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The Effect of Exposure to the AH-64 Combat Mission Flight Simulator On Postural Equilibrium

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Simulator sickness syndrome is a form of motion sickness that may occur during the simulator training exercise, immediately after, or sometime later. It may be induced by either physical or visual motion, and symptoms include: nausea, disorientation, ataxia, dizziness, visual problems, headache, depression, and sweating. An important operational problem associated with simulator sickness is the extent to which an individual aviator is incapacitated. This will determine how long after simulator exposure the aviator needs to be grounded. Previous researchers have measured postural equilibrium with standing and walking tests, but there are limitations associated with these tests. A modern method of objective measurement is the Neurocom Pro Balance Master®. The purpose of this assessment was to determine the effect of exposure to the AH-64 Combat Mission Simulator (CMS) on postural equilibrium. Six instructor pilots, 42 male student pilots, and 3 female student pilots were tested. The results clearly suggested that student training in the AH-64 CMS in its present configuration has an insignificant effect on postural equilibrium. A 2-hour period of "grounding" between training in the flight simulator and actual flight is probably adequate. Further assessments should be conducted in field locations.

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Introduction

Simulator sickness syndrome (SSS) has long posed a threat to the effective use of simulator training in military aviation. SSS is a form of motion sickness that may occur during the simulator training exercise, immediately after, or sometime later. It may be induced by either physical or visual motion, and symptoms include: nausea, disorientation, ataxia, dizziness, visual problems, headache, depression, and sweating. It has been estimated that as many as 29 percent of aviators may experience significant symptoms, and 1 percent will become incapacitated as a result of simulator training (COMASWWINGPAC, 1990).

Symptoms of SSS can be divided into four main categories: general malaise, fatigue related, visual disturbances, and postural changes (Kennedy et al., 1992). In the last category, manifestations such as unsteadiness and ataxia are often observed directly after simulator flights or some time later (Crosby and Kennedy, 1982; Naval Training Systems Center, 1989).

An important operational problem associated with simulator sickness, aside from concerns about training effectiveness, is the extent to which an individual aviator is incapacitated and the time course of the symptoms, especially loss of coordination. This in turn will determine for how long after simulator exposure the aviator should be grounded. Because of the potential practical impact of simulator-induced postural dysfunction, objective and sensitive measures are needed. This is because control of postural stability and balance involves integration of information from visual, vestibular and proprioceptive systems. Regulations concerning the mandatory grounding of aviators are variable throughout U.S. Army aviation, the policies being based upon research that was carried out during early experience with flight simulators using unsophisticated techniques of measurement, such as heel-to-toe walking and balancing on one leg. Furthermore, these simple walking and standing tests often do not permit an analysis of the relative role played by each sensory system in postural control.

It is well established that the incidence of SSS varies considerably between simulators and indeed in the same simulator following modification and upgrading (Braithwaite and Braithwaite 1990). Now that more reliable and sensitive means to assess postural equilibrium are available, it is timely to re-examine the incidence of this phenomenon so that contemporary regulations may be made (or abolished) as appropriate. Such a method now exists in the form of the Neurocom Pro Balance Master®. This device, which is described below, was originally designed to assess clinical states of disequilibrium and assist in the rehabilitation of ataxic patients. When used with a protocol devised by the Naval Aeromedical Research Laboratory (NAMRL), Pensacola, Florida, this device has been successfully demonstrated to discriminate the disequilibrium effects of a centrifuge ride and alcohol intoxication (McGrath et al., 1993 and 1994). The protocol is also described below.

A preliminary questionnaire study conducted at the Goodhand simulator complex at Fort Rucker, Alabama, during the summer of 1996 suggested that the AH-64 combat mission simulator (CMS) was the device in which most aviators were experiencing symptoms of SSS. Gower et al (1988) assessed the prevalence of SSS in this training device and concluded that because of the signs of disequilibrium exhibited by aviators, a mandatory 6-hour grounding policy following a training session should be applied. Technological enhancements in the simulation system are described below, and may have affected the generation of SSS symptoms and signs in aviators.

The objective of this project was to gather contemporary data on the incidence of postural equilibrium in order to make recommendations on grounding policies following simulator exposure. The hypothesis to be tested was as follows: the ability to maintain postural equilibrium following exposure to the AH-64 CMS is reduced. The null hypothesis was to be accepted if there was no significant difference between postural equilibrium measured before and following exposure.

Methods

This study was designed to investigate a single aspect of the SSS - equilibrium. A condition for permission to conduct the assessment was that it was not to interfere with training. There was thus a limited time in which to examine aviators as they attended their simulator training sessions. Consequently, lengthy questionnaires on the SSS were not presented, but there was an open question on the post training session questionnaire for subjects to comment on other symptomatology.

Apparatus

The CMS

The CMS produced by the Singer Link Company is a full motion-based simulator with 6 degrees of freedom, with 60 inches of travel. Each of the two aviators is located on an individual motion platform, one for the pilot (back seat) and the second for the copilot/gunner (front seat). The two motion platforms are linked by computer so that visual and motion information are the same for each. One pilot at a time is designated to "have the controls." Each cockpit has three windows for out-the-window viewing in addition to visual display unit and helmet display unit information of the actual aircraft. The CMS has undergone various upgrades since it has been in service.

The Balance Master

The Neurocom Pro Balance Master® system offers a quantitative assessment of a person's postural movements in relation to balance. The system has a moveable computerized force plate which measures, responds to, and dynamically provokes the subject's postural movements. All measurements are calibrated to each subject's height and weight. Software protocols use the force input and height data to calculate and record the position of the subject's center of gravity.

Sensory Organization Test (SOT) equilibrium scores are based on the assumption that a normal individual can exhibit anterior to posterior sway over a total range of 12.5 degrees (6.25 degrees anterior, 6.25 degrees posterior) without losing balance. The equilibrium score compares subject sway in a 20 second period (A in figure 1) to the theoretical limits of stability for normal subjects (B in figure 1). The score divided by the theoretical limit score is expressed as a percentage between 0 and 100, where a score of 0 indicates a fall, and 100 denotes perfect stability. A Polhemus® Head Tracker System was used to monitor the subject's head position during testing. "Pink noise" was presented through microphone ear inserts to remove any sense of auditory localization.

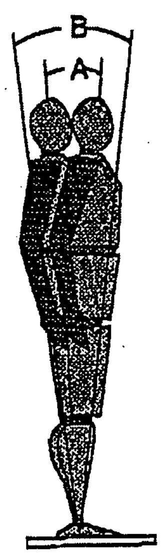

Figure 1. Actual (A) and theoretical (B) anterior to posterior sway.

Subjects

All AH-64 students attending the combat mission skills phase of the flight course during the summer/fall of 1997 were collectively briefed on the nature of the study, and asked to participate. Subjects were disqualified for any of the following reasons: current significant medical problems (including any vestibular or neck disorders), current use of medication, intake of more than 5 cups of coffee or equivalent caffeine per day, or intake of more than 3 units of alcohol per day.

Typically, students undergo simulator training in pairs, one occupying the front cockpit seat and the other the rear seat. After 90 minutes, they change seats for the second part of the training session. Since a condition of this assessment was that it should not interfere with training, we were therefore unable to examine any difference that exposure in either of the two seats might have had on SSS. As the order in which students occupied the cockpit seats might have an effect on the incidence of SSS, it was therefore decided to test students before and after two simulator training sessions with the request to their instructor pilot (IP) that on the second occasion they first occupy the seat that they had occupied last during the previous session. This was not always possible and some students did not return for their second testing session. Table 1 summarizes the seat run orders achieved.

Table 1.
Seat run order.

Seat order	No. of subjects during first run	No. of subjects during second run
FF	1	2
FB	21	11
BB	3	2
BF	9	19

F = front seat, B = back seat

The aim was originally to test at least 60 different aviators over this period, but regrettably, for logistic reasons, it was only possible to test 34 male students on two occasions, and a further 8 male students only once. No restriction on the age or gender of subjects was applied, but as there was no control over the composition of the training courses, the proportion of male to female subjects could not be determined prior to the study. Three female students were all tested on two occasions. The commander of the AH-64 training company requested that the investigators also test the IPs who occupy the simulator operator seat. All six IPs who volunteered were tested on one occasion. The students and IPs that volunteered to participate in the assessment received a full individual brief prior to testing which explained the procedures. Volunteer agreement affidavits, and volunteer registry data sheets were also maintained. Demographic data are described in the results section.

Procedure

Each subject underwent a preexposure and two postexposure assessments at varying times up to 30 minutes of exiting the simulator. The aim of the second postexposure test was to examine the effects of readaptation to the "normal" earth environment following simulator training. Three trials of SOT1 followed by six trials of SOT5 using the NAMRL protocol were performed on each occasion, and are described below. The average of all trials of SOT1, and the final three trials of SOT5 were used to calculate the SOT score. Six trials of SOT5 were performed to minimize any learning effect in this SOT.

The NAMRL protocol for SOTs comprises a series of controlled left/right and fore/aft dynamic head movements during the 20 seconds of the SOT1 and five trials to "activate" the otolith organ (McGrath et al., 1997). The head movements were: left head roll, head upright; right head roll, head upright; head pitch forward, head upright; and head pitch back, head upright. Subjects were instructed to tilt the head as far as possible in each direction without experiencing neck strain or moving the shoulders. Subjects were encouraged to maintain the same angular displacement and velocity of head motion for each set of tests. To achieve a constant frequency of head movements, beginning 3 seconds after the beginning of SOT, the operator provided verbal commands via the intercom at 2 second intervals: at 3 seconds, left; at 5 seconds, up at 7 seconds, right; at 9 seconds, up; at 11 seconds, forward; at 13 seconds, up; at 15 seconds, back; and at 17 seconds, up. The head tracker monitor ensured that the subject made the same magnitude and range of motion for each set of tests.

- SOT1 (figure 2): The test subject stands on the fixed platform with eyes open and performs the head movements as instructed. All sensory modalities (vision, proprioception, and vestibular) are used to maintain equilibrium in this condition.

- SOT5 (figure 3): The test subject stands on the sway-referenced platform with eyes closed and performs the head movements as instructed. Only the vestibular system is available to maintain equilibrium in this condition.

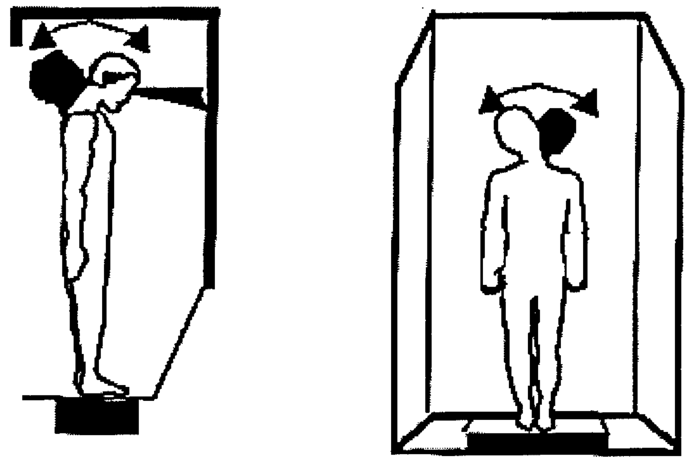

Figure 2. Diagram of SOT1 (after McGrath et al., 1997).

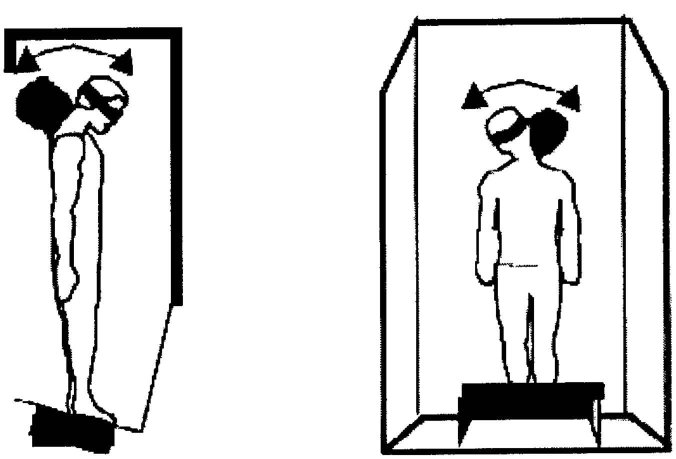

Figure 3. Diagram of SOT5 (after McGrath et al., 1997).

Results

Due to the small size of the samples of IP's and female students, it was not possible to conduct rigorous statistical analyses on these data. Their data are presented at appendices A and B, respectively. This section describes the data analysis for the male aviator students only.

Biographical data

Biographical data are summarized at table 2.

Table 2.
Biographical summary.

Variable	Mean	Standard deviation (SD)	Range
Age (years)	29.2	4.8	21-49
Rank			WO1 - MAJ
Height (inches)	70.8	2.1	66 - 75
Total flying hours	763	924	150 - 4300
Total simulator hours	92.4	86.8	0 - 300

SOT data analysis

The SOT1 and 5 were entered into an Microsoft ACCESS® database, and thence exported into Microsoft EXCEL® and Statsoft STATISTICA® files. Paired t-tests were performed on the pre- and the two postexposure equilibrium scores and these latter data were also analyzed by analysis of variance (ANOVA) with various independent variables.

Preexposure equilibrium scores

There was no significant difference among the three preexposure SOT1 trials, but, as anticipated, during the preexposure trials of SOT5, there was a significant learning effect (equilibrium score increased) between trials 1 and 2 (means 58.1 and 63.9, respectively, $t = -2.836$, $df = 75$, $p = 0.006$). A previous study by McGrath, et al., 1994, indicated that there was a significant learning effect during the first three trials of SOT5. In an attempt to reduce the learning effect, the subjects were given three training trials of SOT5 and only the last three trials were used to calculate the preexposure mean. In addition, there was no significant difference among trials 2 through 6 of SOT5. Figures 4 and 5 illustrate the preexposure equilibrium scores.

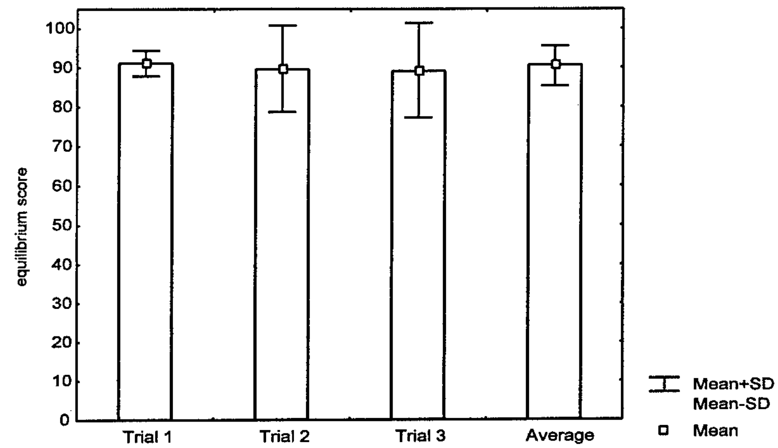

Figure 4. SOT1 preexposure equilibrium scores.

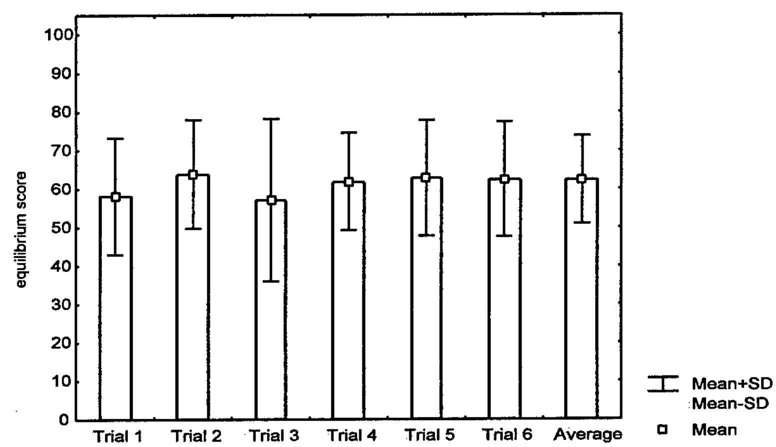

Figure 5. SOT5 preexposure equilibrium scores.

<u>Postexposure equilibrium scores</u>

As a preliminary analysis revealed that there was no significant difference in postexposure SOT scores among the various simulator conditions (e.g., type of visual system employed, status of similar motion base, etc.), the effect of time of postexposure testing was examined by grouping all runs together. Figures 6 and 7 illustrate the mean (+/- 1 SD) of the preexposure and the two postexposure scores of SOT1 and SOT5 grouped as a whole. There was no significant difference between the preexposure and either of the postexposure values for SOT1. However, comparison of the means for SOT5 revealed a significant difference between the preexposure score and both postexposure scores, but not between the two postexposure scores. Table 3 summarizes the statistical analysis. In both significant cases, the equilibrium score was higher following simulator exposure. There is no biological basis to suggest that simulator exposure improves postural stability. It is therefore concluded that these findings indicate a learning effect.

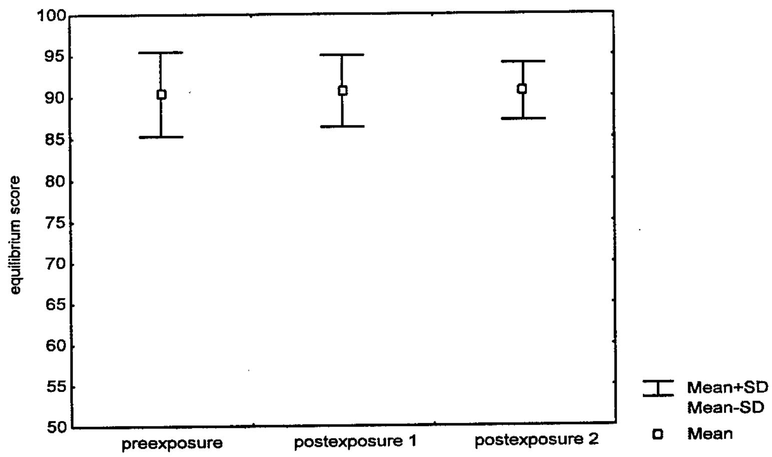

Figure 6. SOT1 mean (+/- 1 SD) of the preexposure and the two postexposure scores.

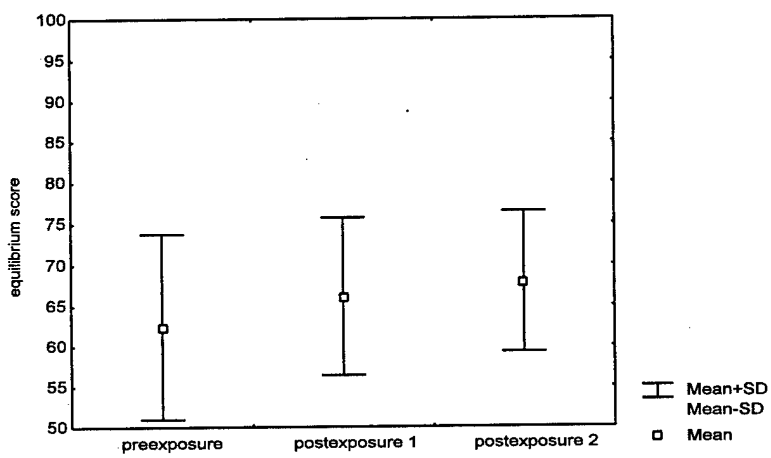

Figure 7. SOT5 mean (+/- 1 SD) of the preexposure and the two postexposure scores.

Table 3.
Summary of SOT5 analysis.

SOT5 Score	Mean	SD	t	df	p
preexposure	62.38	11.40			
first postexposure	66.05	9.65	-3.306	75	0.0014
preexposure	62.38	11.40			
second postexposure	67.86	8.58	-4.818	75	0.0000
first postexposure	66.05	9.65			
second postexposure	67.86	8.58	-1.996	75	0.0531

Figures 8 and 9 illustrate the mean pre- and postexposure equilibrium scores as a function of the time tested in the two postexposure sessions. ANOVA, using time of testing as the independent variable and postural equilibrium scores as the dependent variables, revealed no significant difference between the postexposure values of either SOT1 or SOT5.

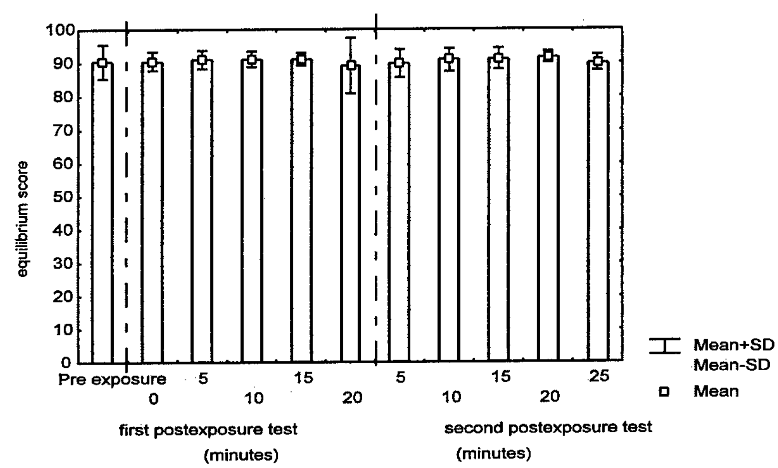

Figure 8. SOT1 mean preexposure and postexposure equilibrium scores as a function of the time tested.

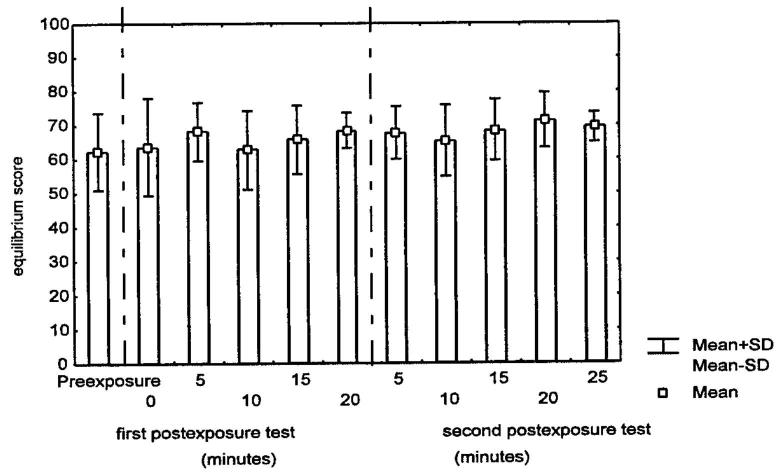

Figure 9. SOT5 mean preexposure and postexposure equilibrium scores as a function of the time tested.

Sensory analysis ratio

To identify the particular sensory dysfunction in the performance of an individual, NeuroCom recommends calculation of the sensory analysis ratio (SAR). Vestibular dysfunction is said to be present when SOT5 performance is poor relative to SOT1 performance (SAR = SOT5/SOT1)

Figure 10 illustrates the SAR as a function of the time tested in the pre- and two postexposure sessions. Although the 10, 15, and 20 minute values show a trend to a higher ratio with increasing time since exposure to the simulator, ANOVA, using time of testing as the independent variable and SAR as the dependent variable, revealed no significant difference between the postexposure values of the SAR. The relatively higher value at the 5 minute time of testing during both sessions is difficult to explain.

Effect of independent variables on equilibrium scores

There was no significant difference in the pre- or postexposure SOT1 or SOT5 scores with age, total flight, or simulator time. Students spent an average of 155 minutes in the simulator (SD = 54.5, range = 60 - 360 minutes). There was no significant difference between the pre- or postexposure SOT1 or SOT5 scores with this variable. The simulator motion system was inoperative for only four training sessions, and there was no significant difference in postexposure SOT1 or SOT5 scores between these two conditions. The night vision system was used by students in 29 training sessions and the naked eye in 47 sessions. Again, there was no significant difference in postexposure SOT1 or SOT5 scores between these two conditions.

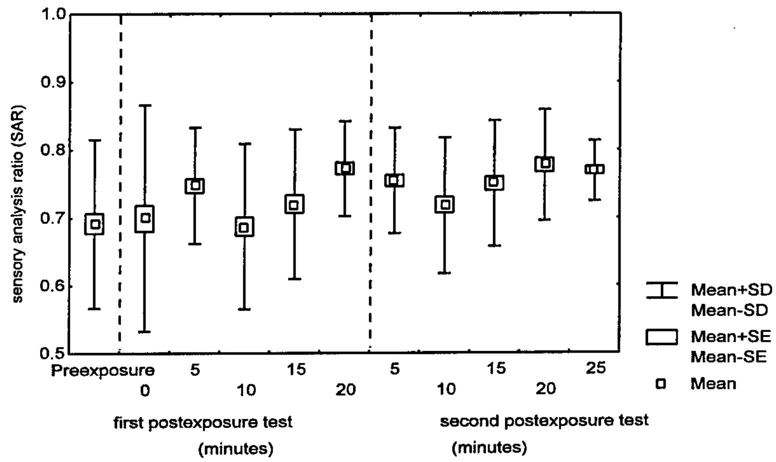

Figure 10. Sensory analysis ratio as a function of the time tested in the pre-and two postexposure sessions.

Comments and other symptoms

There were very few comments elicited from students on other aspects of SSS which was possibly due to the fact that the only direct questions that they were asked were: "Do you feel well?" and "do you have any visual problems?" A summary of these additional comments is at table 4.

Table 4.
Additional comments.

Comment	No. of subjects reporting
Sometimes get visual effects (unspecified).	3
Tendency to nausea when the motion base not activated.	4
Sometimes feel disoriented.	4

Discussion

The results clearly suggest that student training in the AH-64 CMS in its present configuration has an insignificant effect on postural equilibrium. Nothwithstanding the probable existence of a learning effect (that has not been stressed in previous work), postexposure postural equilibrium scores were not significantly different from the preexposure values and indeed, a trend of increasing SAR was seen in direct proportion to the time since leaving the simulator. This suggests that students underwent a rapid readaptation within 20 to 25 minutes to the "normal" earth environment following their training session.

On the basis of their postural dysfunction data (using walking and standing tests), Gower et al., (1988) recommended that a mandatory 6-hour grounding policy be applied following training in the AH-64 CMS. The results of this current assessment suggest that these previous criteria appear draconian, especially as there are no known reported instances within the last 10 years of postural disequilibrium following flight simulation affecting an Army aviator's ability to drive or fly. Our findings must, therefore, call into question the level and variability of grounding policies that exist throughout Army aviation following exposure to this type of flight simulator. It is stressed that this assessment was performed in an "operational" setting. No interference was made (or allowed) with the volunteer students' routine. This is a most important factor when considering interventive mandatory grounding policies - the data must be collected in an environment that is considered by the operational staff to be as normal a setting as possible. Therefore, on the basis of the current study, a more sensible policy of delaying actual flight for just 2 hours after exposure to the AH-64 CMS would be more appropriate. Given the comprehensive medical support that is available at Fort Rucker, it is recommended that cases of self-reported SSS and any other related malaise are dealt with on an individual basis.

As very little continuation training on the AH-64 CMS is done at Fort Rucker, these data are representative of students only. Whether there is any difference between these results and those that might be obtained from simulator field units can only be surmised. It would be an advantage (albeit logistically difficult) to examine postural equilibrium at the other AH-64 simulators.

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Appendix A.
Data for instructor pilots (IPs).

Only six IPs volunteered. All were male and tested on one occasion only. Three occupied the front seat instructor station, and three the back seat station. Table A-1 summarizes the postural equilibrium scores.

Table A-1.
Postural equilibrium scores for IPs.

	Mean	SD
SOT1 preexposure	90.2	4.2
SOT5 preexposure	64.9	14.5
SOT1 first postexposure	90.5	2.4
SOT5 first postexposure	67.4	8.4
SOT1 second postexposure	87.1	3.1
SOT5 second postexposure	67.4	12.3

There was no significant difference between the pre- and postexposure scores for either SOT1 or SOT5. Furthermore, there was no significant difference in the value of these scores between IPs and male students. The recommendations for a grounding policy made for male students attending the Fort Rucker AH-64 CMS is therefore also valid for this group.

Appendix B.
Data for female student pilots.

Only three female students volunteered. All were tested on two occasions only. Table B-1 summarizes the postural equilibrium scores.

Table B-1.
Postural equilibrium scores for female students.

	Mean	SD
SOT1 preexposure	91.3	1.2
SOT5 preexposure	68.2	10.6
SOT1 first postexposure	90.9	2.1
SOT5 first postexposure	72.4	5.0
SOT1 second postexposure	91.8	2.5
SOT5 second postexposure	72.5	6.7

There was no significant difference between the pre- and postexposure scores for either SOT1 or SOT5. Although there were only three subjects in this group, there was no significant difference in the value of these scores between female and male students. A definitive recommendation for female student pilots cannot be made at this stage as the survey sample was so small. However, the recommendations for a grounding policy made for male students attending the Fort Rucker AH-64 CMS is probably valid for this group.