Psychophysiological Studies in Extreme Environments

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Abstract (Study 1)

This paper reviews the results from two studies that employed the methodology of multiple converging indicators (physiological measures, subjective self-reports and performance metrics) to examine individual differences in the ability of humans to adapt and function in high stress environments. The first study was a joint collaboration between researchers at the US Army Research Laboratory (ARL) and NASA Ames Research Center. Twenty-four men and women active duty soldiers volunteered as participants. Field tests were conducted in the Command and Control Vehicle (C2V), an enclosed armored vehicle, designed to support both stationary and on-the-move operations. This vehicle contains four computer workstations where crew members are expected to perform command decisions in the field under combat conditions. The study objectives were: 1) to determine the incidence of motion sickness in the C2V relative to interior seat orientation/position, and parked, moving and short-haul test conditions; and 2) to determine the impact of the above conditions on cognitive performance, mood, and physiology. Data collected during field tests included heart rate, respiration rate, skin temperature, and skin conductance, self-reports of mood and symptoms, and cognitive performance metrics that included seven subtests in the DELTA performance test battery. Results showed that during 4-hour operational tests over varied terrain motion sickness symptoms increased; performance degraded by at least 5 percent; and physiological response profiles of individuals were categorized based on good and poor cognitive performance. No differences were observed relative to seating orientation or position.

Introduction

Previous studies have shown the methodology of multiple converging indicators (physiological measurements, subjective self-reports, and performance metrics) is a more reliable method for assessing how individuals adapt in extreme environments than any one indicator alone.[1] The practical application of this method was demonstrated in a collaborative study with NASA and U.S. Army researchers at Fort Hood, Texas[2]. Operational field tests were performed in the Command and Control Vehicle (C2V), an enclosed armored vehicle, designed to support both stationary and on-the-move operations. This vehicle contains four computer workstations where crew members are expected to perform command decisions in the field under combat conditions. Limited user tests carried out by ARL engineers with a prototype C2V have identified motion sickness as a potential problem and there was some uncertainty of other on-the-move effects (e.g., noise, vibration, visual references). Objectives of the current study were: 1) to determine the incidence of motion sickness in the C2V relative to interior seat orientation/position, and parked, moving and short-haul test conditions; and 2) to determine the impact of the above conditions on cognitive performance, mood, and physiology.

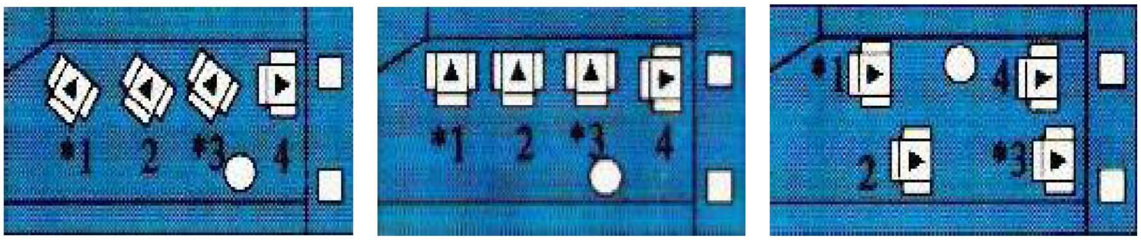
Command and Control Vehicle (C2V)

Classroom Training

C2V Interior View

Methods

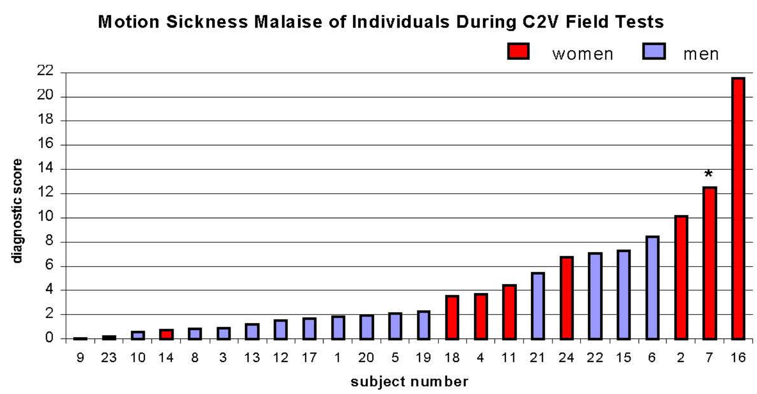
Sixteen men and eight women soldiers (mean age 24.5) from the US Army Tank and Automotive Command volunteered as participants in this study. C2V field tests included three conditions: parked, moving, and short-haul operations conducted over a 4-hour test period. Participants were tested in three different vehicles with interior seating orientations shown in the figure below. A total of twelve, 4-hour test rides that included mixed secondary roads and tank trails were completed by each participant. Test rides were carried out on alternate days with one day off between rides. Data collected during field tests included heart rate, respiration rate, skin temperature, and skin conductance, self-reports of mood states and motion sickness symptoms, and cognitive performance metrics consisting of seven subtests in the DELTA performance test battery. All participants were trained in the classroom on the performance test battery prior to the start of field tests.



C2V Interior Layouts: Oblique (left), Perpendicular (center), Forward (right). Direction of travel is moving to right.

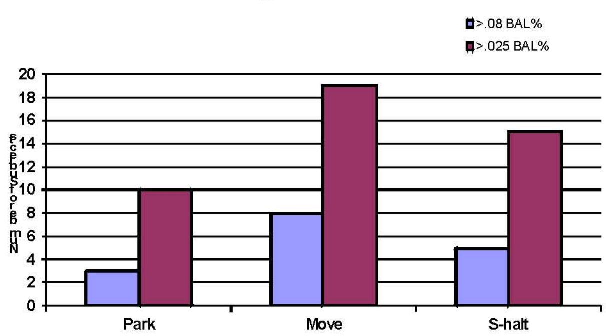
Results

During 4-hour test rides over varied terrain motion sickness symptoms increased, particularly during moving and short-haul conditions. Drowsiness and headache, not nausea, were the most pervasive symptoms occurring in 60 to 70 percent of participants. Cognitive performance was degraded by at least 5 percent in 23 of the 24 soldiers. For 30 percent of these subjects, the performance degradation was operationally equivalent to having a blood alcohol level above 0.80, the legal limit in most US states. Physiological response patterns were categorized based on good and poor cognitive performance. No differences were observed among the different vehicle interior configurations.



Malaise Level
slight 0-3
moderate 4-7
severe > 8

Motion Sickness During C2V Field Tests *subject withdrew from study



Performance Scores Converted to Blood Alcohol Level Equivalencies x Field Test Conditions

Conclusions

The C2V vehicle environment exposes crew to confinement, vibration, noise, heavy workloads, and induction of motion sickness symptoms. Motion sickness symptoms probably resulted from a combination of vehicle pitch and yaw motions and the participants' attention to computer tasks during field tests. While performance deterioration during vehicle movement can result from impairment in visual perception and manual control skills induced by vehicle vibration and movement, it is likely that the performance deterioration during the parked conditions of the field test resulted from the persistent effects of exposure to vehicle vibration, noise, and drowsiness induced by 'Sopite syndrome'.

Abstract (Study 2)

An earlier study by the US Navy in 1961 demonstrated that an individual was capable of remaining at 2.0 g for a period of 24 hours. However, no objective cardiovascular or performance data were obtained. A feasibility study was conducted in the human centrifuge at NASA Ames Research Center with four male volunteer participants. The study objectives were: 1) to determine if humans can function for prolonged periods of time (22 hours) in hypergravity; and 2) to provide an enhanced understanding of changes in orthostatic tolerance during prolonged exposures. Tests were conducted in the centrifuge at constant gravitational loads of 1.0 (baseline), 1.25 and 1.5 g and each test was separated by a 7-day interval. G tolerance tests ($+G_z$) were conducted before and after prolonged exposures. Stand tests to evaluate orthostatic tolerance, performance tests, and self-reports of mood and symptoms were measured at 2-4 hour intervals during prolonged exposures. Results indicate unique physiological profiles for two participants: one with high orthostatic tolerance (a sympathetic autonomic profile) and the other with low orthostatic tolerance (a parasympathetic autonomic profile). Performance on spatial transformation and neuro-motor tasks were significantly impaired in some individuals and some also showed a decline in mood states. One participant reported severe motion sickness during prolonged exposure at 1.5g while another participant experienced syncope during his 1.25g exposure.

Introduction

An earlier study by the US Navy in 1961 demonstrated that an individual was capable of remaining at 2.0 g for a period of 24 hours. However, no objective cardiovascular or cognitive performance data were obtained in that study. Also, since astronauts manifest a decrease tolerance to orthostatic stress in response to prolonged exposure to microgravity, it was hypothesized that increased tolerance may result from prolonged exposure to hypergravity. A feasibility study was conducted in the human centrifuge at NASA Ames Research Center with four male volunteer participants. The study objectives were: 1) to determine if humans can function for prolonged periods of time (22 hours) in hypergravity; and 2) to provide an enhanced understanding of changes in orthostatic tolerance during prolonged exposures.

NASA Ames Human Centrifuge Configured with Cab A (left) and Cab B (right)

+Gz Tolerance Tests in Cab A

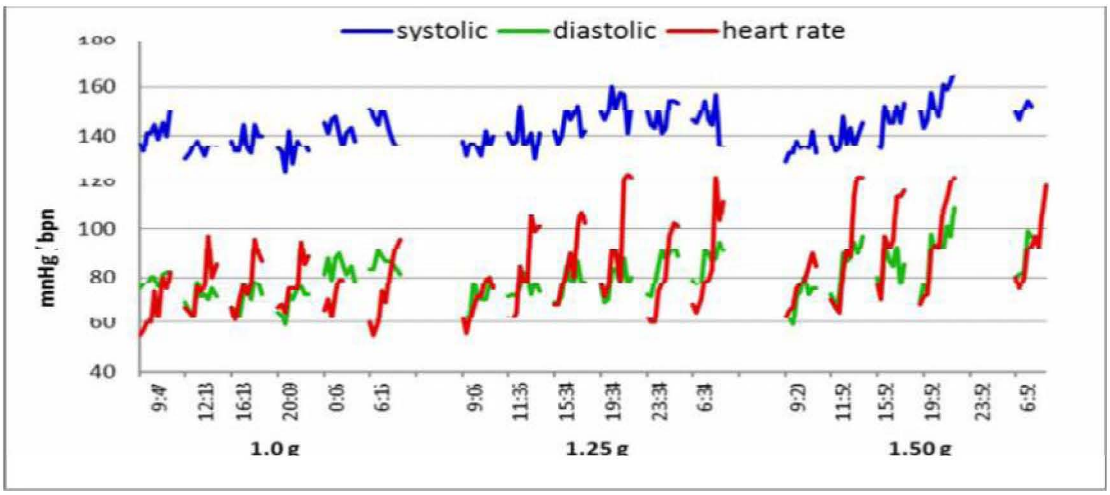
Prolonged 22 Hour Exposures in Cab B

Methods

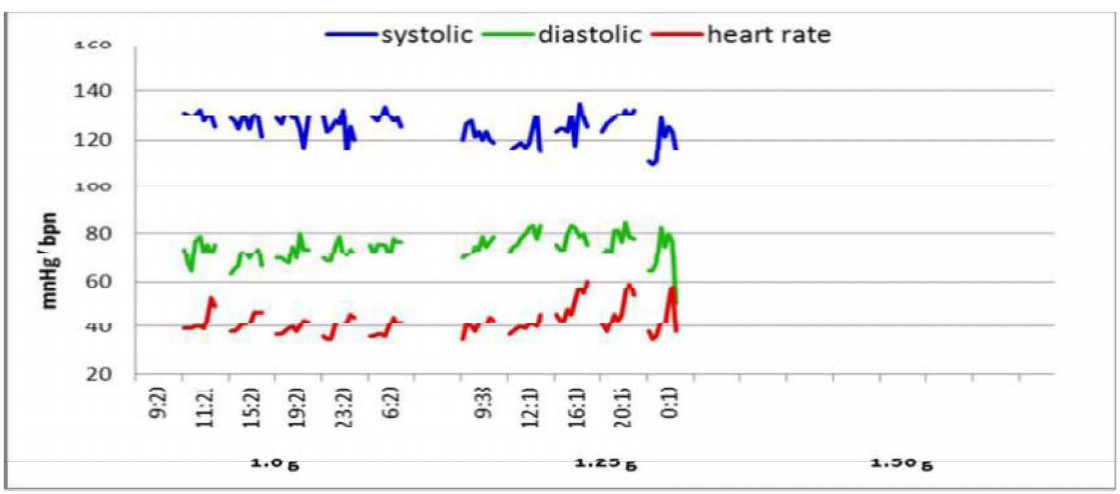
Four healthy adult men, 20 to 34 years old, served as participants in this study. Participants were tested during prolonged (22 hour) exposures in the centrifuge at constant gravitational loads of 1.0 (baseline), 1.25 and 1.5g. These tests were conducted at 7 day intervals in Cab B of the centrifuge which contained a bed, collapsible toilet, storage area for food and water, a television and a laptop computer. Orthostatic tolerance during prolonged exposures was evaluated using a 'stand test' protocol: 3 minutes supine, 3 minutes sitting, and 3 minutes standing. Stand tests, a cognitive performance test battery, and self-reports of mood and symptoms were measured at 2-4 hour intervals during prolonged exposures. $+G_z$ tolerance tests (0.067 g/second) were conducted in Cab A before and after each 22-hour prolonged exposure. Physiological data were collected continuously during the prolonged exposures and g-tolerance tests and included measures of heart rate, respiration rate, skin temperature, skin conductance, impedance cardiography, and blood pressure.

Results

Only participant A completed the prolonged exposure at 1.5g. Participants A, B, and C each completed the1.25g exposure. Participant A (figure below) reported severe motion sickness symptoms at 23:52 hours during his 1.5g exposure, but was able to maintain good orthostatic tolerance during all stand tests at 1.25 and 1.5g exposures. His heart rate, blood pressures were higher at the 1.0g baseline than other participants (a sympathetic autonomic profile) and showed larger magnitude increases during stand tests. In contrast, heart rate and blood pressures of Participant D were much lower (a vagotonic autonomic profile) during the 1g baseline, and this individual was more susceptible to orthostatic intolerance since he experienced syncope after 14 hours at 1.25g. The study was terminated due to potentially high risk of medical injury to the participants. No further testing was conducted at 1.5g. Participant A's performance on spatial transformation and neuro-motor tasks (accuracy and speed) showed significant decrements during both 1.25 and 1.5g exposures. In addition, this individual showed a significant deterioration in mood states during his 1.5g exposure. No consistent trends toward an increase in G_z tolerance were observed following prolonged exposures at 1.25 and 1.50g (table below).



Heart Rate and Blood Pressure of Participant A During Stand Tests at 1.0g, 1.25g, and 1.50g. X-axis shows time of day when stand tests occurred. Each test was 9 minutes in duration.



Heart Rate and Blood Pressure of Participant D During Stand Tests at 1.0g and 1.25g (test terminated due to syncope). X-axis shows time of day when stand tests occurred. Each test was 9 minutes in duration.

Participant	1.0g (baseline) pre	1.0g (baseline) post	1.25g pre	1.25g post	1.5g pre	1.5g post
A	5.21	4.70	4.96	6.29	4.49	4.61
B	3.55	3.89	4.28	3.34	-	-
C	4.63	5.15	4.65	4.25	-	-
D	3.56	3.89	3.91	-	-	-

$+G_z$ Tolerance Test Scores of Each Participant. These tests were conducted immediately before (pre) and after (post) prolonged 22 hour exposures at 1.0g, 1.25g, and 1.5g. Scores in the table represent the maximum g's tolerated.

Conclusions

Prolonged 22 hour exposures at constant gravitational loads above 1 g in a centrifuge can induce motion sickness symptoms, physical inactivity, boredom, fatigue, and susceptibility to orthostatic intolerance. This study used multiple converging indicators to examine individual differences in how humans adapt and function during sustained hypergravity. Participant A experienced severe motion sickness symptoms at 1.5 g after 14 hours exposure, but was able to maintain good orthostatic tolerance. During stand tests his heart rate and blood pressure levels were higher with larger dynamic range than Participant D, suggesting autonomic balance (sympathetic nervous system vs parasympathetic nervous system tone) may play an important role in determining susceptibility to orthostatic intolerance. Higher sympathetic tone as seen in Participant A may provide greater resistance to orthostatic challenge. However, higher autonomic lability in this participant may have been a significant factor in eliciting motion sickness symptoms.[3] For some individuals prolonged exposure to hypergravity can result in cognitive performance impairment and deterioration in mood states. Confinement in a small room, physical inactivity, and boredom are probable contributing factors to these results. Future studies involving adapting humans to prolonged hypergravity need to address these important issues.

References

1. Cowings PS, Toscano WB, DeRoshia C, Taylor B, Hines A, Bright A, Dodds, A. (2007) Converging Indicators for Assessing Individual Differences in Adaptation to Extreme Environments. Aviation, Space, and Environmental Medicine, 78(5, Supp.): B195-215.
2. Cowings PS, Toscano WB, DeRoshia C., Tauson R. (2001) Effects of Command and Control Vehicle Operational Environment on Soldier Health and Performance. Journal of Human Performance in Extreme Environments, 5(2), 66-91.
3. Cowings, P.S., Suter, S., Toscano, W.B., Kamiya, J. and Naifeh, K. (1986). General autonomic components of motion sickness. Psychophysiology, 23, (5), 542-55.