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AUTOGENIC FEEDBACK TRAINING EXPERIMENT: A PREVENTATIVE METHOD FOR SPACE MOTION SICKNESS

Partricia S. Cowings
NASA Ames Research Center
Moffett Field, CA USA

The Problem of Space Motion Sickness

Space motion sickness is a disorder which produces symptoms similar to those of motion sickness on Earth. This syndrome has affected approximately 50% of all astronauts and cosmonauts exposed to microgravity in space, but it differs from what is commonly known as motion sickness in a number of critical ways. There is currently no ground-based method for predicting susceptibility to motion sickness in space. Antimotion sickness drugs have had limited success in preventing or counteracting symptoms in space, and frequently caused debilitating side effects. For example, the Physician's Desk Reference (1988, p. 2300) cautions under Information for Patients that one of the drugs used to counteract motion sickness, "Promethazine may impair the mental and/or physical abilities required for the performance of potentially hazardous tasks such as driving a vehicle or operating machinery." There are no data from space on the effects of this medication on crew performance.

Biomedical data from past space missions indicate that some individuals who have had wide exposure to motion devices and acceleratory forces on Earth or in aircraft, and who have never previously shown any tendency to develop motion sickness symptoms, were severely debilitated in the microgravity environment (Bungo et al., 1987). Conversely, some individuals who had a history of susceptibility to motion sickness were unaffected by symptoms in space.

Symptom episodes vary from mild discomfort to repeated vomiting which sometimes occurs suddenly, with little or no warning. The earliest reported episode began within only 7 minutes of orbit insertion, and malaise has been reported to last from 1 to 5 days. Finding a solution to this biomedical problem has become a high priority goal of NASA because of its potential impact on crew safety, comfort, and operational efficiency during shuttle missions.

Most of the research in this field has been devoted to the study of vestibular physiology, perceptual phenomena, or pharmacological intervention in man and in animals (Reason & Brand, 1975). In contrast, the primary objective of our own research group has been to develop a method of training people to control their own motion sickness symptoms (Cowings, 1990; Blizzard et al., 1975; Cowings et al., 1977; Cowings and Toscano, 1977, 1982; Toscano and Cowings, 1977; Cowings et al., 1986, 1990). Our method of treatment is Autogenic-Feedback Training (AFT), a combination of biofeedback and Autogenic Therapy (Schultz & Luthe, 1969), which involves training physiological self-regulation as an alternative to pharmacological management. The rationale for using AFT to treat motion sickness was based on the observation that there were profound autonomic nervous system (ANS) changes associated with this disorder (Cowings et al., 1986) and, although these responses are highly idiosyncratic, they are repeatable over time (Cowings et al., 1990). By studying physiological and behavioral indicators of human adaptation to the microgravity environment, we hoped to use these training techniques to facilitate adaptation.

Objectives

1. To evaluate the effectiveness of Autogenic-Feedback Training as a countermeasure for space motion sickness.

2. To compare physiological data and in-flight symptom reports to ground-based motion sickness data.

3. To predict susceptibility to space motion sickness based on pre-flight data of each treatment group crew member.

Ground Studies

Physiological Responses to Motion Sickness Stimuli

The relative importance of ANS responses in understanding and treating motion sickness has been a matter of some controversy. Money (1970), in his review of motion sickness research, discussed many possible ANS changes during motion sickness, but correctly noted that there was little consistency in either procedures used or results of the available research.

In a recent paper (Cowings et al., 1986), we examined the data of 127 people, all given the same motion sickness test in order to describe the general trend of ANS responses in all subjects. Our own laboratory work suggested that differences in initial susceptibility may account for at least one major source of variability in ANS responding reported by others. We, therefore, also investigated whether high-, moderate-, and low-susceptible individuals differed in

their ANS responding to motion stimulation. And last, we examined autonomic responses as predictors of motion sickness susceptibility. We used the ANS variables of heart rate, respiration rate, finger pulse volume, and skin resistance because they were easily measured, represent different aspects of the ANS, and have been used in previous studies on motion sickness.

The results clearly showed sympathetic activation of all four ANS responses during motion sickness stimulation. Physiological response levels changed rapidly and dramatically at the onset of stimulation and when the test concluded. We also found differences in ANS responding among motion sickness susceptibility groups, with highly susceptible subjects producing, in general, larger magnitude changes than the moderate or low susceptibles.

In another study, comparisons were made of two separate motion sickness tests on each of 58 subjects (Cowings et al., 1990). Again, the same four physiological responses (heart rate, finger pulse volume, respiration rate, and skin resistance) were measured during both motion tests. The goal of this study was to examine individual differences in physiological responding (i.e., response patterns) to motion stimuli, and determine how these data were related to self-reports of motion sickness malaise experienced. The phenomenon of individual ANS stereotype, that propensity of individuals to respond maximally in the same ANS variable to a variety of different stimuli, is well known in the psychophysiological literature (Cleary, 1974; Engle, 1960; Lacey, 1956; Lacey et al., 1953). In the presence of any stimulus (for example, a loud noise), all subjects might show a rise in heart rate, but some individuals will make a much larger response than others. And for any given individual, the heart rate response may be of greater magnitude than his or her skin resistance level or other measured responses.

The results revealed 11 separate patterns of physiological responding in which all or some combination of the four physiological measures clearly reflected motion sickness malaise levels of each of the 58 subjects. Individual response patterns produced on the first tests were not significantly different than those of the second test. Analyses showed that of the 58 subjects, 27 showed the same response patterns on both tests for all four physiological measures, 14 were stable for three variables, 6 were stable for two, and 11 were stable responders for at least one variable.

General Procedures of Training

Because certain ANS responses were correlated with, and indeed predictors of motion sickness distress, it was hypothesized that training subjects to control these responses might prevent or reduce symptoms. The observed individual differences in responding suggested that, to be effective, such training would have to be directed at the different responses for different people. In other words, training would have to be "tailored" for each individual. The training procedure we used, AFT, was based on the principals of operant conditioning.

Operant conditioning describes a trial and error process in which the response learned and performed must be followed by either a reward or a punishment (i.e., contingent reinforcement). When a novice is learning better voluntary control over where the basketball goes in shooting foul shots, seeing the ball go through the hoop (success) serves as a reward, and seeing it miss (failure) serves as a punishment. If the novice were blindfolded so that he did not have any knowledge of the results of his shots, he would not learn. It was Miller's contention (Miller,

1969) that visceral and CNS events may be modified by contingent reinforcement in the same way overt behaviors or skeletal responses may be conditioned. Hence, the "same rules" apply for describing the process by which athletic skills are acquired, as in the situation where an individual learns voluntary control of his own heart rate or the vasomotor activity of his hands. To learn control of a physiological response, the subject must be given a means of perceiving that response. The "blindfold" is removed by showing a subject (for example) an amplified display of his own heart rate on a digital panel meter. This process is called biofeedback.

AFT is actually a combined application of several physiological and perceptual training techniques, principal among these are Autogenic Therapy (Schultz and Luthe, 1969) and biofeedback. This combined therapies approach produces a methodology which is appreciably more effective than either of these two techniques when used alone (Blizzard et al., 1975; Cowings and Toscano, 1977). Autogenic exercises provide the subject with a specific set of instructions and method of concentration which are likely to produce the desired response. For example, self-suggestions of warmth in the hands and feet are associated with measurable increases in peripheral vasodilatation (Harano et al., 1973). Consequently, the time normally spent by the subject using a trial and error strategy is shortened and the initial probability of making a correct response is substantially increased. Biofeedback complements Autogenic Therapy by providing immediate sensory information to the subject about the magnitude and direction of a response. Operant conditioning procedures allow for more precise control of a response, as the "reward" (or feedback) can be presented only as the subject makes gradually larger response changes in the desired direction. As a result, the ultimate effectiveness of training is significantly increased.

During a typical training session, subjects are instructed to control a pattern of physiological responses and are given many different feedback displays (visual and auditory), simultaneously. Multiparameter feedback requires additional training in attending to a complex set of feedback signals. Verbal instructions by the experimenter are often required to direct the subject's attention to specific feedback signals and to advise him of alternative strategies when an inappropriate response has occurred. Included in these alternative strategies are elements of systematic desensitization and progressive relaxation of muscle tension monitored at several sites.

The protocol for all of our ground-based studies was essentially the same. First, a rotating chair test was used to induce the initial symptoms of motion sickness. In this way, we could document the pattern of his physiological responses to motion stimulation. The rotating chair tests were conducted by initiating rotation at 6 rpm (0.628 rad/s) and incrementing by 2 rpm (0.209 rad/s) every 5 minutes, with a maximum velocity of 30 rpm (3.142 rad/s). During each 5-minute period of rotation, subjects were instructed to make head movements (front, back, left, and right), in random order, at 2-second intervals. It is these head movements combined with rotation which induce motion sickness symptoms. Every 5 minutes during the test, subjects were asked about the symptoms that they were experiencing using a standardized diagnostic scoring procedure so that we can accurately assess the relationship between his perceived distress and his physiological responses at any given time (Cowings et al., 1986; Graybiel et al., 1968).

Initial exposure to the rotating chair was followed by two (or four) resting baseline sessions and a second rotating chair test. This procedure enabled us to clearly identify which

ANS responses changed from the subject's own resting baseline as a function of motion sickness stimulation. During subsequent AFT sessions, emphasis was placed on training control of those ANS variables that were most responsive in the individual's motion sickness tests. AFT was administered in three sets of four 30-minute sessions (maximum 6 hours) under non-rotating conditions. Each AFT set was followed by a rotating chair test in which the subject attempted to apply AFT to control symptoms. The primary criterion for evaluating treatment success was increased tolerance (i.e., ride for longer durations at higher speeds) to this motion sickness stimulus.

Results of Ground-Based Research

In preparation for tests of AFT in space, we have conducted investigations on over 200 people. Each study was designed to test the effectiveness of AFT as a countermeasure for motion sickness and the feasibility of using this method to treat space motion sickness in aerospace crews. Another important objective was to determine if the reduction in symptoms observed could be attributed to some experimental factor other than AFT.

In one study, differences in motion sickness tolerance were compared in subjects given AFT, an alternative cognitive task, or no treatment (Toscano and Cowings, 1982). Two hours of AFT were administered to treatment group subjects before the third, fourth, and fifth motion sickness test (6 hours total). Figure 1 shows the performance of all three groups in the motion sickness tests. Results showed that subjects who received AFT had significantly greater motion sickness tolerance than subjects performing an alternative cognitive task ($p < 0.025$) or those

performing no task ($p < 0.025$). Although the cognitive task group had slightly greater tolerance than the no-task control group, it was not significant.

Another experiment was designed to determine if an individual's initial susceptibility to motion sickness was related to his ability to learn control of symptoms (Cowings and Toscano, 1982). Following an initial exposure to a rotating chair test, subjects were assigned to groups based on their motion sickness tolerance. Two AFT treatment groups (highly and moderately susceptible to motion sickness) were compared to two control groups who were matched to the AFT groups for initial susceptibility but were given no treatment. Figure 2 shows the performance of these groups across six motion sickness tests. Results showed that both AFT treatment groups significantly improved their motion sickness tolerance while neither Control group improved significantly. During the last two tests, after 6 hours of AFT, the high and moderate susceptible treatment groups were no longer significantly different in their motion sickness tolerance, while the high and moderate control groups remained significantly different across all tests.

The results of other studies showed: (1) no significant differences between men and women in their ability to apply AFT for symptom control; (2) the ability to control symptoms could be retained for as long as 3 years after training; and (3) the primary component of the treatment effect in each of these studies could be attributed to learned control of physiological responses (Cowings, 1990). The most important studies, however, revealing the likelihood of AFT being a successful treatment in space, were related to the transfer of training effects to a variety of different environments.

Transfer of Training Effects to Different Motion Environments

Experiments in the literature (Reason and Brand, 1975) and clinical experience show that habituation to a specific nauseogenic situation does not transfer to new situations. Repeated exposure apparently effects primarily the sensory side (or "input" side) of the response system. AFT is aimed at controlling the "output" side, i.e., the various symptoms of motion sickness. To the extent that such control can be learned, we would expect it to be much more likely to transfer to different situations that induce nausea.

An extensive examination of transfer of training was made in another study which involved several different types of motion sickness stimuli. Twenty-four men and women were assigned to two equal groups and matched for sex and initial susceptibility to motion sickness in a rotating chair. The two groups of subjects, an AFT treatment group and a no-treatment control group, were given three types of motion sickness inducing tests at the start of the study: (a) rotating chair test, (b) the combination of optokinetic stimulation with rotation in a chair, and (c) a vertical acceleration test. All subjects received four additional exposures to the rotating chair. Treatment subjects were given 6 hours of AFT over 5 days before tests three, four, and five. The controls received no training. Both groups of subjects were given their second exposure to the battery of different types of motion sickness tests at the end of the experiment. Figure 3 shows the performance of both groups on the transfer tests, vertical acceleration, and optokinetic stimulation. Because these tests had different maximum durations, scores for motion sickness tolerance were based on percentages of the total test completed.

Results showed that subjects given AFT significantly improved their tolerance to the different types of motion sickness tests, whereas the control subjects (habituation only) did not. Furthermore, the Air Force had adopted a similar form of AFT to treat crew members for whom all other methods had proved unsuccessful in combatting persistent air sickness in high performance military planes (Levy et al., 1981; Jones et al., 1985). They have found that such training transfers from the rotating chair on the ground to the variety of maneuvers in military flight well enough to return air crew that otherwise would have been permanently grounded, to active flying duty. These results on transfer of control over response symptoms to different types of stimuli eliciting nausea led us to be hopeful of transfer to the stimuli eliciting symptoms in space. What little preliminary data we have from space flight confirms this hypothesis.

Four crew members (two treatment and two controls) participated in the AFT experiment during a 1985 shuttle mission (Cowings et al., 1986). The treatment subjects were given 6 hours of AFT before the mission (distributed from launch -1 year to launch -3 months), and control subjects received no training. During the mission, one treatment subject was symptom free and the other experienced one symptom episode on the first mission day which did not reach vomiting. The two controls, who had taken anti-motion sickness medication, experienced multiple vomiting episodes on the first day. The physiological data collected in-flight were consistent with reports of malaise, with treatment subjects showing less physiological distress than either of the controls.

Flight Experiment Design

Preflight Training

One year prior to the flight the SL-J crew members began their participation in AFTE. One Mission Specialist will receive 6 hours of AFT for the control of motion sickness, and a second Mission Specialist will serve as a control (i.e., will receive no training). In addition, the alternate crew members and the Japanese Payload Specialist will be provided with this training.

1. Baseline data collection. Physiological data are obtained from all subjects during two types of motion sickness tests, a rotating chair and a vertical accelerator. Additionally, data are recorded during two resting baseline (30 minute) sessions, two 12-hour ambulatory sessions during a mission simulation, during zero-g maneuvers in the KC-135 aircraft, and during a 90-minute reclining baseline in the launch position in a shuttle mock-up.

2. Formal AFT sessions. The design of training is much the same as the ground-based studies described above. Twelve 30-minute sessions are administered (at the PI's laboratory) over a 15-day period, with each block (4 consecutive days) of training followed by a motion sickness rotating chair test. The principal criterion for evaluating the success of the AFT treatment is the increased time that crew members tolerate these tests as training progresses.

If the launch should slip more than 4 months, crew members are offered an additional block of training sessions (4 consecutive days).

3. Follow-up AFT sessions. During the launch-6 to 1 month period, AFT training continues in the form of follow-up sessions at any location (e.g., JSC or MSFC). Flight hardware (see Figure 4) will be used to monitor and feedback physiological measures during training for a total of eight (30 minute) sessions.

4. L-10 day session. This 2-hour session is the last time investigators contact crew members prior to the mission. It allows us to document the amount of physiological control retained by the treatment subjects and any differnces (from previous sessions) in baseline levels of these subjects or the control subjects.

In-Flight Procedures and Flight Hardware

1. Continuous day-time monitoring. During the mission, the physiological responses of both the treatment and control subjects will be monitored and recorded for the first three mission days (waking hours only). The Autogenic-Feedback System-2 (AFS-2) is a portable belt-worn physiological monitoring system (see Figure 4). Developed by NASA in support of space flight experiments, this system can continuously record up to eight physiological responses. This system includes a garment, transducers, biomedical amplifiers, a digital wrist-worn feedback display, and a cassette tape recorder. The entire instrument is powered by a self-contained battery pack. The AFS-2 will record/display: electrocardiogram/heart rate, respiration

waveform/respiration rate, skin conductance level, finger temperature, finger pulse volume, and triaxial accelerations of the head.

2. Timelined and symptom-contingent diagnostic. An eight-item symptom log book will be used by the crew member to note the type and severity of symptoms.

3. Timelined and symptom-contingent AFT sessions. The treatment subject (only) is required to perform daily 15-minute AFT sessions during which control of specific physiological responses are practiced with the aid of the wrist-worn display unit. If that crew member were to experience symptoms in space, he/she is required to apply the AFT methods learned. Symptom-contingent AFT can be performed at the same time that a crew member is conducting other payload activities. It is anticipated that no more than 30 minutes would be required to counteract symptoms.

Post-Flight Procedures

On the day of landing, AFT investigators are granted a brief (10 minute) interview with the crew members on their experiences with the AFT experiment. Flight hardware, data tapes, and diagnostic log books are returned to the PI's laboratory within 24 hours of touch-down. These data are processed and used within 2 weeks post-flight during a 2-hour private debrief with each of the crew members where the final evaluation of AFT effectiveness during the Spacelab-J mission is determined.

Summary

Finding an effective treatment of the motion sickness-like symptoms that occur in space has become a high priority for NASA. This experiment utilizes a behavioral medicine approach to solving this problem. This method, Autogenic-Feedback Training (AFT), involves training subjects to voluntarily control several of their own physiological responses to environmental stressors. AFT has been used to reliably increase tolerance to motion sickness during ground-based tests in over 200 men and women under a variety of motion sickness conditions. Such transfer would be expected because the effects of AFT are on the final common response mechanism rather than on initiating stimuli. Thus we might expect it to transfer to space sickness, and our preliminary data suggest that it may. Validation of the effectiveness of AFT as a treatment for space motion sickness will require obtaining data on a total of 16 individuals in space, 8 treatment and 8 control subjects. With the completion of Spacelab-J, this procedure will have been tested on 6 people.

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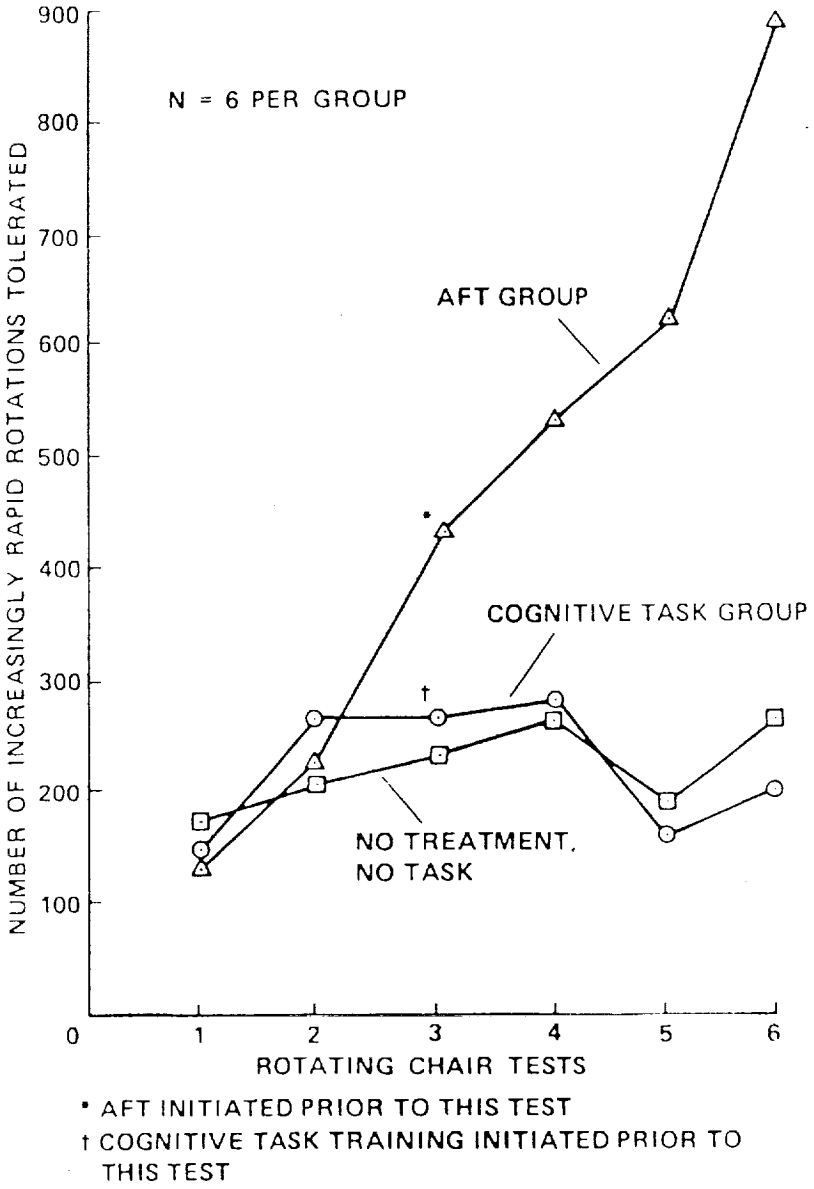

Figure 1. Effects of AFT treatment compared with those of a distracting cognitive task and no treatment.

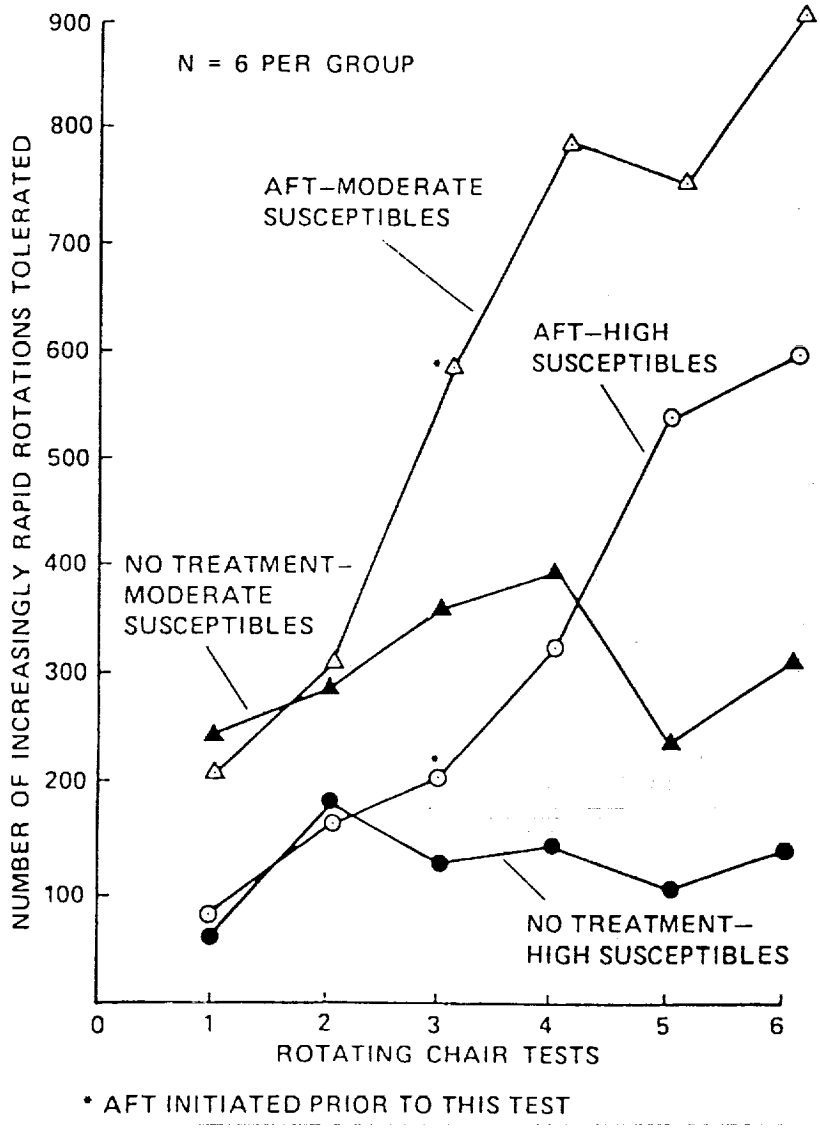

Figure 2. Effects of AFT treatment for highly and moderate motion sickness susceptible subjects compared to matched controls given no treatment.

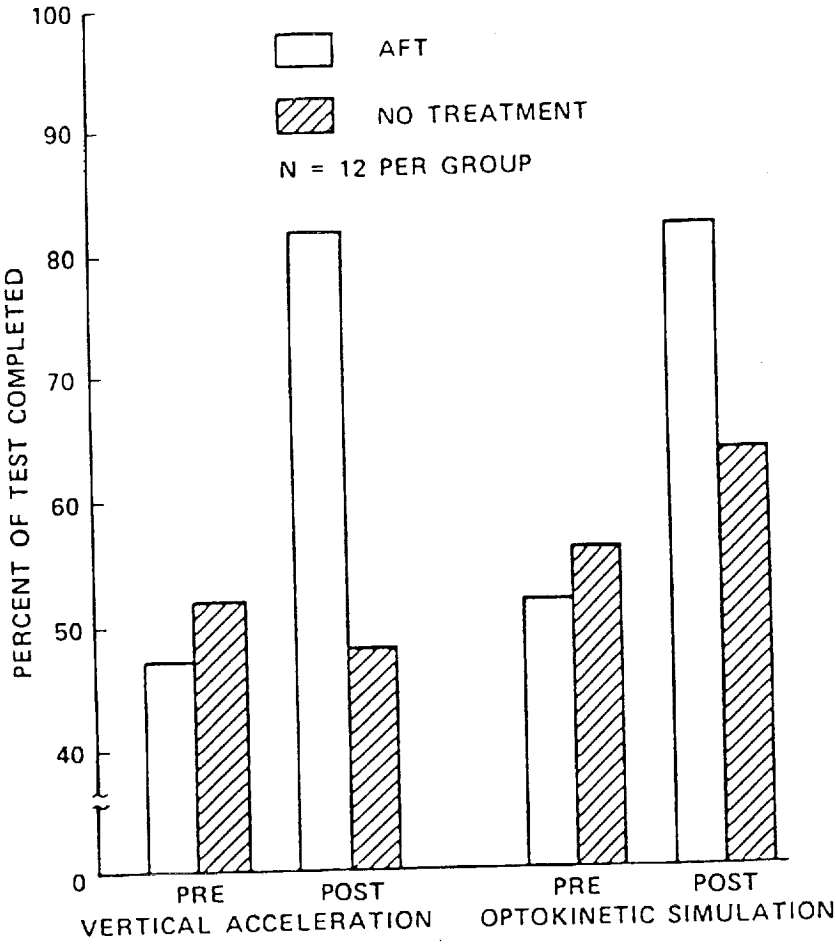

Figure 3. Positive transfer of training for AFT compared to a control group given no treatment.

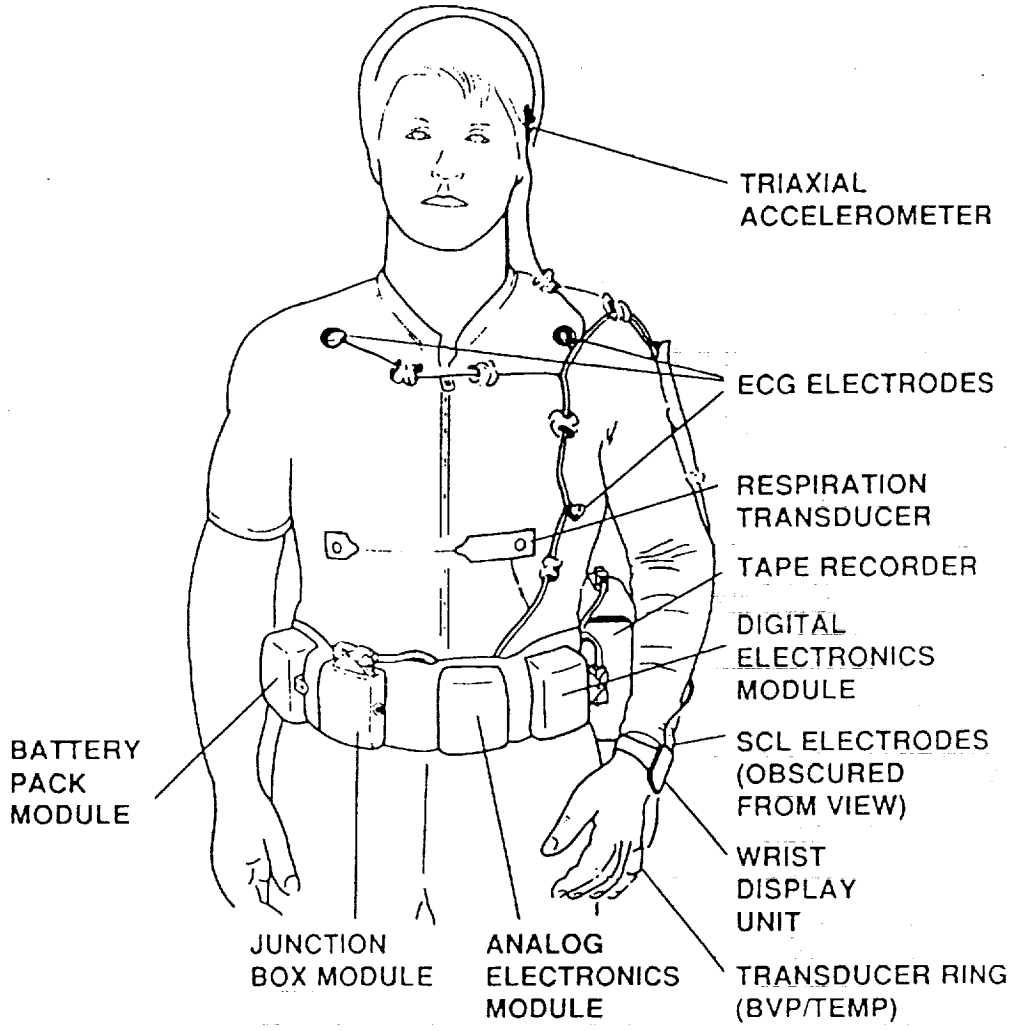

Figure 4. The Autogenic-Feedback System-2 (AFS-2). An ambulatory monitoring system as worn by crew members.