM,

and

QUESTIONNAIRES

INFORMATION SHEET

MOTION STUDY FOR THE MH-60G OPERATIONAL FLIGHT TRAINER

Information Protected by the Privacy Act of 1974

Work Unit: MH-60G PAVE HAWK OFT, 58TH Special Operations Wing, Kirtland AFB, NM, 87117

1. a. Nature. A flight simulator motion study is being conducted on the MH-60G OFT. You are invited to participate in this evaluation because of your extensive flying experience.

b. Purpose. The objective of this evaluation is to identify any incidence of possible side effects as a result of flying the MH-60G OFT.

c. Forms. Attached are two forms. The first is a consent form for participation in this study. The second one is a motion history questionnaire to baseline our study. These two are to be filled out at the beginning of the study only (see below). For each flight, there are also two additional forms: Post-Flight and Prolonged Effects questionnaires. The Post-Flight questionnaire is to be filled out immediately following each flight. The Prolonged Side Effects questionnaire is to be filled out the following day prior to beginning the next scheduled flight. The simulator flights vary from 3 - 3.5 hours, five days per week, for two weeks. This evaluation is being conducted in conjunction with the Qualification Operational Test and Evaluation (QOT&E) by HQ AFOTEC/TFM.

2. Prior to beginning the first flight, a motion history questionnaire for each crewmember is requested to baseline each individual's flight history. The data collected applies to this evaluation only and will not be released except for the purposes of reporting the findings. Participants will not be referenced by name, but by team number, thus disassociating their names with any incidence of reporting purposes. Confidentiality will be assured.

3. We request that the information be gathered as part of the normal QOT&E procedures and task accomplishment, not as specific mission parameters. Subjects are requested to adhere to normal operating procedures and not to instigate any behavior for the purposes of modifying data collection pertaining to this investigation.

INFORMED CONSENT FORM

I consent to the release of information relating to the motion study and simulator side effects evaluation on the MH-60G OFT, subject to federal law, including the Federal Privacy Act, 55 U.S.C. 552a, and its implementing regulations. This means information will not be released to an unauthorized source without my permission.

I UNDERSTAND THAT I AM REQUIRED TO REFRAIN FROM FLYING AN ACTUAL AIRCRAFT FOR AT LEAST 12 HOURS AFTER I FLY A FLIGHT SIMULATOR IN THIS STUDY.

I FULLY UNDERSTAND THAT I AM MAKING A DECISION WHETHER OR NOT TO PARTICIPATE. MY SIGNATURE INDICATES THAT I HAVE DECIDED TO PARTICIPATE HAVING READ THE INFORMATION PROVIDED ABOVE.

Volunteer Signature and SSAN _____

Test Manager Signature _____

INFORMATION PROTECTED BY THE PRIVACY ACT 1974

Authority: 10 U.S.C. 8012, Secretary of the Air Force; powers and duties; delegation by; implemented by DOI 12-1, Office Locator.

Purpose: Request consent for participation in approved medical research studies. Disclosure is voluntary.

Routine use: Information may be disclosed for any of the blanket routine uses published by the Air Force and reprinted in AFP 12-36, and in Federal Register 52 FR 16431.

MOTION HISTORY QUESTIONNAIRE

NAME: _____ DATE: _____

TEAM NUMBER: _____

AC ___ CP ___ FE ___

1. Total Flying Hours by aircraft type (if known): _____

2. Have you ever been airsick? Yes/No (Circle one). If yes, how many times? _____

3. Have you ever flown in a flight simulator with a visual system? Yes/No (Circle one). If yes, total number of hours in a visual flight simulator: _____

4. Have you ever experienced any sensory distortion or imbalances in any simulator? Yes/No (Circle one). If yes, what type of maneuvers were you flying? (e.g., low level threat avoidance)_____

If yes, list the simulator and its location: _____
If yes, how long did the symptoms last? _____
What, in your opinion, was the cause of the disorientation? _____
_____

5. Have you experienced any adverse symptoms that did not occur until after a simulator flight? Yes/No (Circle one). If yes, list the symptoms and the time lapse in noticing them: _____
_____

6. Have you ever experienced any motion sickness under any conditions not listed above (i.e., sea sickness)? Yes/No (Circle one). If yes, please list them: _____
_____

7. Have you had any incidence of nausea FOR ANY REASON during the past eight weeks? Yes/No (Circle one). If yes, please explain: _____
_____

8. Is there any current medical condition, such as cold or flu, that might cause you dizziness or nausea more readily than if you did not have the condition presently? Yes/No (Circle one). If yes, please explain, listing any medication you may be taking: _____
_____

9. Please list any other factors regarding your present physical condition that might affect your simulator flights over the next two weeks: _____
_____

10. Do you wear eyeglasses? Yes/No (Circle one).

POST-FLIGHT QUESTIONNAIRE
INFORMATION PROTECTED BY THE PRIVACY ACT OF 1974

1. Date of mission: _____
2. Time of mission: _____
3. Name and crew position for the flight: _____

4. Mission profile: _____

5. Did you experience any disorientation during the simulator flight? Yes/No (Circle one).
If yes, please describe the sensation: _____
_____
If yes, please list the type of profile you were flying at the time the disorientation occurred:
_____
If yes, did you adjust your control inputs to lessen the effects of the disorientation? Yes/No (Circle one). If yes, did the changes you made have any effect? (And if so, what were they?): _____

6. What impact, if any, would the addition of a six-degree-of-freedom motion base add to the profile you just flew as far as sensory disruption is concerned? _____
_____

7. Would a different visual system or motion platform, in your opinion, affect your performance on the mission you just flew? If so, please state why: _____
_____

8. Did you experience any disconnect between the "out-of-the-window" view and the "seat-of-the-pants" feel in the cockpit? If so, please describe what you felt: _____
_____

9. Circle below any of the symptoms you might have experienced:

a. Eyestrain
b. Blurred vision
c. Difficulty focusing
d. Difficulty concentrating
e. Headache
f. Drowsiness/Fatigue
g. Sweating
h. Nausea
i. Dizziness/Vertigo
j. Stomach awareness

10. Compared to symptoms experienced under the same conditions during flight in an actual aircraft, would you describe your symptoms, if any, that you experienced during the simulator flight as being: (Circle one) Less Symptomatic Same as the aircraft More symptomatic

11. Was there a noticeable difference between control inputs and a corresponding change in inside-the-cockpit or out-the-window presentation? Yes/No (Circle one).

12. If you experienced any symptoms of any kind, how did they compare to symptoms you might have experienced in flying the aircraft? _____
_____

PROLONGED SIDE EFFECTS QUESTIONNAIRE

Name and Date: _____

PURPOSE. The purpose of this questionnaire is to assess any prolonged side effects caused by the MH-60G OFT. If no side effects are noted, please fill out the questionnaire to fulfill requirements of data continuity.

DEFINITION. Prolonged side effects are those which are manifest after more than one hour from sortie termination.

DATA COLLECTION. This data will be used in a confidential manner. Nothing contained herein will be used for the purposes of action taken against any crewmember. If, however, the effects are such that an individual is incapacitated or unable to perform his duties, that individual will be directed to the flight surgeon's office immediately. Your safety is paramount.

1. From the time since the last simulator flight, have you experienced any of the following:

a. Vertigo	d. Faintness	g. Stomach disorders
b. Visual illusions	e. Loss of appetite	h. Sensory Confusion
c. Visual flashbacks	f. Increased appetite	I. Vomiting
		j. None of the above

2. If you noticed any symptoms, including those above, please note the time lapse since you completed the mission , and when the symptoms began and their duration. _____

_____

3. Were there any symptoms you experienced that are not listed above? If so please explain:

_____

4. Did you experience any equilibrium imbalances, such as the leans, visual tracking problems, or motor mechanical difficulties? If so, please explain: _____

_____

5. What task were you doing when the symptom(s) occurred? _____

_____

6. Did you do anything to alleviate the symptom? If so, what? _____

_____

7. If you did experience any prolonged symptoms, how will it impact the manner in which you will conduct further sorties in the OFT _____

_____

8. If you experienced any prolonged symptoms what, in your opinion, do you believe is the cause for the symptoms? _____

_____

APPENDIX C

VERBATIM VERBAL RESPONSES REGARDING CONTROL INPUT CHANGES

WEEK 1:

"Closed eyes, slowed control inputs."

"Yes, stopped problem."

"Stopped maneuver, did straight [and] level."

"Transferred controls and closed my eyes."

"Transferred controls."

"Got my eyes off the screen."

"Passed controls."

"Closed my eyes during rapid aircraft movements."

"Made the visuals dusk."

WEEK 2:

"When yank/bank is reduced to more gentler profile, symptoms reduce but aftereffect lingers."

"Concentrated more, kept flying [the] same way."

"Looked inside at the FLIR."

"Requested the visuals have a haze, less than one mile visibility."

"Yes, lessened control inputs."

"Rest eyes. Look away."

APPENDIX D

GLOSSARY OF ACRONYMS

AC	Aircraft Commander
AETC	Air Education and Training Command
AFB	Air Force Base
AFOTEC	Air Force Operational Test and Evaluation Center
AFSOF	Air Force Special Operations Forces
AL/HRA	Aircrew Training Research Division of the Armstrong Laboratory
AR	Air Refueling
ASPT	Advanced Simulator for Pilot Training
ASR	Air Surveillance Radar
CP	Co-Pilot
DoD	Department of Defense
DT	Day Tactical
EP	Emergency Procedure
FE	Flight Engineer
FLIR	Forward Looking Infrared
FOV	Field of View
GAT-2	Singer-Link General Aviation Trainer
IFS	Instrument Flight Rules
IG	Image Generator
IOS	Instructor Operator Station
ILS	Instrument Landing System
LZ	Landing Zone
Mdn	Median
MRS	Mission Rehearsal System
NT	Night Tactical
NVG	Night Vision Goggles
OFT	Operational Flight Trainer
PAR	Precision Approach Radar
QOT&E	Qualification, Operational, Test, and Evaluation
SAAC	Simulator for Air-to-Air Combat
SAR	Search and Rescue
SI	Instruments
SOF	Special Operations Forces
SOW	Special Operations Wing
SR	Remote Operations
TACAN	Tactical Air Navigation
UDRI	University of Dayton Research Institute
USAF	United States Air Force
VCE	Vector Combination of Errors
VHF	Very High Frequency
VOR	Omnidirectional Ranging
WST	Weapon System Trainer