NASA Space Technology Can Improve Soldier Health, Performance and Safety

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Introduction

One of the primary goals of NASA Life Sciences research is "...to enable a permanent human presence in space." To meet this goal, NASA is creating alternative protocols designed to evaluate and test countermeasures that will account for and correct the environmental effects of space flight on crewmembers health, safety and operational performance. NASA investigators have previously evaluated the effects of long-duration space flight on physiology and performance of cosmonauts aboard the MIR space station. They also initiated tests of a countermeasure, Autogenic-Feedback Training Exercise (AFTE) designed to prevent and/or correct adverse effects, i.e., facilitate adaptation to space and re-adaptation to Earth. AFTE is a 6-hour, physiological training program that has proven to be a highly efficient and effective method for enabling people to monitor and voluntarily control a range of their own physiological responses, thereby minimizing adverse reactions to environmental stress. However, because of limited opportunities to test this technology with space flight crews, it is essential to find operational or "real world" environments in which to validate the efficacy of this approach.

The Relevance of AFTE to the Army

Combat-vehicle crews operating in land, sea and air systems are expected to perform their mission tasks with very little margin for error, even during extreme conditions of continuous operations over extended days, or during high stress situations. Environmental stressors experienced by aerospace crews and military personnel are both chronic (requiring sustained vigilance) and acute (requiring immediate actions). Exposure to such situations can eventually lead to symptoms of fatigue, and physical and emotional exhaustion or, in the case of an acute stress, a hyper-reactive physiological state, which may affect both individuals and even entire units. Motion sickness has also been associated with deployment from amphibious vehicles, operations within enclosed tracked vehicles, and during tactical combat maneuvers in high-performance aircraft. Any combination of these adverse conditions can produce degraded performance and may cause human-error casualties. Crew operational readiness in extreme environments, whether on the battlefield or in space, is an important topic for both the military and NASA.

AFTE involves "exercising smooth muscles," where subjects are taught to both increase and decrease physiological response levels. Changes in response levels are achieved through alternating imagery of "emotional" stimuli and relaxation. Each daily training session is 30 minutes long during which subjects are taught to alternate increases and decreases in their response levels (e.g., heart rate accelerations and decelerations, peripheral vasodilatation and constriction, increases and decreases in skin conductance, etc.). Changes in these specific responses are learned without the influence of respiration (hypo or hyper-ventilation) or muscle contractions (measured at multiple sites). The purpose of this training is to provide subjects with the ability to recognize bodily sensations associated with changes in their physiological response levels and, with practice, to improve their skill in controlling them. Training utilizes components of operant conditioning, self-suggestions, systematic desensitization, progressive muscle relaxation and verbal instruction. Feedback for multiple parameters using both visual displays and auditory tones requires additional training in attending to a complex array of information.

Laboratory studies have demonstrated that subjects can be trained with AFTE to control motion sickness symptoms in response to rotating chairs, vertical accelerators, and to a rotating visual surround. In addition, it has been shown that this type of training successfully transfers to other situations. In studies of more than 300 subjects, 65% completely suppressed symptoms and 85% significantly increased their tolerance. Further, no gender gap was present; women were shown to learn at the same rate as men. Highly susceptible subjects also showed benefit; although the training takes longer, the rate of learning is comparable. The effects of training are cumulative, the more you do it, the better you get. Learned autonomic control is retained for up to three years with rapid re-learning.

AFTE was tested on astronauts and cosmonauts as a countermeasure for space motion sickness, and as a means of facilitating their physiological adaptation to space and readaptation after returning to Earth. Preliminary results indicate that the incidence of space motion sickness was reduced with AFTE, without the side effects of anti-motion sickness medication. Further, when AFTE was practiced effectively during long-duration flights (6 months on MIR), little or no post-flight orthostatic intolerance (low blood pressure) resulted upon return to Earth.

In addition, AFTE has proven beneficial effects in the treatment of intractable airsickness in military pilots flying high-performance aircraft. Pilots, for whom all other treatments failed, were typically able to return to active flight status after AFTE training. Even when airsickness is not a primary problem, AFTE has been a useful adjunct to pilot training. In Coast Guard helicopter and C130 pilots flying high-stress, search and rescue missions, AFTE was shown to improve their overall performance, as well as crew communication and coordination skills.

Finally, in clinical studies with patients, AFTE provided substantial relief from symptoms of nausea, fainting, and severe abdominal pain.

Other applications of AFTE that are relevant to the Army may be tested in the future. These include improving performance during sustained operations; as a treatment for Post Traumatic Stress Disorder; facilitating sleep under adverse environmental conditions; and eliminating simulator sickness. AFTE could be used to supplement regular exercise to improve overall performance in students at military academies and in officer training programs.

The AFTE Hardware

The Autogenic-Feedback System-2 (AFS-2) is a portable ambulatory monitoring system worn on the subject's belt designed to monitor human physiological responses in space. The AFS-2 has been used by Shuttle astronauts, MIR space station cosmonauts, military pilots flying high-performance aircraft, various patient populations as part of diagnostic evaluations, and soldiers during field operations in command and control vehicles. The system includes a garment, transducers, biomedical amplifiers, a digital wrist-worn feedback display, and a cassette tape recorder. The physiological measures recorded include: heart rate, respiration rate, blood flow and temperature, skin conductance level and head and upper-body movements using a tri-axial accelerometer. Ambulatory physiological data are recorded on analog cassette tapes and subsequently digitized and processed with customized software.

Insert Figure 1

The Autogenic Clinical Laboratory System (ACLS), a desktop PC-based physiological monitoring and training system configured with four monitors (2 for the researcher and 2 for the subject) is used during AFTE training. This system can acquire and digitally display 20 physiological parameters, plus coupled audible tones. It provides voice commands and respiratory pacing signals, and can calculate and display derived variables such as cardiac output, and stroke volume. The two monitors of the ACLS trainer's console are used for analog and numeric data displays. During training, the subject is seated in a separate room that contains two additional monitors. The trainer can select specific physiological parameters that are displayed to the subject, and can choose any two parameters for providing audible feedback tones. Training can be delivered over the internet to PC systems at any location, thereby reducing time and costs of transporting personnel to a centralized training center.

Previous NASA/Army Research (NASA Technical Memorandum 1999-208786)

In a recently completed study, the AFS-2 system described above was used to evaluate motion sickness incidence and performance of soldiers in an enclosed armored vehicle, the U. S. Army's Command and Control Vehicle (C^2V), equipped with four computers. By examining physiological responses, self-reports of symptoms and a battery of performance subtests, it was possible to decisively answer the Army's questions of: "who?" (how many soldiers were affected), "how serious?" (what is the practical or operational impact) and "when?" (under which environmental conditions did problems occur). Results showed that when the vehicle was moving, motion sickness symptoms increased in all subjects, and this was accompanied by degraded performance. Drowsiness and headache, not nausea, were the most pervasive symptoms occurring in 60 to 70% of the soldiers. Performance was degraded by at least 5% in 23 of the 24 soldiers. For 30% of these subjects, the performance degradation was operationally equivalent to having a blood alcohol level above the legal limit. Physiological data reflected performance changes and symptom reports as those individuals most affected showed larger magnitude responses (hyper-reactivity) when the vehicle moved. Further, these negative effects were not mitigated by intermittent short-halts or by the orientation of the seats. It was concluded that mobile operations in the C2V would make it unlikely that a majority of soldiers could successfully perform their mission objectives.

The use of multiple converging indicators (i.e., measurements of cognitive and psychomotor skills, symptoms, and physiology) provides more definitive information about the environmental impact on human functional state than any one indicator. The methodology employed in the C2V study and aboard the MIR space station, may also be useful for examining environmental impact on soldiers in other land, sea and air vehicles.

Insert figure2 here.

Conclusions

Potentially AFTE provides a single-intervention approach for solving multiple problems. The goal of AFTE is to train individuals to recognize early physiological changes associated with stressful situations and thereby increase situational awareness. AFTE is not a relaxation training method, but rather a means of gaining a quantifiable skill (where skill level can be tracked over time). During training, subjects learn to effectively **control** their own autonomic nervous system; decreasing or increasing their response levels, as needed, to compensate for environmental or situational demands.

Consider the potential benefits of AFTE compared to other countermeasures. Much work has been published in recent years on the benefits of allowing pilots to take brief naps to correct for the debilitating effects of cumulative sleep loss. However, there are many situations in military and commercial aviation, as well as during long duration space flight, where naps are not feasible. A crewmember may be **compelled** to continue work despite a lack of sleep or heavy workloads under life-threatening conditions or facing the potential loss of significant mission objectives. Unlike pharmacological agents like stimulants, tranquilizers, or antimotion sickness medications which produce deleterious side effects, there are no side effects with AFTE. Extended use of medications may also be contraindicated, as they can be potentially hazardous to crew health. AFTE may be one option for mitigating negative environmental effects on soldiers and astronauts when the use of medication is untenable and when modification of the vehicle, crew tasks or sleep schedules is not feasible. Operational field tests of AFTE are required for validation prior to its use as a countermeasure in space, and collaborations are actively sought. NASA/Army collaborations which enable tests of protocols for mitigating the adverse effects of environment benefit both federal agencies by providing effective procedures for utilization in operational settings.

BIOSKETCH: Dr. Patricia Cowings is the Science Director of the Psychophysiological Research Laboratory in the Life Sciences Division at NASA Ames Research Center. She was the principal investigator of three Space Shuttle experiments and co-investigator on a MIR space station study on long duration spaceflight. She holds adjunct academic positions in medical and clinical psychology at the Uniformed Services School and in both psychiatry and biomedical engineering at other universities. Dr. William Toscano is on the staff of the Department of Psychiatry at the University of California, Los Angeles and has served as a coinvestigator with Dr. Cowings on flight and ground-based research projects.

FIGURE CAPTIONS

Figure 1. Soldier wearing the AFS-2 and an Illustration of System Components.

Figure 2. Exterior and Interior Views of the Command and Control Vehicle.