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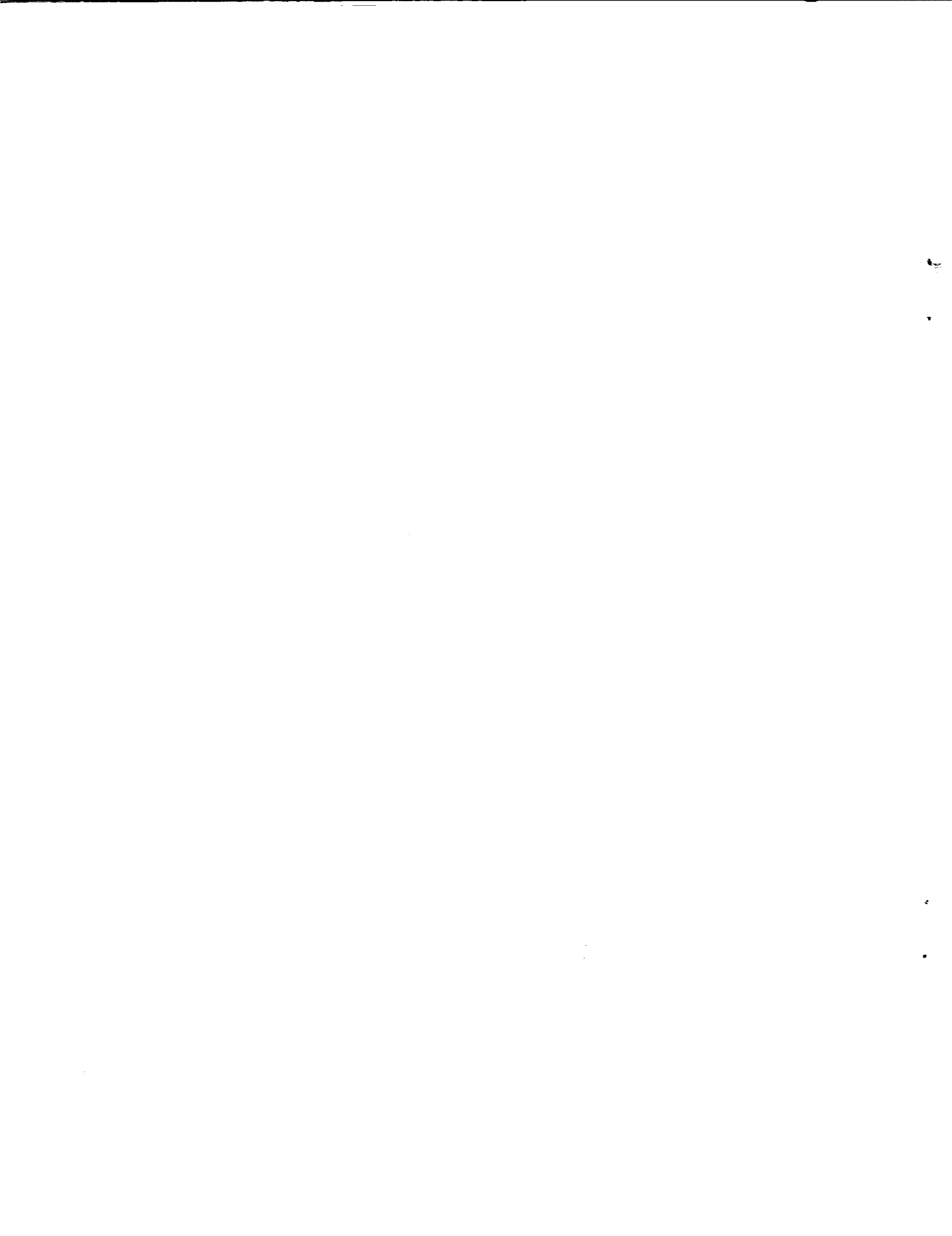
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Autogenic Feedback Training as a Treatment for Airsickness in High-Performance Military Aircraft: Two Case Studies

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Summary

The purpose of this paper is to present a detailed description of the physiological and performance responses of two military pilots undergoing a treatment for motion sickness. The treatment used, Autogenic-Feedback Training (AFT), is an operant conditioning procedure where subjects are taught to control several of their autonomic responses and thereby suppress their motion sickness symptoms. Two male, active duty military pilots (U.S. Navy and U.S. Marine Corps), ages 30 and 35, were each given twelve 30-minute training sessions. The primary criterion for success of training was the subject's ability to tolerate rotating chair motion sickness tests for progressively longer periods of time and at higher rotational velocities. A standardized diagnostic scale was used during motion sickness to assess changes in the subject's perceived malaise. Physiological data were obtained from one pilot during tactical maneuvers in an F-18 aircraft after completion of his training. A significant increase in tolerance to laboratory-induced motion sickness tests and a reduction in autonomic nervous system (ANS) response variability was observed for both subjects after training. Both pilots were successful in applying AFT for controlling their airsickness during subsequent qualification tests on F-18 and T-38 aircraft and were returned to active duty flight status.

Introduction

Motion sickness is a completely artificial disease that has always plagued mankind since we first stepped onto a floating raft or climbed onto an animal's back. Characterized by symptoms of nausea, emesis, pallor, vertigo, sweating, and general malaise, motion sickness is not only debilitating, but, in the case of military fighter pilots or astronauts in space, it can be potentially life threatening. Typically, motion sickness is treated with medications such as scopolamine or promethazine (refs. 1-3). While these medications may be highly effective, they produce unwanted side-effects such as blurred vision, slower reaction time, decreased short-term memory, and impairment of decision making skill. Thus, American military pilots under the influence of such medications are not allowed to fly solo (refs. 4 and 5).

Most research in this field has been devoted to the study of vestibular physiology, perceptual phenomena, or pharmacological intervention in man and animals (ref. 2). In contrast, the primary objective of this research has been to develop a method of training people to control their motion sickness symptoms (refs. 6-16). Autogenic-Feedback Training (AFT), a combination of biofeedback and Autogenic Therapy (ref. 17), involves training physiological self-regulation. 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 (ref. 11) and, although these responses are highly idiosyncratic, they are repeatable over time (ref. 10). AFT was developed for use in the NASA space program as an alternative to traditional pharmacological treatment for space motion sickness, and has been tested successfully aboard two shuttle missions (refs. 13 and 14).

Even when actual vomiting or extreme nausea have not occurred, reasonable evidence exists to conclude that pilots may lose control of their aircraft as a direct result of reactive stress (refs. 18–21). The condition in which a high state of physiological arousal is accompanied by a narrowing of the focus of attention can be referred to as autonomous mode behavior (AMB), which can lead to fatal "human error" accidents. A number of studies demonstrated that this type of training effectively reduces physiological arousal with a resultant efficacious effect on operational efficiency in pilots (refs. 20, 22–25).

AFT has advantages over other methods for this particular application because it enables training individuals to regulate the levels of multiple physiological responses simultaneously, thus enabling a more system-wide reduction in reactivity to stressors. Numerous laboratory studies (refs. 7–9, 12, 16) demonstrate increased motion sickness tolerance in subjects given AFT as compared to alternative treatments and to no treatment control groups, (i.e., repeated exposure to a motion stimulus). The primary component of the treatment was learned control of physiological responses. Subjects who increased their motion tolerance consistently showed a significant reduction in the magnitude of ANS response change after training (ref. 14). AFT can be administered in a relatively short period of time (6 hours), can reliably produce sufficient autonomic control necessary to reduce responses to severe environmental stressors (motion sickness stimuli), and has been demonstrated to be effective in a wide population of subjects under a variety of stimulus conditions (ref. 7).

Jones (ref. 23) and Levy (ref. 25), using similar methods, attempted to treat U.S. Air Force pilots suffering from intractable airsickness for whom all other forms of treatment had failed. The first study (ref. 25) began with a population of 20 pilots, although one was eliminated for medical reasons other than airsickness. Of the remaining 19 pilots, 16 (84%) were returned to active flight status after training, and 3 (14%) failed to learn sufficient control of their symptoms and were grounded. In the second study (ref. 18), 53 pilots were trained and 42 (79%) were returned to satisfactory operational flying status, 3 (6%) were partially successful, and 8 (15%) were later grounded for recurrent airsickness. In the latter

study, the three pilots for whom AFT was partially successful did not qualify for high-performance tactical aircraft (F-4) but did achieve flying status for the C-130 air transport craft.

These studies demonstrate the effect of training on motion sickness tolerance. However, they omit physiological data that would characterize the nausea and vomiting response in those crew members undergoing AFT. This omission impedes an elucidation of the mechanism by which this behavioral intervention moderates the nausea and vomiting response, which, in turn, impedes the acceptance of behavioral treatments by health-care professionals for routine use in aviation medicine and pilot training.

The purpose of this paper is to present a detailed description of the physiological and performance data of two military pilots undergoing a protocol of AFT for the treatment of motion sickness. Physiological data of one pilot during an F-18 flight test are also provided. Objective evidence is presented which demonstrates that the degree of improved tolerance was directly related to the degree of learned autonomic control achieved by these individuals. The ANS variables of heart rate, respiration rate, finger pulse volume, hand temperature, and skin resistance were used because they were easily measured, represented different aspects of the ANS, and were used in previous studies on motion sickness. Our aim is to promote the value of including AFT in existing training protocols given to military and civilian pilots.

Methods

Subjects

The subjects were two male, active duty military pilots (ages 30 and 35), one from the U.S. Navy and the other from the U.S. Marine Corps. The military aircraft that they were attempting to qualify for were the F-18 tactical fighter and the T-38 trainer. Their voluntary consent was obtained after all procedures and risks of this experiment had been explained to them. Subjects were not paid, but were assigned to the NASA facility for a three week period as temporary duty. With the exception of their reported susceptibility to motion sickness, both subjects were otherwise medically qualified for flight. The study was approved by the Human Research Experiments Review Board of NASA Ames Research Center.

Apparatus

A Stille-Werner rotating chair was used to provoke the symptoms of motion sickness using a standard test

procedure (refs. 11 and 26). The rotating chair was located in a sound attenuated room and was capable of both clockwise and counterclockwise rotation, with speeds ranging from 6 rpm (0.628 rad/s) to 30 rpm (3.142 rad/s). Padded headrests mounted at 45 deg from the vertical on the left, right, front, and back of the chair enabled subjects to execute head movements in these directions.

Physiological responses were monitored using the Autogenic-Feedback System-2 (AFS-2), a portable belt-worn physiological monitoring system (fig. 1). Developed by NASA in support of spaceflight experiments, this system can continuously record up to eight channels of data, and 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 responses recorded with this instrument were: (1) electrocardiogram (ECG), measured by precordial placement of three silver-silver-chloride disposable electrodes, with heart rate (HR) computed beat to beat; (2) respiration rate (RR) derived from the respiratory waveform as measured by a piezoelectric transducer enclosed within a rubber ribbon and

mounted on the front of the garment with snaps; (3) skin conductance level (SCL) was measured by pre-gelled disposable electrodes mounted on the volar surface of the left wrist; (4) skin temperature (Temp) was measured by a miniature solid-state transducer mounted within a ring worn on the small finger of the subject's left hand; and (5) finger pulse volume (FPV) was derived from a photoplethysmograph mounted within the same ring transducer. Movement of the subject's head and upper body were monitored by a triaxial accelerometer mounted to a headband.

In addition to the AFS-2, other biomedical amplifiers were mounted on the sides and rear of the rotating chair and these were used to measure FPV, SCL and Temp from the subject's right hand. Electromyography (EMG) was measured using pre-gelled disposable electrodes attached to the subject's forearm extensor muscles and the gastrocnemius muscles of the legs. Physiological signals were sent through slip rings in the chair to the laboratory where they were recorded on two 8-channel strip-chart recorders, on a 14-track analog tape recorder and were digitized and stored as 15-sec averages on a Masscomp 6600 computer.

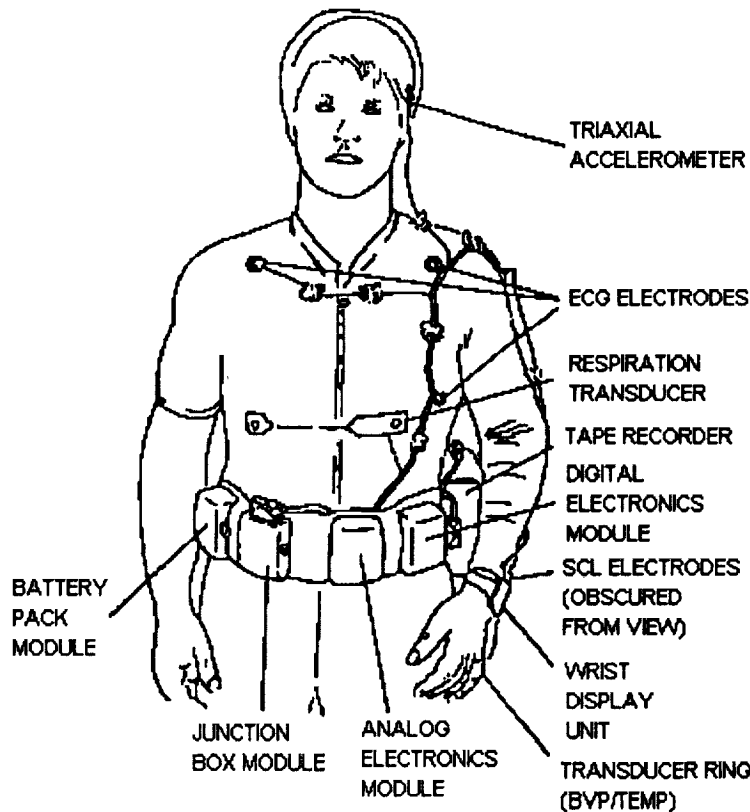


Figure 1. Autogenic-Feedback System-2 (AFS-2). An ambulatory monitoring system worn by crew members.

The subject's physiological responses were displayed on 12 digital panel meters; a wide-screen oscilloscope showed analog traces and was mounted at eye level at a distance of 4 feet from the subject. Auditory tone feedback was provided through speakers mounted above the subject's head. The experimenter was in continuous verbal communication with the subject through an inter-com system.

Procedure

Autogenic-feedback training— Previous research (refs. 10 and 11) showed that certain ANS responses were correlated with and were indeed predictors of reports of motion sickness distress. Based on these results, it was hypothesized that training subjects to control these responses might prevent or reduce symptoms. The observed individual response differences suggested that to be effective such training would have to be directed at different responses for different people. The training procedure used in this study was AFT.

One important component of AFT is operant conditioning. Operant conditioning may be simplistically described as a trial-and-error process in which the response learned and performed must be followed by either a reward or a punishment (contingent reinforcement) (ref. 22). When a novice is learning better voluntary control over where the basketball goes in shooting fouls, 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 (improve his accuracy). It was Miller's contention (ref. 27) that visceral and central nervous system 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 apply 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. For example, the "blindfold" is removed by showing a subject an amplified display of his own heart rate on a digital panel meter. This process is called biofeedback (ref. 4).

AFT is a combined application of several physiological and perceptual training techniques. Principal among these are Autogenic Therapy (ref. 17) and biofeedback. This combined-therapies approach produces a methodology that is appreciably more effective than either technique used alone (refs. 6 and 7). Autogenic exercises provide the subject with a specific set of instructions and a 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 (ref. 17). 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 because the "reward" (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 (ref. 7).

During a typical training session, subjects are instructed to control a pattern of physiological responses and are given visual and auditory feedback displays 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. AFT also includes elements of systematic desensitization and progressive relaxation of muscle tension monitored at several sites.

In the present study, subjects were trained individually in a darkened, soundproof room. Each AFT session was 30 minutes long (ten 3-minute trials) and was preceded and followed by a 6-minute resting baseline. There were 12 training sessions (under nonrotating conditions), administered on 4 consecutive days per week for 3 weeks (6 hours). Rotating-chair motion sickness tests were administered before training and at one week intervals on the days following the fourth, eighth, and twelfth AFT sessions.

Rotating-chair tests and the motion sickness diagnostic scale— The rotating-chair tests were conducted by initiating rotation at 6 rpm (0.628 rad/s) and increasing the rotation in increments of 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 made 45° head movements (front, back, left, and right) in random order at 2-sec intervals until motion sickness symptoms were induced.

During the test, subjects were asked to report their motion sickness symptoms using a standardized diagnostic scoring procedure, referred to as the Coriolis Sickness Susceptibility Index (CSSI) (refs. 11 and 26). The CSSI scores enabled us to accurately assess the relationship between perceived distress and physiological responses to this motion stimulus. Table 1 is an outline of the

Table 1. Motion sickness diagnostic scale

Malaise Level	Points	VMT	TMP	DIZ	HAC	DRZ	SWT	PAL	SAL	NSA	ED	EA
Pathognomic	16	I										
Major	8					III	III	III	III	II,III		
Minor	4					II	II	II	II	I		
Minimal	2					I	I	I	I		I	
AQS	1		I,II	I,II	I,II							I

VMT = vomiting, TMP = increased warmth, DIZ = dizziness, HAC = headache, DRZ = drowsiness, SWT = sweating, PAL = pallor, NSA = nausea, ED = epigastric discomfort, EA = epigastric awareness, AQS = Additional qualifying symptoms. I = mild, II = moderate, III = severe.

diagnostic scale used. An array of possible symptoms included salivation (SAL), sweating (SWT), drowsiness (DRZ), and pallor (PAL). The presence, absence, and/or strength of most symptoms were assessed subjectively by the subject. Other symptoms were rated as minor or “additional qualifying symptoms,” and were scored as mild or moderate levels only. These include increased warmth (TMP), dizziness (DIZ), and headache (HAC). Stomach sensations were evaluated on five levels. Epigastric awareness (EA) is described as not nausea and not particularly uncomfortable, but as an increased awareness of the stomach (e.g., hunger). Epigastric discomfort (ED) is described as not nausea, but becoming increasingly uncomfortable (e.g., lump in the throat or stomach distended by gas). Nausea is reported when it can clearly be differentiated from ED and EA, as either mild, moderate, or severe. Frank vomiting (VMT) is indicated as either present (I) or absent.

The primary criteria for evaluating treatment success was increased motion sickness tolerance (i.e., subjects could tolerate the rotating chair motion sickness tests for longer durations and at higher speeds after training than before).

Results

Subject A— Physiological data (one-minute means) from the subject’s first rotating chair test were used to describe the hierarchy of ANS response magnitudes during motion stimulation, ANS response covariance, and the rate at which the subject’s responses returned to pretest baseline levels when rotation stopped. These individual response characteristics are referred to as an ANS stress profile. The profile is generated by normalizing all variables using z-score transformation. First, a mean and standard deviation of each ANS response during the 10-minute pretest baseline is computed. Raw scores are subtracted

from the mean and divided by the standard deviation to generate z-scores.

Figure 2 shows the ANS stress profile of subject A during his first motion sickness test. The y-axis shows the number of standard deviations that each response varied from the pretest baseline mean. At the onset of rotation, heart rate and skin conductance increased sharply with a corresponding decrease in blood volume to the hands (FPV), while respiration rate did not change. These changes in response magnitudes were associated with increases in malaise reported during rotation. During the 10 minutes of posttest baseline, heart rate returned rapidly to pre-stimulus levels. Skin conductance level dropped more slowly, and FPV, which had begun to increase toward the end of the test, showed continued vasodilation.

Figure 3 shows the data of subject A during his first and last AFT session, which completed his 6 hours of training. In each graph, training was preceded and followed by 6 minutes of baseline. The 30-minute training period consisted of ten 3-minute trials in which the subject was instructed to produce alternating “arousal” and “relaxation” responses. Arousal responses were associated with increases in heart rate and skin conductance, and decreases in blood flow to the hands. Relaxation responses were associated with decreases in heart rate and skin conductance, and increases in blood flow to the hands.

The criteria for success in controlling ANS responses was based on the magnitude and duration of response changes, both within and across training sessions. By the end of training, subject A could increase his heart rate consistently by an average of 25 beats per minute (bpm) at the beginning of arousal trials, maintain this level for the 3-minute duration of the trial and decrease heart rate rapidly during relaxation trials. The average level of heart rate varied from day to day for this subject and this was

ANS response	Finger pulse volume (FPV) units/min	Respiration rate (RR) breaths/min	Heart rate (HR) beats/min	Skin conductance level (SCL) μ mhos/min
Baseline mean =	160.4	13.6	58.8	25.6
Standard deviation =	57.00	1.95	4.5	4.1

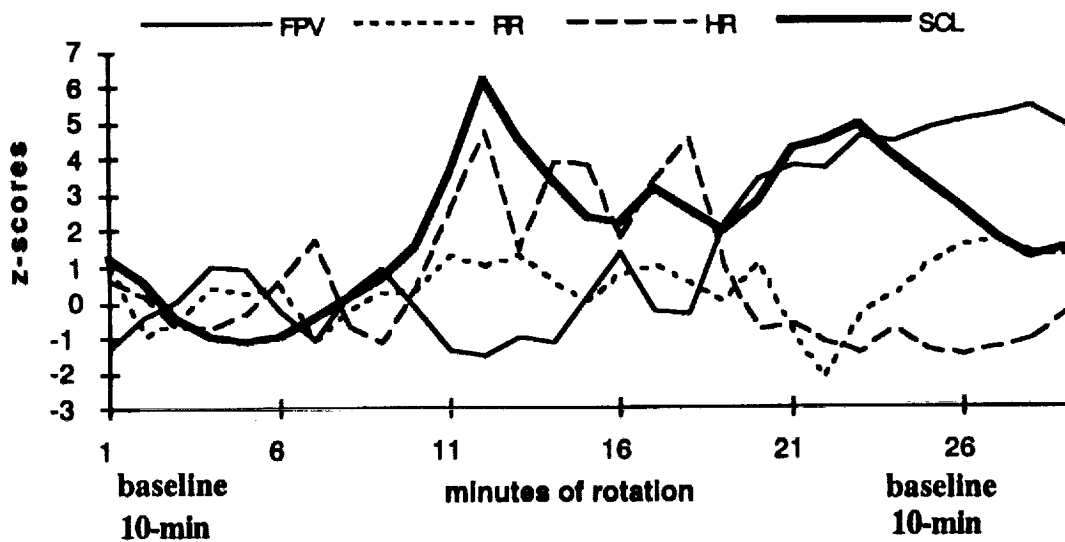


Figure 2. ANS stress profile of subject A during the first rotating-chair test.

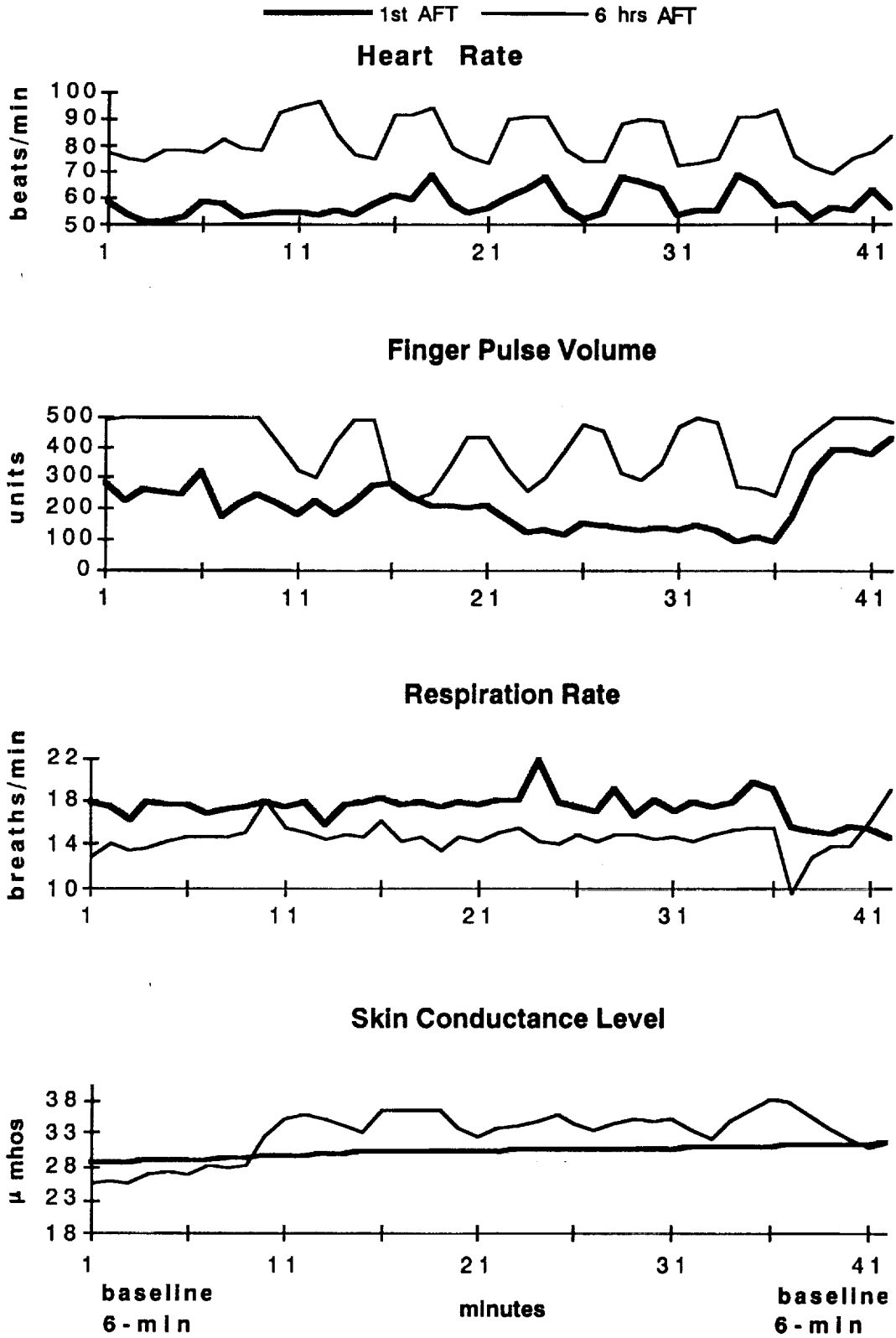


Figure 3. Physiological responses during AFT sessions: subject A.

attributed to strenuous physical exercise immediately before some of the sessions. However, the 25 bpm range of voluntary increases and decreases of heart rate was unaffected by changes in his baseline. Voluntary control of peripheral vasodilation and constriction (increases and decreases in FPV) is also apparent during the last session as well as the ability to increase and decrease skin conductance level across training trials.

Throughout training the subjects were instructed to maintain constant respiration rate and volume and not to constrict their skeletal muscles during arousal trials. These "control" responses were also monitored and displayed to the subjects during training sessions. At the end of training, subject A was able to maintain a constant volume and rate of respiration at 15 breaths per minute, with no discernible change in muscle activity (not shown) across trials.

Figure 4 compares subject A's physiological responses to rotating-chair motion sickness tests administered before and after AFT. Each test is preceded and followed by a 10 minute resting baseline. The posttest baseline data of the first test have been separated and placed on the x-axis with those of the last rotating chair test in order to facilitate comparison of response levels after rotation ended in both tests. Subject A significantly increased his tolerance to motion sickness. His first test terminated at 18 minutes (8 minutes of rotation) and after training he tolerated over 58 minutes of rotation.

During the motion sickness tests following AFT, the subject's goal was to reduce response variability, despite accelerations of the rotating chair, every 5 minutes. Although subject A's average heart rate is higher during the final rotating-chair test, there is very little change as rotation is initiated at 10 minutes. As rotation continues, his mean heart rate gradually decreases with an abrupt drop below pretest baseline when the rotation ends (minute 68).

During the final rotating-chair test, respiration rate was held constant at 15 breaths per minute with small changes noted as the subject verbally reported his symptom levels. Average finger pulse volume was higher during the pretest baseline. Vasoconstriction still occurred at the start of rotation and when chair speed increased, but subject A was able to counter this reaction by vasodilating.

Last, the overall level and variability of skin conductance level is reduced in the final rotating-chair test, indicating a reduction in sympathetic tone. Subject A reported that he felt he was able to successfully regulate his own responses and this ability enabled him to reduce his symptoms and ride longer.

Figure 5 shows how subject A's perception of motion sickness malaise changed after two, four, and six hours of training. In the first rotating-chair test, he was only able to tolerate 8 minutes of rotation, terminating the test after reaching 8 rpm (10 diagnostic points). The second test shows that at 8 rpm, he had only 2 diagnostic points (very mild symptoms) and tolerated 20 minutes of rotation, terminating at 12 rpm. His tolerance to this stimulus continued to increase such that during the final test, he reported no symptoms for the first 15 minutes of the test. Symptom onset was more gradual than previously reported and the subject tolerated a maximum of 58 minutes (24 rpm).

Thirty days after completing AFT, subject A was scheduled to fly the F-18 aircraft to test the effectiveness of training for controlling his airsickness. He was accompanied by an instructor pilot who evaluated subject A's ability to perform tactical maneuvers required to qualify as a pilot on this aircraft. Before this flight, subject A practiced these flight maneuvers in an F-18 flight simulator while wearing the AFS-2. Although no data were collected during this simulator test, subject A reported that he was able to use the feedback from his wrist display unit to both track and more readily modify his own physiological responses. He also wore the AFS-2 under his flight suit during the actual F-18 flight and reported that it had no impact on his mobility or comfort.

Figure 6 shows the data collected during this flight. These data are shown as 15-second averages over the course of a 70-minute flight. The top graph shows the summed output of a triaxial accelerometer mounted on the subject's head. The first (approximately) 18 minutes of data were obtained as subject A performed aircraft checkouts, taxiing, takeoff, and normal level flight. The start of tactical maneuvers, which began with a rapid series of high-g aileron rolls, can be seen as sharp rises in the accelerometer data. The second graph shows subject A's heart rate. Interestingly, his heart was beating considerably faster on the way out to the test site (anticipatory stress), than during the actual maneuvers. Once the maneuvers began, however, subject A found that he could control this response; bringing heart rate near his own baseline quickly after pulling high-g, and maintaining it more readily for the remainder of the flight. Skin conductance levels remained below 24 μ mhos and continued to drop as the flight continued. These levels were comparable to those in his post-AFT rotating-chair test.

Hand temperature is displayed as a relative measure of blood volume to the hands because FPV measures could not be analyzed because of movement. During AFT, subject A had been taught to successfully increase blood flow to his hands (also measured as increased skin

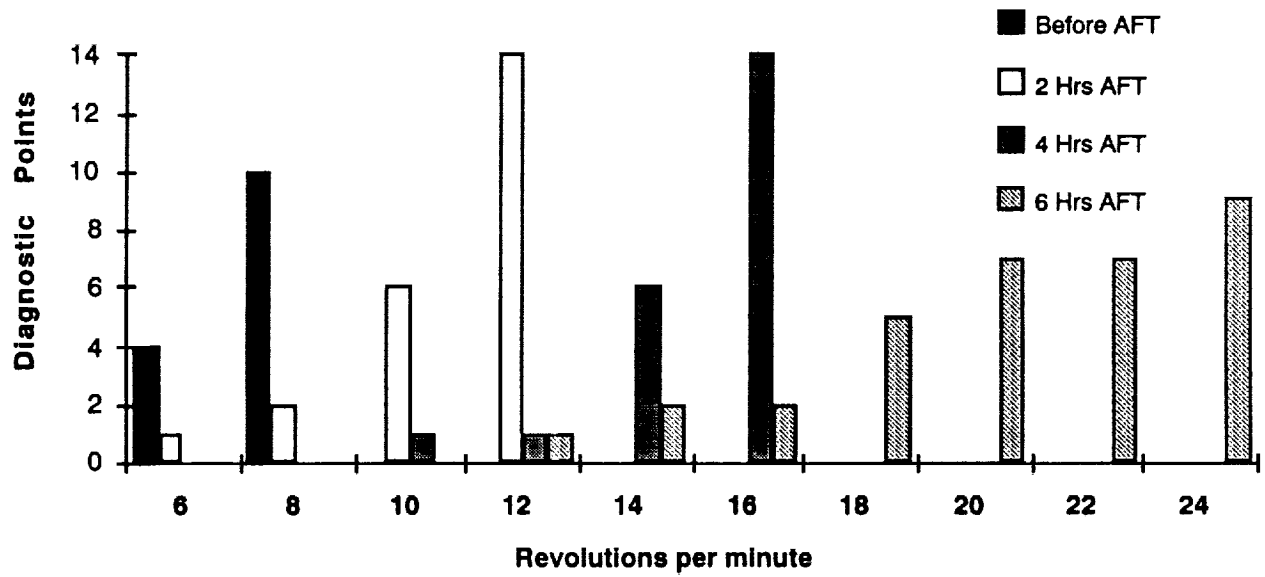


Figure 5. Changes in motion sickness malaise during rotating-chair tests before and after two, four, and six hours of AFT: subject A.

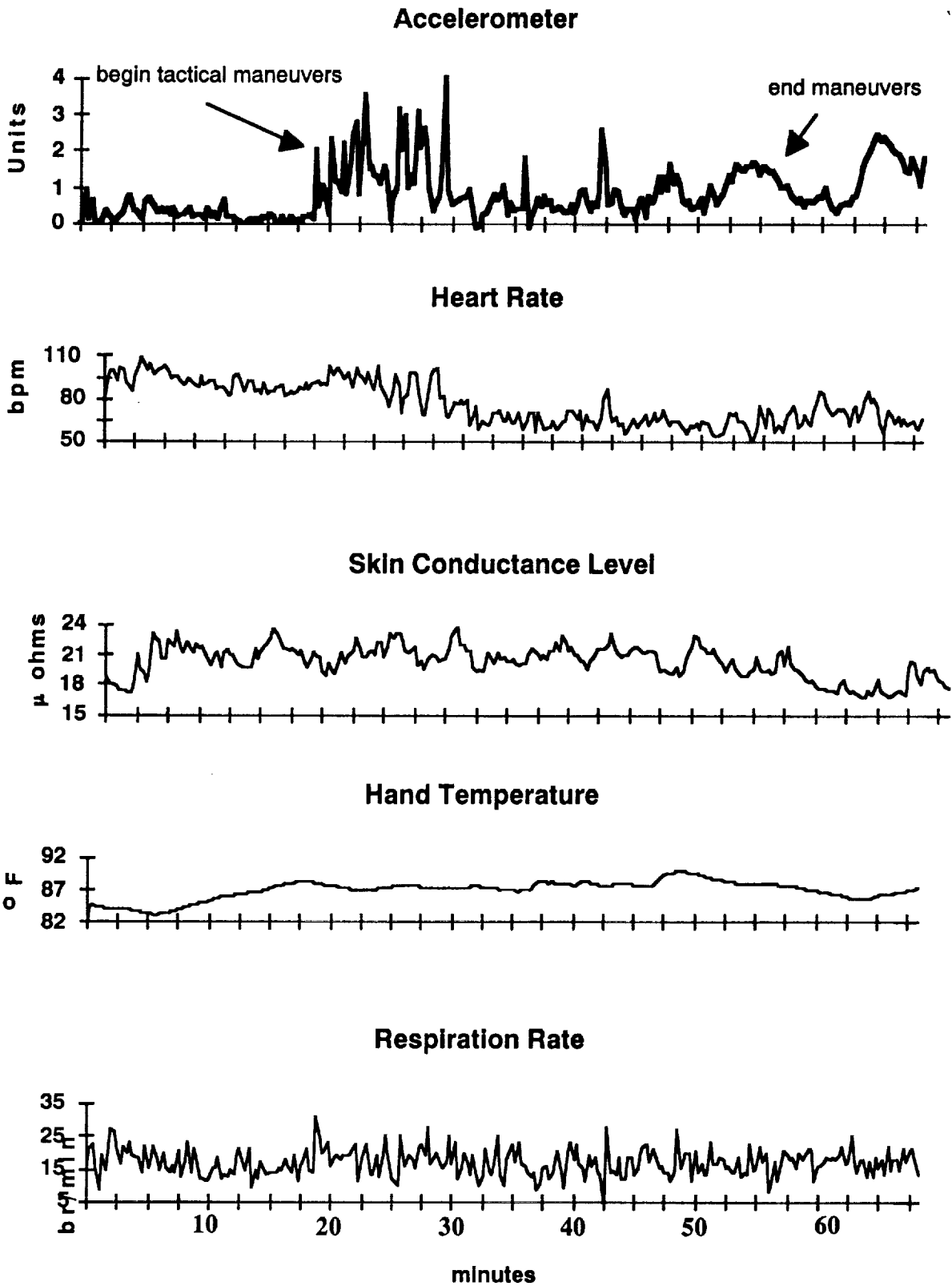


Figure 6. Physiological and accelerometer data during F-18 qualification flight.

temperature of the hands). During his first rotating-chair test, he displayed vasoconstriction (decreased blood flow) and lower hand temperature as his symptom levels increased. After training, however, his overall average FPV was higher and remained stable throughout the motion sickness test. During the F-18 flight, subject A's hands were initially cold at the same time he showed accelerated heart rate. However, as the flight progressed, he reported that he was able to increase his hand temperature.

Subject B- Figure 7 shows the ANS stress profile of subject B during his first rotating-chair test. Immediately after the start of rotation, physiological levels diverge rapidly from baseline. As observed with subject A, increases in heart rate and skin conductance levels were noted. The physiological response profile of subject B (hierarchy of response magnitude) was quite different from the first subject. Although all responses show a change from baseline, the largest magnitude change was FPV. A typical response to motion sickness stimulation is vasoconstriction and heart rate acceleration (refs. 10 and 11). This subject showed a paradoxical response (pronounced vasodilation with fluctuations in heart rate).

Figure 8 depicts the physiological data of subject B obtained during his first and last (6 hours) AFT sessions. Again, the subject's task was to produce alternating arousal and relaxation responses across the ten 3-minute trials of each session. By the end of training, control of heart rate accelerations and decelerations with respiration rate held constant was achieved, however, the magnitude and duration of these changes are less stable than observed for subject A. In fact, more time was spent with this subject in controlling the phase relationship of ANS responses (e.g., simultaneously increasing heart rate and SCL while decreasing FPV). This was most apparent in conditioning control of blood flow to the hands, which was poorly learned by subject B. By the end of training, this subject had some control over reducing the variability (stabilizing the amplitude) of FPV, but he could not voluntarily increase blood flow to his hands on command. Control of skin conductance level was learned and there was a tendency for this response to decrease tonically (drop in overall level) as training progressed as was seen in subject A.

Figure 9 shows the raw physiological data (one-minute means) of subject B during his first rotating-chair test and after 6 hours of AFT. Again, the 10-minute post-baseline data of the first test have been separated and placed on the x-axis beside those of the last test to facilitate comparison of post-stimulus levels. After AFT, subject B was also

able to maintain all physiological levels at or near his own baseline and could tolerate rotation at higher velocities for a longer time. Pretest baseline heart rate was higher after training than on the first rotation-chair test; however, there was relatively little change in response variability at the onset of rotation and as the speed of the chair increased at 5-minute intervals. The average heart rate dropped slowly as the test continued with a rapid decrease to baseline levels at the end of rotation, which occurred at the same rate as seen on his first test. Skin conductance level showed a tonic decrease after training, indicative of reduced sympathetic tone.

The largest response magnitude change during the first rotating-chair test was FPV. Although this subject demonstrated poor control of this variable during training sessions, he clearly reduced the variability of this measure during the rotating-chair tests administered after AFT. Unlike his first test however, large changes in vasodilation occurred during the posttest baseline and were accompanied by increased sensations of nausea.

Figure 10 shows how subject B's perception of motion sickness malaise changed from before AFT to after two, four, and six hours of training. In the first rotating-chair test, he was able to tolerate less than 15 minutes of rotation, terminating the test at 10 rpm (15 diagnostic points). His motion sickness tolerance improved throughout training so that after 6 hours of AFT, he reported no symptoms at 10 rpm and was able to tolerate 41 minutes of rotation, stopping the test at 18 rpm. Although this subject showed less improvement in motion sickness tolerance than subject A, his performance was significantly better than one would expect from habituation alone (participating in equally spaced motion sickness tests with no treatment) (refs. 11-13, 16, 19). Both subjects increased their tolerance to the rotating-chair test (fig. 11) with subject A tolerating twice the number of rotations as subject B on the final motion sickness test. Subject A was successful at controlling his symptoms with AFT during tactical maneuvers in the F-18 aircraft during his qualification flight. Before AFT, this subject reported extreme nausea and vomiting after performing five aileron rolls during flight. After receiving AFT during a second flight test conducted 20 days after the one reported here, he could perform over 50 of these maneuvers before the onset of minor motion sickness symptoms. Although subject B was also able to qualify for a high performance aircraft (T-38) after training, he felt he had not achieved sufficient control of his motion sickness symptoms and therefore chose to transfer to C-130 aircraft.

ANS response	Finger pulse volume (FPV) units/min	Respiration rate (RR) breaths/min	Heart rate (HR) beats/min	Skin conductance level (SCL) μ mhos/min
Baseline mean =	35.9	16.3	72.7	14.2
Standard deviation =	3.1	3.2	4.9	0.63

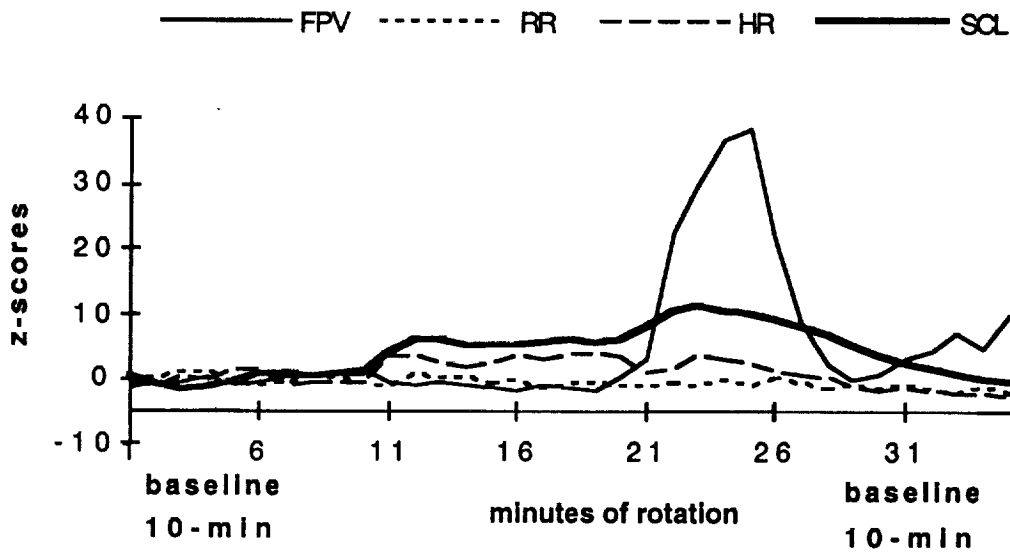


Figure 7. ANS stress profile of subject B during the first rotating-chair test.

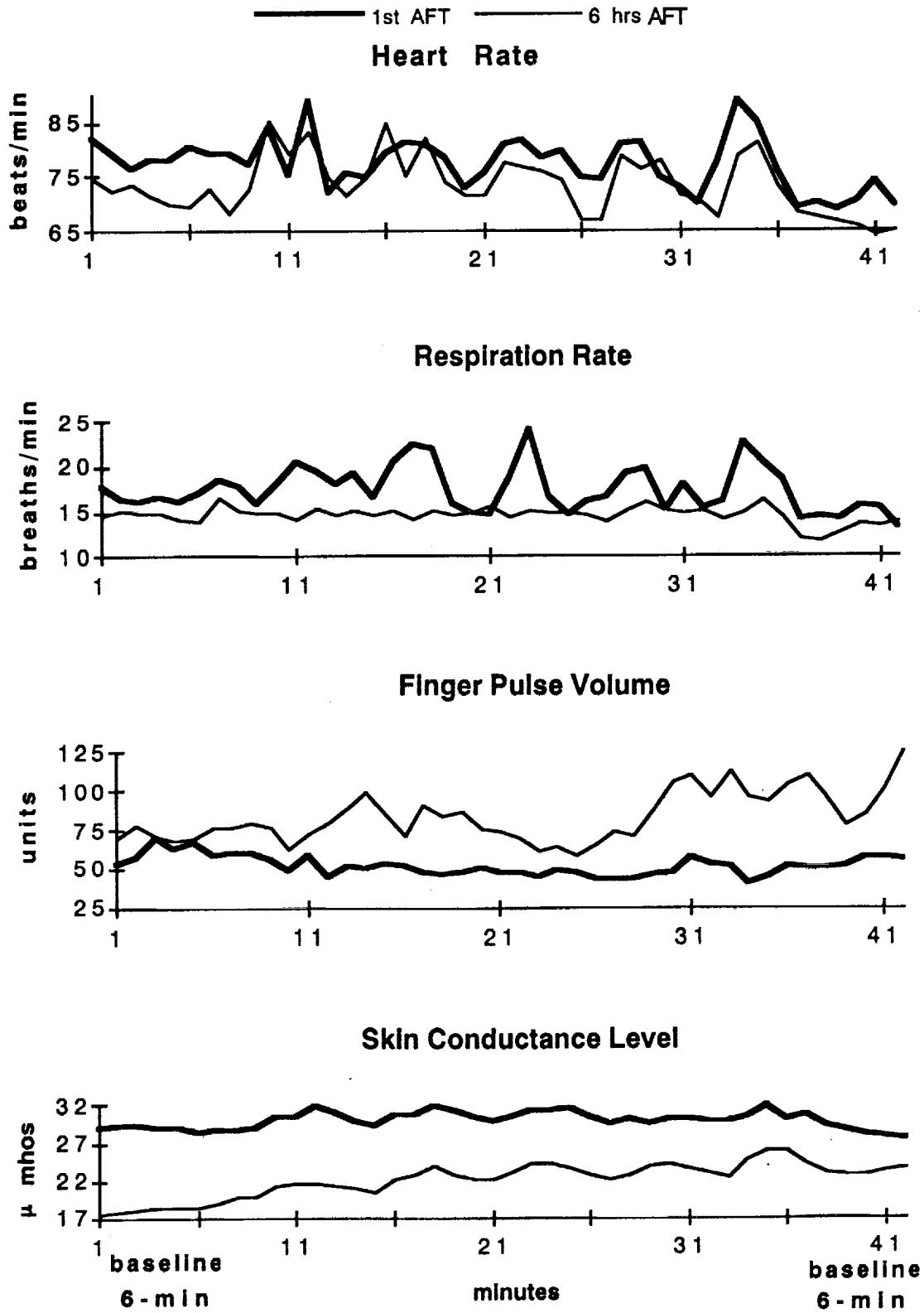


Figure 8. Physiological responses during AFT sessions: subject B.

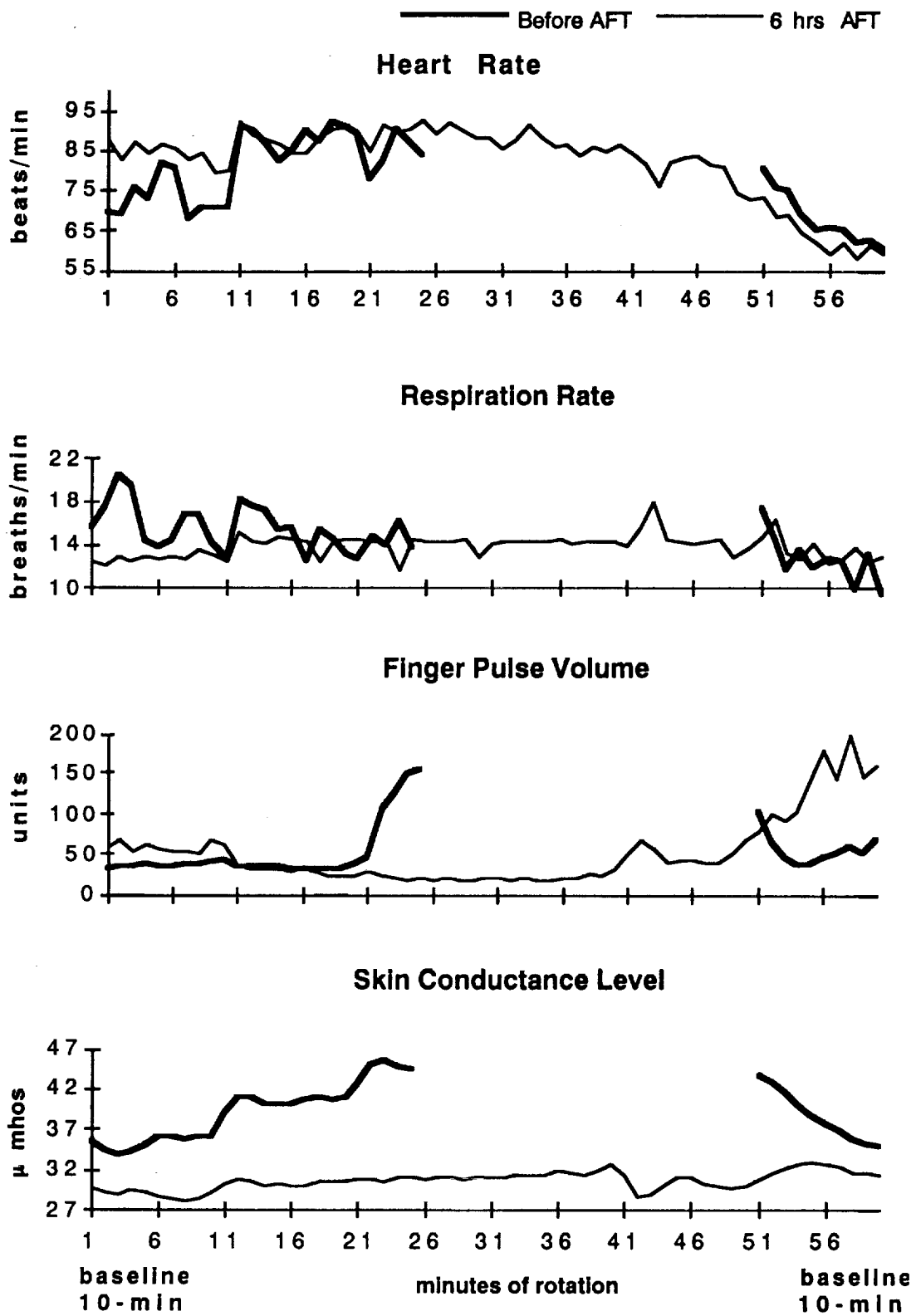


Figure 9. Changes in physiological response levels during rotating-chair tests before and after AFT: subject B.

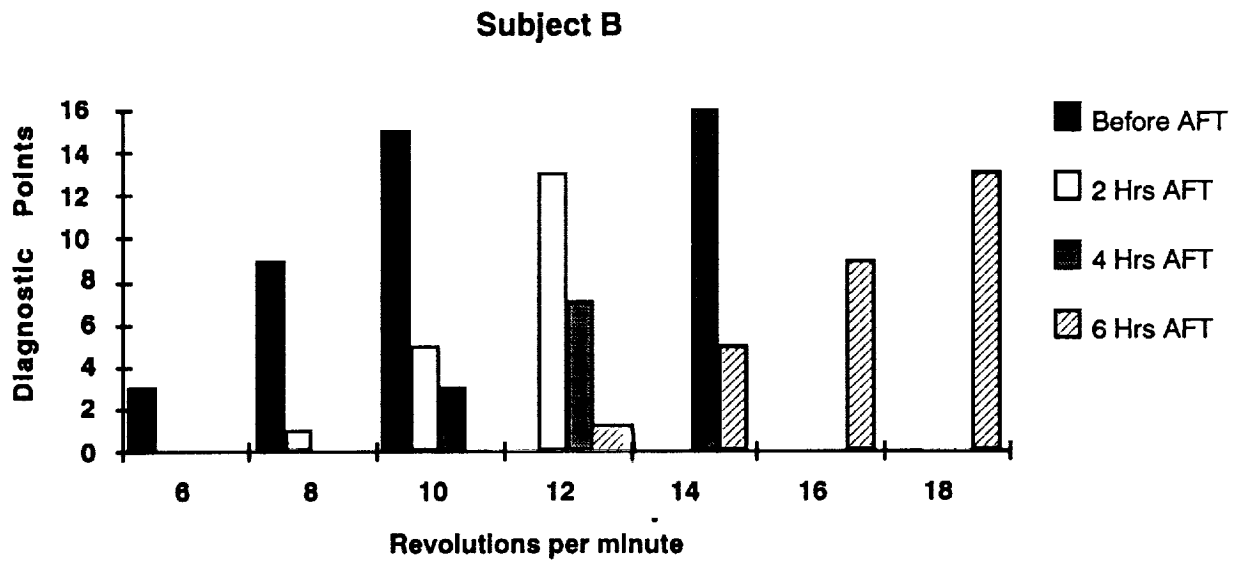


Figure 10. Changes in motion sickness malaise during rotating-chair tests before and after two, four, and six hours of AFT: subject B.

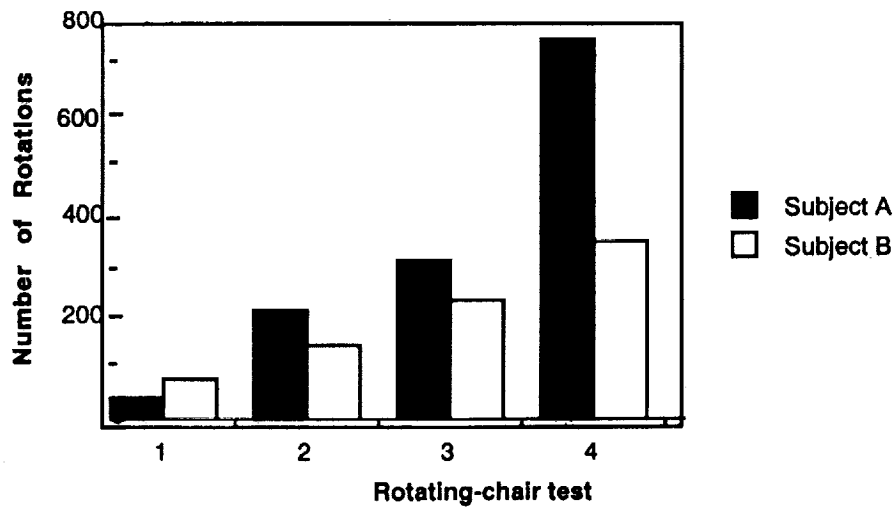


Figure 11. A comparison of subjects A and B: number of rotations tolerated during motion sickness tests.

Discussion

These data indicate that AFT was an effective method for controlling the symptoms of motion sickness in these military pilots. As we have previously observed in other studies, individuals learn symptom control at different rates (refs. 7-9, 12). The current study provided only a maximum of 6 hours of AFT. If increases in motion sickness tolerance are viewed as individual learning curves, neither of these subjects had reached a learning plateau, which suggests that both subjects may have continued to improve with additional training.

In the two cases reported here, we believe that further investigation into methods for facilitating the transfer of learned control of symptoms from the rotating chair to an aircraft is warranted. Future studies of this kind should be conducted using aircraft simulator flights as a substitute for the rotating-chair tests or alternatively including flight simulation as an experimental condition. Subject A reported that measurements taken with physiological feedback provided under simulated and actual flight conditions contributed significantly to his ability to apply the symptom suppression techniques he learned with AFT.

A number of space medicine "spin-off" applications for AFT in finding solutions to Earth-based problems have been and continue to be explored. These include tests of AFT for training cancer patients to suppress the nausea associated with radiation or chemotherapy and successful research on training paralyzed patients who suffer from

chronic low blood pressure to increase their blood pressure voluntarily. Of these applications, one that is most relevant to pilot training was demonstrated in a recent collaborative study conducted by NASA, the U.S. Army and the U.S. Coast Guard (ref. 5). In that study, four pilots of HC-130 aircraft and four pilots of HH-65 helicopters were given AFT for control of physiological responses. After training, their performance during an emergency flying scenario was compared to that of a matched (for flight hours) control group that received no training. The results showed that the AFT group significantly improved performance in a number of areas including crew coordination and communication, planning and situational awareness, stress management, and aircraft handling. It was concluded from this preliminary study that the performance improvements observed were due to learned self-regulation of autonomic responses to environmental stressors.

The investment of time and money made by government and industry in training aircrew and keeping them safe is enormous (refs. 18-22). Given the amount of time and money spent in training a military pilot to fly tactical aircraft, an investment of an additional 6, 12 or even 30 hours of AFT for that pilot would seem cost effective. The aeronautical health-care community may wish to investigate the value of using AFT in their practices as a means of promoting crew health, safety, and operational efficiency.

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13. ABSTRACT (Maximum 200 words) The purpose of this paper is to present a detailed description of the physiological and performance responses of two military pilots undergoing a treatment for motion sickness. The treatment used, Autogenic-Feedback Training (AFT), is an operant conditioning procedure where subjects are taught to control several of their autonomic responses and thereby suppress their motion sickness symptoms. Two male, active duty military pilots (U.S. Navy and U. S. Marine Corps), ages 30 and 35, were each given twelve 30-minute training sessions. The primary criterion for success of training was the subject's ability to tolerate rotating chair motion sickness tests for progressively longer periods of time and at higher rotational velocities. A standardized diagnostic scale was used during motion sickness to assess changes in the subject's perceived malaise. Physiological data were obtained from one pilot during tactical maneuvers in an F-18 aircraft after completion of his training. A significant increase in tolerance to laboratory-induced motion sickness tests and a reduction in autonomic nervous system (ANS) response variability was observed for both subjects after training. Both pilots were successful in applying AFT for controlling their airsickness during subsequent qualification tests on F-18 and T-38 aircraft and were returned to active duty flight status.			
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