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The Effect of Vehicle Noise and Vibration (Caused by Moving Operations) on Cognitive Performance in the Command and Control Vehicle

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To maintain the pace of modern battle and to support the fielding of digital command and control systems, the U.S. Army needed to develop a new command and control vehicle (C^2V). As part of an evaluation of human performance on automated command and control tasks in the C^2V, this study attempted to quantify the effect of vehicle movement on computer operators. Fourteen subjects, who had computer and tracked vehicle experience, completed a subset of the Expanded Complex Cognitive Assessment Battery (CCAB) running on U.S. Army tactical command and control system (ATCCS) common hardware in the C^2V. The tests were performed in stationary, vehicle idle, road march (secondary road at 20 mph), and cross-country (sandy river bed at 10 mph) conditions. Subjects were exposed to each condition for 30 minutes in the morning and again in the afternoon. After each condition, subjects completed questionnaires about human-machine interface and subjective discomfort. Subjects also completed a stress assessment questionnaire at the beginning of the test, after each cross-country trial, and at the end of the day.

Although some subjects experienced discomfort and one was completely incapacitated by motion sickness, vehicle movement did not degrade cognitive performance of most of the test measures. In all cases, subjects were able to operate the computer in all vehicle movement conditions. The questionnaires and stress measurements showed a small effect from vehicle movement. An analysis of variance of the CCAB scores showed a significant degradation in performance for one subtest when idle and road march conditions were compared. The overall conclusion was that, at the speeds tested, the subjects were able to compensate for any stressors caused by vehicle movement. Future testing should consider operations at more operational speeds, longer exposure to vibration conditions, and alternate cognitive stress measurements with more emphasis on short-term memory tasks.

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THE EFFECT OF VEHICLE NOISE AND VIBRATION (CAUSED BY MOVING OPERATIONS) ON COGNITIVE PERFORMANCE IN THE COMMAND AND CONTROL VEHICLE

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U.S. ARMY RESEARCH LABORATORY

Aberdeen Proving Ground, Maryland

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EXECUTIVE SUMMARY

A prototype command and control vehicle (C^2V) is being developed under contract for the U.S. Army by United Defense Industries (UDI). As part of an evaluation of human performance of automated command and control tasks in the developmental command and control vehicle, this study attempted to quantify the effect of vehicle movement on computer operators. Fourteen subjects, who had computer and tracked vehicle experience, completed a subset of the Expanded Complex Cognitive Assessment Battery (CCAB) running on Army tactical command and control system (ATCCS) common hardware in the C^2V. The tests were performed in stationary, vehicle idle, road march (secondary road at 20 mph), and cross-country (sandy river bed at 10 mph) conditions. Subjects were exposed to each condition for 30 minutes in the morning and again in the afternoon. After each condition, subjects completed questionnaires about the human-machine interface and subjective discomfort. Subjects also completed a stress assessment questionnaire at the beginning of the test, after each cross-country trial, and at the end of the day.

Although a number of subjects experienced some degree of discomfort and one was completely incapacitated by motion sickness, vehicle movement did not degrade cognitive performance of most of the test measures. In all cases, subjects were able to operate the computer in all vehicle movement conditions. The questionnaires and stress measurements showed a small effect from vehicle movement. An analysis of variance (ANOVA) of the CCAB scores showed a significant degradation in performance for one subtest when idle and road march conditions were compared. The overall conclusion was that at the speeds tested, the subjects were able to compensate for any stressors caused by vehicle movement. Future testing should consider operations at more operational speeds, longer exposure to vibration conditions, and alternate cognitive stress measurements with more emphasis on short-term memory tasks.

THE EFFECT OF VEHICLE NOISE AND VIBRATION (CAUSED BY MOVING OPERATIONS) ON COGNITIVE PERFORMANCE IN THE COMMAND AND CONTROL VEHICLE

INTRODUCTION

Background

In the last decade, digital communications, microprocessor-assisted message distribution, and enhanced human-machine computer display techniques have dramatically changed information distribution and availability in many civil applications. At the same time, the fast moving, widely diffused nature of modern conflicts makes information distribution in military command and control (C^2) systems critical to the mission and survival of U.S. forces.

To exploit technology to improve command and control systems, the U.S. Army initiated a two-pronged program. The Army tactical command and control system (ATCCS) is a digitally based, information distribution system that will allow rapid transmission, distribution, and exploitation of tactical information, both vertically through the chain of command and horizontally through adjacent units and between the battlefield functional areas. To allow ATCCS to physically keep pace with the battle, the command and control vehicle (C^2V) was proposed as the second prong of this modernization effort. The C^2V will provide a platform from which command personnel will use automated command and control systems to track and control the battle, either from stationary, dispersed locations or while moving with the force. The union of these two systems will provide the force with a qualitatively different ability to maintain command and control, but it will also create a major challenge in terms of task distribution and human interface. Issues that must be resolved include how to best group and allocate tasks under ATCCS, how to group personnel and task groups within different C^2Vs, and how to interface the C^2V with ATCCS hardware and software to maximize human performance. These issues are being addressed by the Human Research and Engineering Directorate (HRED) of the U.S. Army Research Laboratory (ARL).

One requirement for the C^2V will be that its crew must provide at least some C^2 capability while the C^2V is moving, although this may be a subset of the operations possible in a stationary vehicle. The effects of shock, road noise, and vibration associated with tracked vehicle movement on human performance are not well understood. These effects were among a number of concerns raised in the initial human engineering assessment of the C^2V (Martin, 1993).

Prior Research

A few studies have addressed performance degradation in military vehicular environments. In a literature review, Lewis (1962) noted that vehicle shock and vibration frequently contributed to lower back and renal damage but did not cite any research about cognitive performance degradation. At the conclusion of a series of studies about the effect of vehicular confinement for as long as 12 hours in stationary or moving armored personnel carriers (APCs), no difference was found between moving and stationary conditions and only a few of the gross motor tasks evaluated were significantly affected by the period of confinement (Hicks, 1961). More recently, fire support teams operating in a prototype command and control vehicle in various mission-oriented protective postures (MOPPs) showed a cognitive variation that followed normal core temperature changes associated with the circadian cycle but no systematic degradation with time (Rauch, Witt, Banderet, Tauson, & Golden, 1986). In another test, which used the same prototype as a battery fire direction center, two crews effectively processed fire missions for 72 hours and 54 hours and 37 minutes, respectively (Field Artillery Board, 1985). Although the crews were not restricted to the vehicle for the entire time, they were under full nuclear-biological-chemical (NBC) protective discipline, and activity outside the vehicle was extremely limited.

Several studies showed that noise levels in moving tracked vehicles degrade human performance. An early study (Torre & Garinther, 1958) found that noise levels in early APCs caused temporary hearing loss, made communication difficult, and were generally irritating. Another evaluation of APCs (Shoemaker, Garinther, & Kalb, 1980) found that most tracked vehicles in the U.S. Army inventory still exceeded the noise limits for verbal communication and required hearing protection to prevent damage. One study of an early version of the 577 command post vehicle (Garinther & Donley, 1963) found that noise levels when moving were dangerous and communication was impossible. Even when the vehicle was stationary, communication was difficult because of the generator and on-board C2 equipment. It is important to note that all these studies considered ambient vehicle noise, without considering the use of on-board vehicle intercoms.

The results of existing research about the effect of vibration on cognitive processes are ambiguous. When subjects performed a complex counting task in noise levels of 65 or 100 dBA and with no vibration or a 0.36-root-mean-squared (rms) gigahertz sum-of-sines vibration, an interaction was found between noise and vibration (Harris & Shoenberger, 1980). When subjects were not exposed to vibration, they performed better in the 65-dBA noise condition than in the 100-dBA condition. In the relatively quiet (65-dBA) condition, adding vibration caused performance to degrade. However, in the more noisy (1000-dBA) condition, vibration caused performance to improve enough that it was better than performance in the 65-dBA vibrating environment. In another study (Sherwood & Griffin, 1990), subjects performed a short-term memory task while being exposed to a 16-Hertz (Hz) sinusoidal curve at 0.0 (stationary), 1.0, 1.6, and 2.5 ms^{-2} rms. Performance was most degraded in the 1.0-rms condition. Both studies indicate that there is some relationship between cognitive functions and vibration, but that it is not a simple inverse correlation. The authors of both studies speculated that the degree of stress caused by the vibration and the subject's perception and compensation for the stress may eventually explain the results.

Objective

This study was part of an overall program to map requirements for automated command and control against available equipment, vehicles and personnel, with the intention of improving the use of human resources in future C^2 environments. The purpose of this study was to obtain an initial indication of the effect of vehicle noise and vibration on the cognitive capability of people working at automated workstations during various conditions of vehicle movement. The hypothesis for this evaluation was that the noise and vibration of vehicle movement would degrade performance and increase stress.

METHOD

Subjects

The subjects for this evaluation were 16 volunteers with some experience in both computer operations and in moving, tracked vehicles. The subjects included 15 males and 1 female, and consisted of 4 civilians and 12 military personnel with from 4 to 26 years in service. Subjects ranged from 29 to 49 years of age. Subjects reported prior experiences of motion sickness ranging from never to several previous episodes of motion sickness. A more detailed listing of subject demography is shown in Appendix A.

Materials

C^2V

The command and control vehicle used in this evaluation was a prototype developed under contract for the U.S. Army by United Defense Industries (UDI). The vehicle has a Bradley chassis with a cab and rear compartment similar to a multiple launch rocket system (MLRS) vehicle except that a 574-cm-long, lightly armored crew compartment replaced the missile pods. The crew compartment had four ATCCS workstations and two crew seats for support or supervisory personnel. A schematic of the crew compartment is presented in Figure 1. The ATCCS crew stations were equipped with pneumatically cushioned, adjustable seats to minimize shock and vibration to the operator. The C^2V crew compartment was equipped with a primary power unit (PPU), which provided power for the ATCCS computers, lighting, radios, and other systems in the crew compartment. The crew compartment also was supplied with cooled or heated, filtered air by the C^2V life support systems. The crew compartment was accessible through a rear door, a small roof hatch, or a crawl-through to the vehicle cab.

ATCCS Workstations

The ATCCS workstations used in this evaluation were standard hardware supplied by MILTOPE. Each workstation was a 486 processor running under the UNIX operating system. The system had hard and 3.25-inch removable floppy disk drives, a tethered QWERTY keyboard, a trackball, and a 19-inch (diagonal) color cathode ray tube (CRT) display. For this evaluation, a disk operating system (DOS) window was opened to run the CCAB software. The DOS window was approximately 9.24 inches (diagonal) and displayed 0.95- by 0.2-inch characters in the standard DOS display. Characters generated by the CCAB software tended to be larger. Normally, the UNIX operating system identifies the active window by the position of the trackball cursor. Since vehicle vibration caused the cursor to move even when the trackball was immobilized, the trackball on each ATCCS system was disabled for this evaluation. Since the CCAB relies on keyboard input, this had no impact on the test, but vehicle vibration could be a major problem with mouse- or trackball-driven applications.

Road Courses

This evaluation took place at Camp Roberts, California, with most of the activity occurring at four locations. Training was conducted at a building about 2 miles from the test sites. Stationary vehicle activities were performed outside the UDI testing and maintenance facility. Road march operations were performed on a secondary, dirt road, shown in Figure 2. The ride on the road march course was characterized by steady vibration interspersed with sharp bumps from the holes and dips in the road.

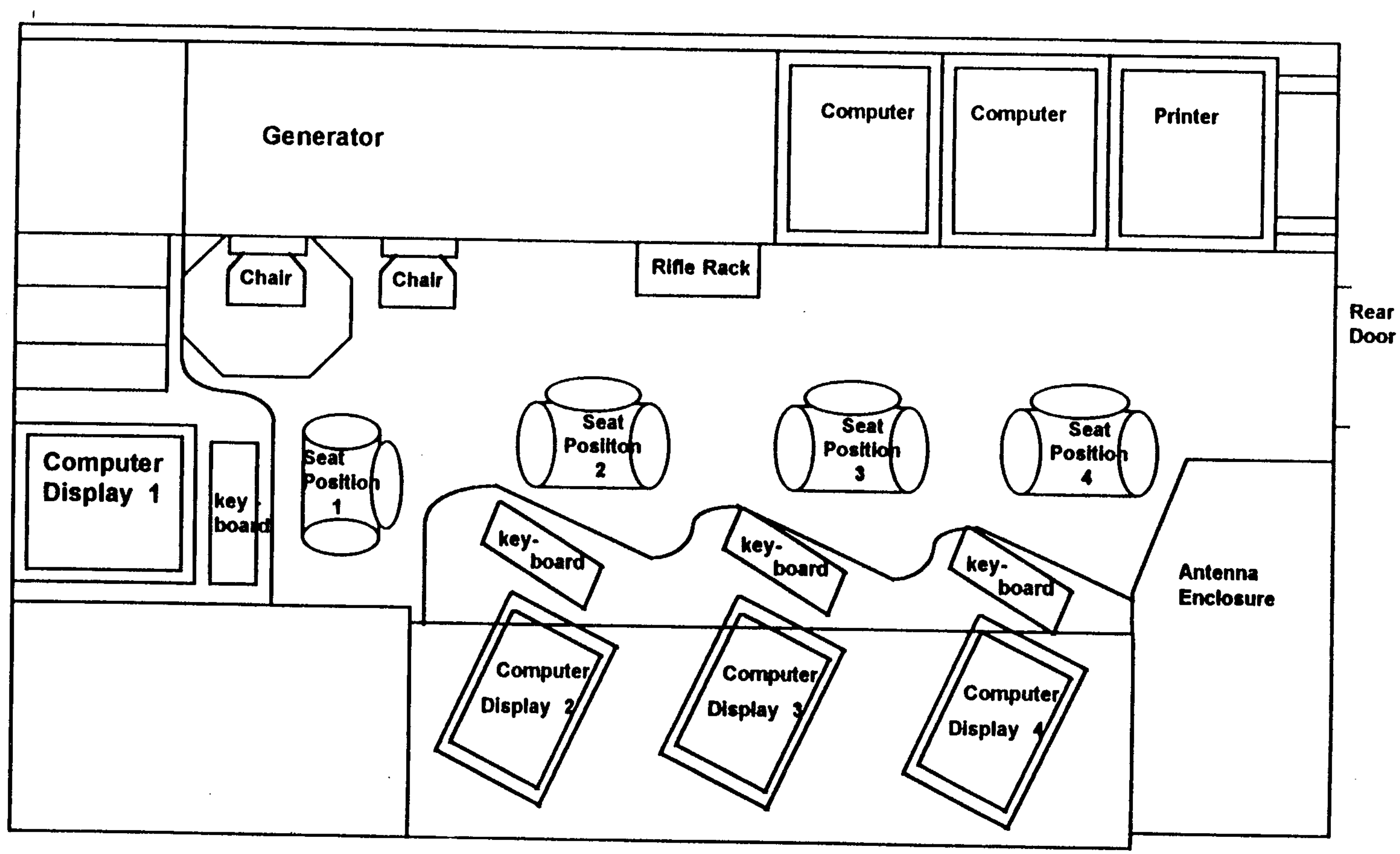

Figure 1. Schematic of the C^2V interior.

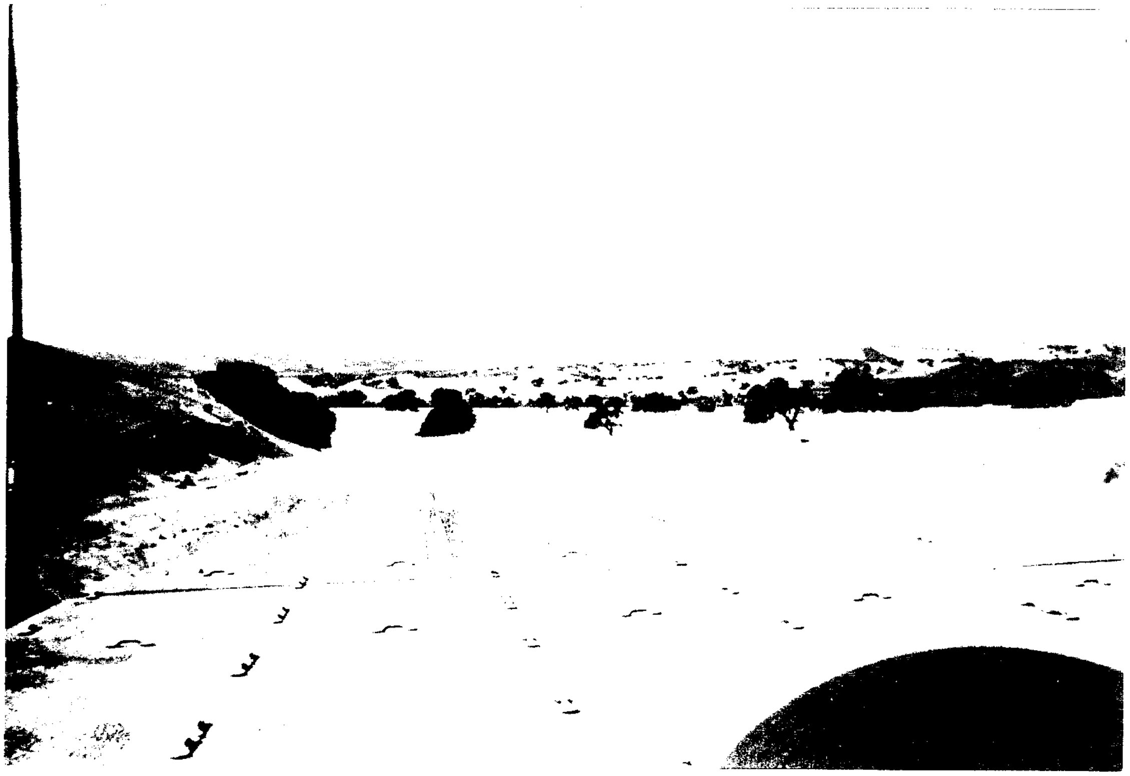

Figure 2. Road march course.

In cross-country conditions, the C^2V traveled on a sandy stream bed in a rough 8-shaped pattern (see Figure 3). The ride on the cross-country course consisted of undulating, wave-like movements. The safety release for the C^2V restricted road march operations to 20 mph and cross-country operations to 10 mph, with a maximum exposure of 60 minutes per day to cross-country conditions.

For one day of this evaluation, accelerometers and rotation rate sensors were placed on the back of the rear crew station chair and on the vehicle hull near the in-board top corner of the left sponson. Vibration data include frequency responses of 0 to 300 Hz rms. Rotation data include all frequencies below 50 Hz. The data collected by these sensors are shown in Table 1.

Figure 3. Cross-country course.

Table 1

C²V Vibration and Rotation on Test Courses

Sensor location	Linear vibration Average RMS, Level G 20 MPH road march	Average RMS Level G 10 MPH cross country
Enclosure, longitudinal	0.32	0.10
Enclosure, transverse	0.57	0.24
Enclosure, vertical	0.56	0.18
Seat, longitudinal	0.36	0.15
Seat, transverse	0.45	0.29
Seat, vertical	0.48	0.28

Sensor location	Rotation rate Average RMS, level, degree/sec. 20 MPH road march	Average RMS level, degree/sec. 10 MPH cross country
Vehicle pitch	2.99	17.08
Vehicle roll	3.46	5.79
Vehicle yaw	2.09	10.51

The subjective experience provided by each course corresponds with the vibration and rotation, or roll, data. The road march course generated high frequency, low amplitude vibration similar to driving a car over a washboard with occasional potholes in the road, causing sharp jarring movements. The cross-country course provided less vibration, but had broad, rolling movements associated with crossing the sand dunes in the stream bed.

Demographic Survey

A paper and pencil questionnaire, provided in Appendix B, gathered initial demographic data about each subject.

Post-Training Questionnaire

This questionnaire asked subjects to rate their training on the CCAB battery (described below) at the end of the training day. A copy of this questionnaire is in Appendix B.

Posttest Questionnaire

This questionnaire captured each subject's impression of the effect of the various road conditions on his or her performance. Subjects were also asked to rate the presence or severity of several physical symptoms. This two-part questionnaire is in Appendix B.

CCAB Test Battery

A subset of the Expanded Complex Cognitive Assessment Battery (CCAB) was administered during each of the vehicle movement conditions to measure cognitive performance. This test series ran in an MS-DOS window on the ATCCS workstation.

This evaluation used four tests from CCAB. Each test presented the subject with a different type of problem. The Logical Relations (LR) Test presented two statements about the relationships among three objects, such as "X is greater than Y" and "X is less than Z." The subject answered a question (such as "Which is greatest, X, Y, or Z?") that completed the syllogistic relationship. The Information Purchase (IP) Test showed the subject a blank matrix of 6 rows and 14 columns. By pressing the space bar, the subject "purchased" the numeric values (0, 1, or 2) for one column. The task was to determine which row had the highest sum. Points were lost for time, the number of columns purchased, or an incorrect guess. The trial ended when a correct response was entered, no time remained, or two incorrect responses were entered. In the Route Planning (RP) Test, a five-by-five matrix was displayed with each cell filled with a letter or filled with dots. One letter had a square drawn around it, indicating the subject's position, and one letter was highlighted, indicating the goal. The subject had to find a way to move from his position to the goal, using moves of two squares in one direction and one square perpendicular (in an "L" pattern, similar to a knight on a chess board), and without using any of the dot-filled squares. The Missing Items (MI) Test provided a set of six numbers or letters, with one missing. The subject selected the one of four choices that fit the pattern set by the other five numbers or letters.

The cognitive constructs measured by each test are described in Appendix C. A more detailed description of the CCAB battery is presented in Samet, Marshall-Mies, and Albarian (1987).

Each administration of the CCAB battery included a presentation of each of the four tests. Each presentation consisted of the following number of trials: Logical Relations - eight, Information Purchase - six, Route Planning - three, and Missing Items - eight. An administration of the CCAB took approximately 15 minutes.

Stress Assessment Battery

Two questionnaires were administered to measure the stress perceptions of participants in the C^2V operations:

1. The "Today" form of the Multiple Affect Adjective Checklist-Revised (MAACL-R) was develped by Zuckerman and Lubin (1985). Because of the improved discriminant validity and the control of the checking response set, the MAACL-R with its five subscales (anxiety, depression, hostility, positive affect, and sensation seeking) has been particularly suitable for investigations that postulate changes in specific affects in response to stressful situations. The subjects were instructed to answer according to how they felt "right now" or how they felt during the time period immediately preceding the test administration.

2. The Subjective Stress Scale was developed by Kerle and Bialek (1958) to detect significant affective changes in stressful conditions. Subjects were instructed to select one word from a list of 15 adjectives that describe how they felt "right now" or how they felt during the time period immediately preceding the test administration.

The stress assessment questionnaires have been used in several previous ARL research investigations (Hudgens, Malkin, & Fatkin, 1992; Blewitt et al., 1994). This battery has proved sensitive to the degree of stress experienced in a variety of situations and includes standardized measures that have demonstrated construct validity within the stress research literature.

Both questionnaires are used to assess stress levels of a particular population by comparing the subject population's scores to standardized scores. A pre-stress measurement is collected from each subject. Then, after a stress condition has been experienced by the subject, a post-stress measurement is taken. This is true even for control groups in which the post-stress test is taken during conditions as similar as possible to the pre-stress condition. Copies of both questionnaires are in Appendix B.

Procedures

This study was conducted over 5 days, with one crew of three subjects each day. The schedule for each day is shown in Table 2. Before testing, each crew underwent 1 day of training. During training, the subjects took the cognitive battery approximately 20 times. The last three scores were compared to ensure that learning effectively stopped. Adequate learning was confirmed by subjective report from the subjects. The test subjects were also familiarized with the questionnaires used during testing. At the conclusion of the training day, the subjects were asked to complete the demographic survey, the post-training questionnaire, and one copy of each stress assessment battery. This administration of the Stress Battery (S0) served as a baseline.

At the beginning of each test day, the CCAB files that controlled test administration were loaded onto the ATCCS hardware on the C^2V. The order in which the four CCAB tests were given in any presentation were pre-determined by a random drawing. All the subjects on a given day received the tests in the same order, but a different order was used for each day.

Each day of testing began at approximately 07:30 with one presentation of the stress assessment battery (S1). Then, subjects entered the C^2V and completed two administrations of the cognitive battery in the baseline condition. During baseline, the vehicle was stationary and all systems were turned off except the main engine. Ideally, the main engine would have been shut down, but on the first day, it was found that battery power in the vehicle would not sustain the computers and the environmental control unit (ECU). Because of a switch failure, the ECU could not be shut down without losing power to the computers. This was an abnormal condition and does not reflect a failure of the vehicle. After taking the baseline iterations of the cognitive test battery, the crew completed the "stationary" section on both pages of the posttest questionnaire.

Table 2

Daily Test Schedule

	Initial briefing out of vehicle		S1 Stress battery	Questionnaire
A.	Baseline	CCAB		
B.	Baseline	CCAB		Questionnaire
C.	Idle	CCAB		
D.	Idle	CCAB		Questionnaire
E.	Road march	CCAB		
F.	Road march	CCAB		Questionnaire
G.	Cross country	CCAB		
H.	Cross country	CCAB	S2 Stress battery	Questionnaire
I.	Baseline	CCAB		Questionnaire
		Lunch		
L.	Baseline	CCAB		Questionnaire
M.	Cross country	CCAB		
N.	Cross country	CCAB	S3 Stress battery	Questionnaire
O.	Road march	CCAB		
P.	Road march	CCAB		Questionnaire
Q.	Idle	CCAB		
R.	Idle	CCAB		Questionnaire
S.	Baseline	CCAB		
T.	Baseline	CCAB		Questionnaire
	Out of vehicle		S4 Stress battery	
	Posttest debriefing			

Note. Tests J and K were not administered because of a change in test design.

The second presentation condition was "idle." The crew completed two iterations of the cognitive battery in idle, with the main engine and primary power unit (PPU) running, simulating normal stationary operations. The crew then completed the "idle" section of the posttest questionnaire.

The vehicle was driven to the road march course, and the crew completed two iterations of the cognitive battery with the vehicle moving on the course. The road march course consisted of a fairly straight dirt road traveled at 20 miles per hour. It was characterized by high frequency, low amplitude vibration, with occasional shock from potholes. About once every 10 minutes, the driver announced a 180° turn as the vehicle reached the end of the course. After finishing the road march, the crew completed the "road march" section of the posttest questionnaire.

The vehicle was then driven to the cross-country course, and the crew completed two iterations of the cognitive battery while the vehicle negotiated this course. The cross-country course was a sand-filled stream bed, traveled at about 10 miles per hour. It was characterized by broad pitch and roll, rather than vibration. After completing the cognitive battery, the crew completed the stress assessment battery (S2), reflecting how they felt during the cross-country course. Then they completed the "cross-country" section of the posttest questionnaire.

Finally, the vehicle returned to the base site and the crew completed one iteration of the cognitive battery in the baseline condition and did the final "stationary" questionnaire section.

After a lunch break (approximately 1 hour), the process was repeated in reverse order. Presentations were baseline (1 CCAB), cross country (2 CCAB + stress assessment battery [S3]), road march (2 CCAB), idle (2 CCAB), and baseline (2 CCAB). At the end of the afternoon, the crew left the vehicle and, after 5 minutes, took a final stress assessment battery (S4). Finally, the crew completed a written debriefing and was released at approximately 16:00.

Design

The statistical layout for the CCAB data produced a mixed design with one between subjects factor and three within subjects factors. The between subjects variable was seat position (Seat 1 at the front, Seat 2 or 3 in the middle, and Seat 4 at the rear). The within-subjects variables were road condition (idle, road march, cross country), presentation order (first or second presentation in each condition), and time of day (morning or afternoon).

Stress data comprised a mixed design with one between subjects variable and one within subjects variable. The between subjects variable was generated by comparing stress levels from the subjects in the C^2V to stress levels from several referent groups, discussed in the results section. The within-subjects variable was time of day (pretest [S1], morning:post-cross country [S2], afternoon:post-cross country [S3], and posttest [S4]).

RESULTS

Subject Attrition

Although there are four workstation in the C^2V, only three subjects participated in each day of testing because of computer failures at Stations 2 and 3. As a result, data from seat

Positions 2 and 3 are combined, since subjects used whichever workstation was working at the time. The availability of three workstations for five crews allowed 15 subjects to be tested.

One subject suffered motion sickness, which was effectively incapacitating during the cross-country section. The medical monitor for the test removed that subject for the afternoon and a sixteenth subject was introduced for the last half of that day of testing. For these two subjects who were only tested for half days, the data from the questionnaire, comments, and stress assessment batteries were included in the analysis, but the CCAB data were not included.

Of the 14 subjects who completed the entire day of testing, two vomited because of motion sickness during the cross-country course, and a number of subjects reported various degrees of nausea.

Training

Subjective and objective measures assessed the subjects' training about the CCAB battery. First, subjects rated their training at the end of the training day. The results are in Table 3. Most subjects indicated that they felt fairly well trained and understood the tests. One subject, who reported that he did not understand the tests, indicated in the comments section that he was referring to difficulty in meeting the time limits on the CCAB trials.

Table 3

Subjects' Rating of Training

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
1. At the beginning of this trial, I was fully trained on the test battery.	3	7	1	2	2
2. The test battery was easy to complete in training.	5	8	1	1	0
3. I did have problems under-standing how to do the following test:					
Logical relations	1	0	1	7	6
Information purchase	0	1	3	7	4
Route planning	0	1	4	5	5
Missing items	0	1	2	5	7

To provide objective support for the subjects' observations, a comparison (Tukey) was made between the last training score, the first baseline score, and the last baseline score of each subject. If subjects lost proficiency overnight, there should be a difference between training and first baseline. If learning was continuing during the test, the last baseline should be better than the first baseline or the last training score. None of the comparisons showed a significant difference for any of the CCAB tests.

Posttest Questionnaire

The questionnaires administered after each road condition were combined across morning and afternoon sessions and across subjects. A mean overall score was calculated for each question during each road condition. These means are presented in Table 4. In cross-country, and to a lesser extent in road march conditions, some subjects indicated minor difficulty in keyboard operation. In addition, the questionnaires show that subjects had some minor difficulty in concentrating and some physical discomfort associated with vehicle movement conditions.

In addition to their responses to the structured questions, some subjects also included comments at the bottom of the questionnaire or in the posttest debriefing. Appendix D contains all of the subjects' comments grouped by topical area. The comments support the observation that vehicle movement did not directly prevent human interaction with the keyboard or display.

CCAB Test Battery

The analysis of the CCAB scores was performed on the 14 subjects who completed the entire day of testing.

Power or computer failures during testing caused four individual test scores to be lost. A power problem caused the loss of IP for Subject 2 in Crew 3 during the morning road march first administration. LR, IP, and RP for Subject 4 of Crew 4 during the afternoon's first road march administration were lost because of a computer failure.

A summary score, based on time, accuracy, and problem difficulty, was the basic unit of measure for each trial of each CCAB test. For all tests, higher scores indicate better performance.

A preliminary one-way ANOVA was performed on the baseline scores (CCAB presentations A, B, I, L, S, and T, Table 2) to determine if there was a practice effect over time. The unit of analysis was each subject's median summary score for the trials in each CCAB test. Because no significant difference was found among scores of the six baseline presentations, the baseline scores were considered a homogenous set of scores. A median overall baseline score was calculated for each subject from all of that subject's baseline scores.

Table 4

Mean Responses to Posttest Questionnaires

	Stationary	Idle	Road march	Cross country	Stationary
Questionnaire Section 1 - Interface problems 1 = no problem 5 = critical problem					
1. Computer screen's visibility (location)	1.40	1.35	1.25	1.48	1.34
2. Computer keyboard accessibility (location)	1.57	1.50	1.48	1.70	1.48
3. Size of letters on the computer screen	1.09	1.09	1.09	1.17	1.09
4. Brightness of the computer screen	1.00	1.04	1.05	1.05	1.10
5. Key size on the keyboard	1.07	1.11	1.17	1.20	1.15
6. Ability to keep hands on the keyboard	1.61	1.43	1.80	2.05	1.24
7. Ability to hit the correct keys on the keyboard	1.14	1.32	1.74	1.85	1.23
8. Workstation chair - comfort and support	1.05	1.03	1.10	1.17	1.00
9. Workstation chair - how stable it felt	1.00	1.10	1.10	1.17	1.00
10. Personal concentration	1.22	1.45	1.78	2.22	1.34
11. Noise	1.07	1.34	2.00	1.87	1.15
12. Vibration	1.04	1.25	1.64	2.09	1.04
13. Gross shaking and movement	1.00	1.04	1.90	2.30	1.04
	Stationary	Idle	Road march	Cross country	Stationary
Questionnaire Section 2 - Physical symptoms 1 = no experience 5 = major experience: unable to work					
1. Nausea	1.04	1.00	1.11	1.70	1.20
2. Headache	1.28	1.20	1.29	1.52	1.36
3. Blurred vision	1.10	1.07	1.18	1.40	1.07
4. Dizziness	1.00	1.00	1.00	1.07	1.00
5. Distraction from noise	1.14	1.07	1.75	1.40	1.29
6. Distraction from vibration	1.00	1.11	1.77	1.90	1.14
7. General difficulty concentrating	1.27	1.32	1.65	2.10	1.43
8. Other (explain)					

This median baseline score was then subtracted from the median of the trials' score for each test during each road condition. These converted scores were used to minimize the effect of individual variation. Thus, for each administration of the CCAB, four values were derived for each subject: a change score for each of the LR, IP, RP, and MI tests.

A separate mixed effects ANOVA was performed on the converted scores of each of the four cognitive tests. Road condition was the main variable of interest, but several other variables addressed several secondary issues. Seat position was included to evaluate the effect of stress from different amounts and angles of movement in the C^2V workstations. Presentation order was included to identify subject's ability to adapt or acclimatize to road conditions. Time of day was included to check for either improvement, because of learning or acclimatization, or deterioration because of fatigue.

The converted scores were grouped by road condition, presentation order, time of day, and seat position. Means and standard deviations (SDs) of the median change scores were calculated and are displayed in Table 5. Because scores are presented in the form of differences (baseline score - raw score), scores are inversely proportional to performance.

Table 5

Summary Statistics for CCAB Median Change Scores

	Logical relations		Information purchase		Route planning		Missing items	
Main effect	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Road condition								
Idle	-89.53	280.72	4.40	92.75	19.59	200.25	20.25	135.62
Road march	44.78	300.92	96.65	3.00	209.85	12.00	139.06	20.75
Cross country	-67.36	283.30	19.76	159.18	47.69	207.61	61.45	175.10
Presentation								
First	-28.21	292.09	7.57	101.57	71.43	211.06	28.80	122.38
Second	-47.39	294.54	4.05	95.57	-20.56	189.96	53.13	174.97
Time								
Morning	-7.88	300.09	1.52	105.44	32.01	205.54	60.52	164.24
Afternoon	-68.21	283.40	10.06	91.04	18.22	206.21	21.41	134.69
Seat								
1	41.58	323.26	10.85	99.82	104.25	212.32	28.81	156.42
2 or 3	-28.55	246.55	-12.14	89.50	-82.04	196.02	84.35	194.96
4	-126.57	273.62	14.93	103.08	31.94	166.39	18.42	87.25

The complete results of all the ANOVAs are compiled in Appendix E, but the significant results ($p <= 0.05$) are presented in Table 6. For this evaluation, only the significant main effects were further analyzed by post hoc comparisons (Tukey's Honestly Significant Difference [HSD] Test). For the main effect of road condition, logical relations scores were significantly ($p = 0.04$) worse in the road march condition than in the idle condition. For the Road Condition x Presentation x Seat Position interaction, the only significant ($p = .04$) effect found in a Tukey HSD Test was between stationary, second presentation, Seat 4 and road march, second presentation, Seat 1. No other significant differences existed for road condition. The main effect of Presentation Order showed (F=5.42, $p = 0.04$) that, in the Route Planning Test, the performance was better on the second presentation. In the Missing Item Test, performance was significantly (F=7.17, $p = 0.02$) better in the afternoon than in the morning.

A second attempt to determine if vehicle movement conditions affected cognitive performance was the analysis of "timed out trials." Each of the tests allowed a fixed amount of time for each trial. Maximum trial times in this evaluation were 15 seconds for logical relations, 60 seconds for information purchase, 60 seconds for route planning, and 30 seconds for missing items. The number of timed out trials in each presentation of each test was obtained as a possible measure of performance degradation and is displayed in Table 7. An ANOVA was conducted on the number of timed out trials, with seat as a between-subjects variable and with road condition, time of day, and presentation order as within-subject variables, similar to the analysis of the transformation scores discussed previously. The only significant effect was for road condition in logical relations ($F = 7.32$, $p < 0.01$). A subsequent post hoc comparison (Tukey HSD Test) revealed that the number of timed out trials per presentation was significantly ($p < 0.01$) greater in the road march condition (mean = 0.91, SD = 0.87) than in idle (mean = 0.05, SD = 0.60) or cross country (mean = 0.05, SD = 0.54).

Table 6

Significant Differences from the ANOVAs of the CCAB Data

CCAB test	Predictors (main or interactive effects)	F	p
Logical relations	Road condition	4.94	0.02
Logical relations	Road condition*presentation*seat	4.23	0.01
Information purchase	Time*presentation*seat	10.60	<0.01
Route planning	Presentation	5.42	0.04
Missing items	Time	7.17	0.02
Missing items	Time*presentation*seat	6.65	0.01

It is tempting to try to draw some meaningful interpretation from the significant change in logical relations scores during the road march trials (see Tables 6 and 7). However, the lack of any consistent pattern combined with the relatively high number of ANOVAs performed in this analysis suggests that the significant findings may be a matter of chance rather than actual effects. The improvement over time suggested by the significant main effects of time for missing items and presentation order for route planning may indicate that the subjects were adapting or learning coping mechanisms through the testing day. The lack of a consistent trend makes any conclusion extremely tenuous.

Table 7

Distribution of Timed Out CCAB Trials

Main effect	Logical relations		Information purchase		Route planning		Missing items	
	Timed out trials	Total trials	Timed out trials	Total trials	Timed out trials	Total trials	Timed out trials	Total trials
Road condition								
Idle	28	416	0	312	38	156	7	416
Road march	50	408	2	300	36	153	6	416
Cross country	28	416	1	312	47	156	8	416
Presentation								
First	47	616	2	456	67	231	7	624
Second	59	624	1	468	54	234	14	624
Time								
Morning	58	624	1	462	65	234	12	624
Afternoon	48	616	2	462	56	231	9	624
Seat								
1	40	448	1	336	35	168	6	448
2 or 3	34	352	0	258	53	132	8	352
4	32	440	2	330	33	165	7	448
Total trials administered		1240		924		465		1248
Trials planned (no lost data)		1344		1008		504		1344

Stress Assessment Batteries

Psychological data from C^2V were compared with data from five referent protocols (see Figure 4). Each of these referent protocols included one pre-stress measurement and a post-stress measurement. The referent protocols for the present evaluation are (a) ONCOSURG -

men visiting a hospital on a day when their wives were facing cancer surgery under general anesthesia; (b) ABDMSURG - men visiting a hospital on a day when their wives were facing abdominal surgery under general anesthesia; (c) WR EXAM - third year male medical students taking a written examination required for completion of the clerkship portion of their medical training; (d) SS COMP - male soldiers representing elite units in marksmanship competition; and (e) INDCNTRL - men investigated during normal work days when they were experiencing no unusual stress. The ONCOSURG and ABDMSURG protocols represent a relatively high stress level when compared with the WR EXAM and SS COMP protocols, which represent a relatively moderate level of stress. The INDCNTRL protocol represents a relatively low stress level to a condition of no stress. The INDCNTRL pre-stress responses are an independant, unstressed measure, which was used as a basis for comparison against the C^2V results.

A multivariate analysis of variance (MANOVA) was conducted to compare baseline data (S0, taken at the end of the training day) and pre-test (S1) C^2V data with the pre-stress data obtained in the referent independent control group (INDCNTRL). The results are shown in detail in Appendix F. The C^2V participants did not report stress levels that were significantly different from the independent control group. The psychological measures of anxiety used in this study (i.e., MACCL-R Anxiety and Subjective Stress Scale) typically relate to the level of uncertainty perceived by the individual. The test participants in the C^2V reported relatively low levels of baseline and pre-test anxiety or uncertainty. This result may be attributable to the participants' being well informed of their duties or their being confident in their abilities to perform well.

However, significant differences were found among the C^2V data collected during the operations (S2 and S3) and after the operations (S4) when compared with the post-stress data from the independent control group (Wilks' $\lambda = .488$; $F(21,161) = 2.18$; $p = .003$). The results of the post hoc comparisons for the measures described below are indicated in the shaded boxes in Figure 4.

MAACL-R Positive Affect

The C^2V participants reported significantly lower positive affect results during and after the testing (S2, S3, and S4) when compared to the independent control (univariate $F(3,62) = 4.696$; $p = .005$). C^2V participants reported positive affect levels comparable to those of moderate to high referent protocols, indicating a relatively low sense of well-being.

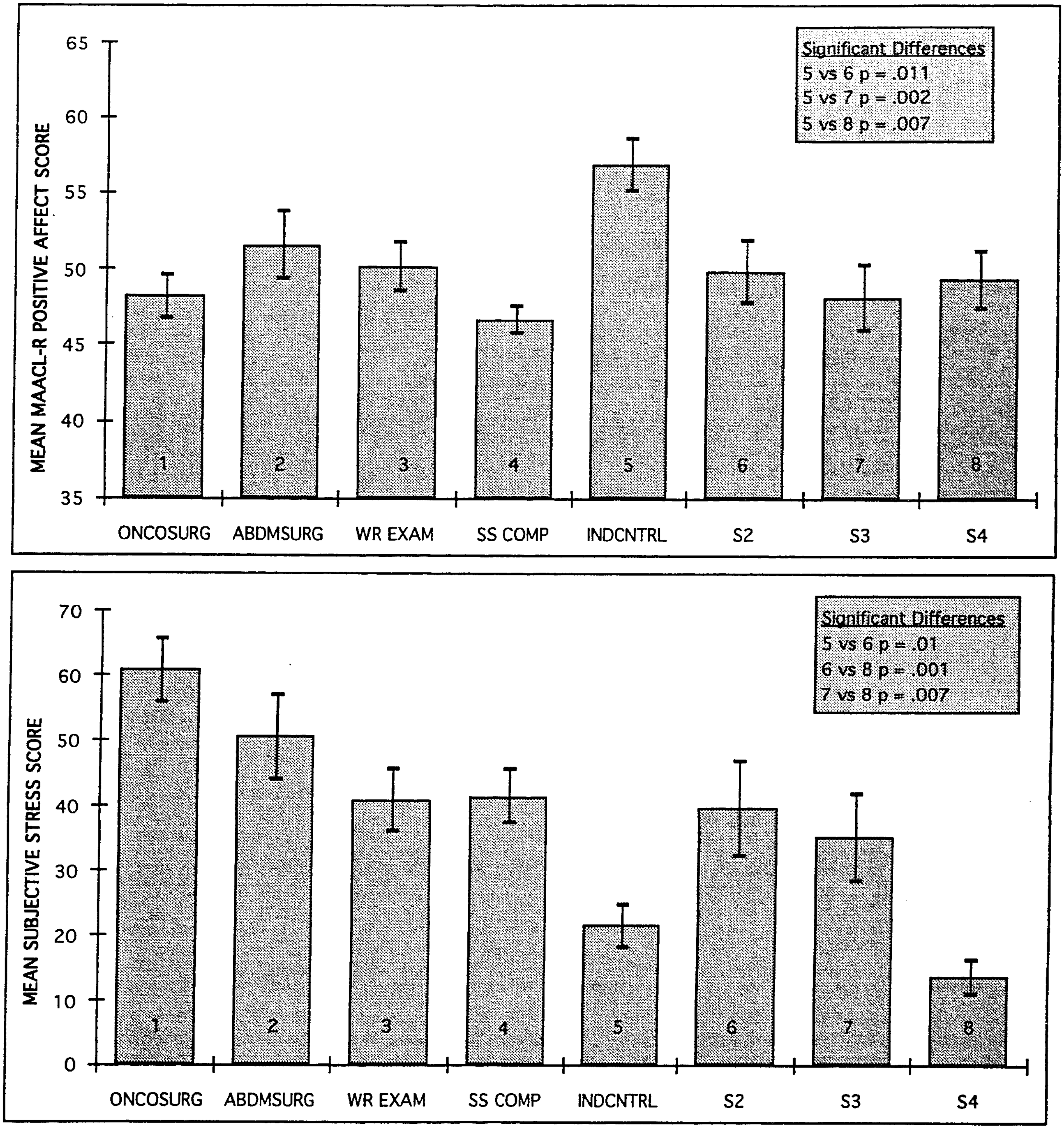

Figure 4. Comparison of mean post-stress MAACL-R positive affect scores and subjective stress scores (±SEM) for C^2V with those for subjects in the following conditions: (1) spouse having cancer surgery under general anesthesia; (2) spouse having abdominal surgery under general anesthesia; (3) taking an important medical school written exam; (4) performing in military weapon-firing competition; or (5) the independent non-stress control condition.

Subjective Stress Scale

Stress levels reported by the C^2V participants showed significant differences when compared to those of the independent control group (univariate $F(3,62) = 5.129$; $p = .003$). During S2, the C^2V subjects reported a significantly higher affective stress level than that of the independent control group and comparable to that of the moderate stress level. Responses obtained at S4 indicated significantly lower stress levels than those at S2 and S3.

CONCLUSIONS

Overall, although vehicle movement may have introduced some stress or discomfort, it was not enough to affect the metrics in this evaluation.

The posttest questionnaires, subjects' comments, and observations indicated that subjects were able to operate ATCCS hardware during all the vehicle movement conditions in this experiment. In the cross-country and road march conditions, some difficulty in keyboard use was reported, but none of the subjects indicated that this was a major consideration. However, subject reports and observations by the test monitor indicated that vehicle movement indirectly affected performance in a few subjects by inducing motion sickness.

Although a few significant changes in CCAB test scores were found, the general conclusion is that noise and vibration of vehicle movement did not directly affect performance in the CCAB. This probably reflects a combination of factors.

First, the maximum allowable speeds dictated by the safety release (10 mph for cross country and 20 mph for road march) may have restricted noise, shock, and vibration to tolerable levels. The results from the posttest questionnaires and stress assessment batteries indicate that some mild stressing took place. However, the low magnitude of the stressing and the lack of a consistent change in the CCAB scores suggest that the subjects were able to compensate.

Second, the task type and duration may not be sensitive to noise and vibration stress. Previous studies that have found a relationship between cognitive performance and vibration (Harris & Shoenberger, 1980; Sherwood & Griffin, 1990) used tasks that were closely related to short-term memory. None of the four CCAB tasks in this study were especially dependent on short-term memory. Also, Harris and Shoenberger suggested that an exposure of 40 minutes was necessary to fully evaluate the effects of vibration.

Finally, the constraints of the evaluation may have made any experimental effects on cognitive ability difficult to detect. The number of subjects available constrained the statistical power of the experiment. This, combined with the high error variance in the CCAB scores (see Table 6) indicate that, while there is not sufficient evidence from this study to conclude that vehicle movement degrades cognitive performance, it is also not possible to say that vehicle movement does not have an effect.

The results of the stress assessment batteries support the premise that the test conditions were not sufficiently stressful to influence cognitive performance. Participants reported little or no anxiety in the two sessions before C^2V operations. The stress levels were not significantly different from those of an independent control group. Only two measures administered during and after the C^2V operations showed any stress response. The C^2V participants reported significantly lower positive affect during and after operations. These levels are comparable to those reported by moderately stressed referent groups. Immediately after cross-country operations, the participants reported significantly higher stress levels than those of the independent control group and comparable to moderate stress. This was true for the MAACL-R in morning and afternoon and for the Subjective Stress Scale in the morning only. Shortly after moving operations were completed, participants reported significantly lower stress levels than those experienced during operations. This result may be attributed to the participants' sense of relief after completing the task.

The overall results of low to moderate stress levels may be attributable to the relatively non-threatening nature of the task, the prior knowledge of the participants, or their level of training. At most, the cross-country condition produced moderate stress, and recovery was nearly complete at the time of the posttest administration. In light of the significant degradation in CCAB scores taken during road march conditions, it is unfortunate that the stress battery was not given after road march conditions.

On the primary topic of this study, the effect of vehicle movement on cognitive performance, the hypothesis cannot be confirmed. It may be that future testing will find aspects of cognition that are degraded by vehicular movement. However, in the conditions tested, cognitive degradation was not consistently associated with vehicle movement.

REFERENCES

Blewitt, W.K., O'Hern, M., Harris, L., Redmond, D.P., Fatkin, L.F., Rice, D.J., & Popp, K. (1994). A P2NBC2 report: Patient decontamination at mobile medical facilities. (in print). Aberdeen Proving Ground, MD: Edgewood Research, Development, and Engineering Center.

Field Artillery Board. (1985). Final letter report of the customer test of the command and control vehicle (C2V) FDC-72-hour evaluation under simulated nuclear, biological, and chemical (nbc) conditions (TRMS 850000677). Ft. Sill, OK: U.S. Army Field Artillery Board.

Garinther, G. & Donley, R. (1963). Human factors evaluation of the carrier, command post, light, tracked XM577: Systems noise evaluation (Technical Memorandum 14-63). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory.

Harris, C., & Shoenberger, R. (1980). Combined effects of broadband noise and complex waveform vibration on cognitive performance. Aviation Space and Environmental Medicine, 51(1), 1-5.

Hicks, S. (1961). The effects of twelve hours of confinement in mobile armored personnel carriers on selected combat relevant skills: Study IV (Technical Memorandum 2-61). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory.

Hudgens, G.A., Malkin, F.J., & Fatkin, L.T. (1992). Stress evaluation of soldiers participating in the JFKSWCS special forces assessment and selection course (Technical Memorandum 6-92). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory.

Kerle, R.H., & Bialek, A.M. (1958). The construction, validation, and application of a subjective stress scale (Staff Memorandum Fighter, IV, Study 23). Presidio of Monterey, CA: U.S. Army Leadership, Human Research Unit.

Lewis, J. (1962). A partial review of the literature on physiological disorders resulting from the operation of motor vehicles (Technical Memorandum 17-62). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory.

Martin, J. (1993). Human engineering assessment for the command and control vehicle. Aberdeen Proving Ground, MD: U.S. Army Research Laboratory, Human Engineering and Research Directorate, MANPRINT Division.

Rauch, T., Witt, C., Banderet, L., Tauson, R., & Golden, M. (1986). The effects of wearing chemical protective clothing on cognitive problem solving (Technical Report T18/86). Natick, MA: U.S. Army Research Institute of Environmental Medicine.

Samet, M., Marshall-Mies, J., & Albarian, G. (1987). Expanded complex cognitive assessment battery (CCAB): Final test administrator user guide. Analytical Assessment Center, Los Angeles, CA, for the U.S. Army Research Institute, Alexandria, VA.

Sherwood, N. & Griffin, M. (Dec 1990). Effects of whole-body vibration on short-term memory. Aviation Space and Environmental Medicine, 1092-1097.

Shoemaker, C., Garinther, G., & Kalb, J. (1980). Verbal communication in tracked combat vehicles (Technical Memorandum 19-80). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory.

Torre, J., & Garinther, G. (1958). Dynamic human engineering performance of the armored personnel carriers T113 and T117 (Technical Memorandum 7-58). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory.

Zuckerman, M., & Lubin, B. (1985). Manual for the multiple affect adjective checklist--revised. San Diego, CA: Educational and Industrial Testing Service.

APPENDIX A

SUBJECT DEMOGRAPHICS

SUBJECT DEMOGRAPHICS

Team - Seat	Age	Sex	MOS / years in Army	Hours/ Week on Comp -uter	Hours/ Year in Track Vehicle	Previous Motion Sickness
1-1	49	M	Civ	+10	+10	Yes - In high performance aircraft
1-2	38	M	13F / 15	+10	+10	No
1-4	29	M	91G / 4	+10	0	No
2-1	38	M	/ 16	5-10	5-10	No
2-2	46	M	Civ	0-1	3-5	Yes - On ocean
2-4	37	M	13A / 13	5-10	5-10	No
3-1	44	M	Civ	3-5	0-1	No
3-2	31	M	12A / 9	5-10	0	No
3-4	34	M	25C / 9	3-5	0	Yes - On ocean, rough seas
4-1	40	M	97 / 22	3-5	1-3	Yes - Aircraft in rough conditions
4-2	45	M	Civ	+10	3-5	Yes - Aircraft; previously in tracked vehicle
4-2	33	M	/ 9	+10	5-10	Yes - On ships
4-4	41	M	25A / 15	+10	0	Yes - Amusement park rides
5-1	39	M	11B / 21	+10	0	Yes - Airborne ops
5-2	36	F	96B / 16	+10	1-3	Yes - Aircraft or boats when pregnant
5-4	34	M	11A / 4	+10	1-3	Yes - On ocean, rough seas

Note 1: Subject 4-2 was incapacitated by motion sickness after the morning trials. He was replaced by a second subject for the afternoon.

Note 2: Some MOS information was not completed on the survey and is left blank on this table.

APPENDIX B

QUESTIONNAIRES AND SURVEYS

QUESTIONNAIRES AND SURVEYS

Demographic Survey
Crew ID - 1 2 3 4 5
Individual ID - 1 2 3 4 .

After each section of this evaluation, you will be asked to complete a portion of this questionnaire booklet. Please be as complete as possible, and ask the test controller if there a section you do not understand. You are encouraged to look through the booklet at any time to see what sort of questions we will be asking, but please only complete the section you are asked to at any given time. You may add comments on the back or in the lined areas. If necessary additional paper will be supplied for your comments. Please do not put your name, or any personal identifier, on this form.

1.) Age - __________________

2.) Sex - Male Female

3.) Job - Military Civilian

4.) Job Title or MOS _____________________

5.) Number of years with the Army _________________

6.) How many hours per week do you typically use a computer at home and/or work?

_____ None
_____ 1 hour or less
_____ 1 to 3 hours
_____ 3 to 5 hours
_____ 5 to 10 hours
_____ more than 10 hours

7.) How many hours have you spent in the last year on a moving tracked vehicle?

_____ None
_____ 1 hour or less
_____ 1 to 3 hours
_____ 3 to 5 hours
_____ 5 to 10 hours
_____ more than 10 hours

8.) Have you ever suffered from motion sickness or been sea sick?

_____Yes _____No

If so, please explain the circumstances (for instance, "Every time I am on an airplane", or "Once, 3 years ago on a small boat in a hurricane")

____

____

9. Do you now or have you ever had any of the following conditions? (If yes, check the appropriate blank.

_____ Hypertension (High blood pressure)
_____ Heart problems
_____ Respiratory Problems
_____ Allergies
_____ Corrected Vision (glasses or contacts)
_____ Seizures
_____ Inner ear disorder
_____ Claustrophobia
_____ Color Blindness

Post-Training Questionnaire

For each of the following questions, circle the number which best describes your experience in the most recent vehicle trial (this morning or this afternoon).

Test Battery

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. At the beginning of this trial, I was fully trained on the test battery.	1	2	3	4	5
2. The test battery was easy to complete in training.	1	2	3	4	5
3. I did have problems understanding how to do the following test:	1	2	3	4	5
Logical Relations	1	2	3	4	5
Information Purchase	1	2	3	4	5
Route Planning	1	2	3	4	5
Missing Items	1	2	3	4	5

Additional Comments:____

During each condition in which you worked at the computer, a number of things may have made you job more easy or difficult. Please list how each of the following things affected your performance in each movement condition. Please circle one number in each block where the number indicates:

1 - Completely Adequate, Presented No Problems At All
2 - A Minor Problem
3 - A Noticeable Problem with Measurable Mission Impact
4 - A Major Problem Which Caused Significant Mission Degradation
5 - A Critical Problem Which, in a Tactical Environment Would Have Caused Mission Failure.

Please answer only in terms of this morning's experience.

	Stationary	Idle	Road March	Cross Country	Stationary
1. Computer Screen's visibility (location).	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
2. Computer keyboard accessibility (location).	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
3. Size of letters on the Computer Screen	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
4. Brightness of the computer screen.	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
5. Key size on the keyboard.	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
6. Ability to keep hands on the keyboard.	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
7. Ability to hit the correct keys on the keyboard..	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
8. Workstation chair - comfort and support.	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
9. Workstation chair - how stable it felt.	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
10. Personal concentration.	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
11. Noise	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
12. Vibration	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
13. Gross shaking and movement	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5

Additional Comments:____

Post-Test Questionnaire
(Section 2)

During each condition in which you worked at the computer, you may have experienced one or more physical symptoms. Please indicate which experiences you had and how strong they were in each movement condition. Please circle one number in each block where the number indicates:

1 - No experience
2 - Minor experience, this did not affect me noticeably
3 - Minor experience, this probably affect my performance
4 - Major experience; this definitely affected my performance
5 - Major experience; this made me largely unable to work.

Please answer only in terms of this morning's experience.

	Stationary	Idle	Road March	Cross Country	Stationary
1. Nausea	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
2. Headache	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
3. Blurred vision	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
4. Dizziness	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
5. Distraction from noise	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
6. Distraction from vibration	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
7. General difficulty concentrating	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
8. Other (explain)	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5

Additional Comments:____

SUBJECTIVE SCALE

Circle <u>one</u> word that best describes how you feel <u>right now</u>.

Wonderful

Fine

Comfortable

Steady

Not bothered

Indifferent

Timid

Unsteady

Nervous

Worried

Unsafe

Frightened

Terrible

In agony

Scared stiff

A D H

PA SS

1 ☐ active
2 ☐ adventurous
3 ☐ affectionate
4 ☐ afraid
5 ☐ agitated
6 ☐ agreeable
7 ☐ aggressive
8 ☐ alive
9 ☐ alone
10 ☐ amiable
11 ☐ amused
12 ☐ angry
13 ☐ annoyed
14 ☐ awful
15 ☐ bashful
16 ☐ bitter
17 ☐ blue
18 ☐ bored
19 ☐ calm
20 ☐ cautious
21 ☐ cheerful
22 ☐ clean
23 ☐ complaining
24 ☐ contented
25 ☐ contrary
26 ☐ cool
27 ☐ cooperative
28 ☐ critical
29 ☐ cross
30 ☐ cruel
31 ☐ daring
32 ☐ desperate
33 ☐ destroyed
34 ☐ devoted
35 ☐ disagreeable
36 ☐ discontented
37 ☐ discouraged
38 ☐ disgusted
39 ☐ displeased
40 ☐ energetic
41 ☐ enraged
42 ☐ enthusiastic
43 ☐ fearful
44 ☐ fine
45 ☐ fit
46 ☐ forlorn
47 ☐ frank
48 ☐ free
49 ☐ friendly
50 ☐ frightened
51 ☐ furious
52 ☐ lively
53 ☐ gentle
54 ☐ glad
55 ☐ gloomy
56 ☐ good
57 ☐ good-natured
58 ☐ grim
59 ☐ happy
60 ☐ healthy
61 ☐ hopeless
62 ☐ hostile
63 ☐ impatient
64 ☐ incensed
65 ☐ indignant
66 ☐ inspired
67 ☐ interested
68 ☐ irritated
69 ☐ jealous
70 ☐ joyful
71 ☐ kindly
72 ☐ lonely
73 ☐ lost
74 ☐ loving
75 ☐ low
76 ☐ lucky
77 ☐ mad
78 ☐ mean
79 ☐ meek
80 ☐ merry
81 ☐ mild
82 ☐ miserable
83 ☐ nervous
84 ☐ obliging
85 ☐ offended
86 ☐ outraged
87 ☐ panicky
88 ☐ patient
89 ☐ peaceful
90 ☐ pleased
91 ☐ pleasant
92 ☐ polite
93 ☐ powerful
94 ☐ quiet
95 ☐ reckless
96 ☐ rejected
97 ☐ rough
98 ☐ sad
99 ☐ safe
100 ☐ satisfied
101 ☐ secure
102 ☐ shaky
103 ☐ shy
104 ☐ soothed
105 ☐ steady
106 ☐ stubborn
107 ☐ stormy
108 ☐ strong
109 ☐ suffering
110 ☐ sullen
111 ☐ sunk
112 ☐ sympathetic
113 ☐ tame
114 ☐ tender
115 ☐ tense
116 ☐ terrible
117 ☐ terrified
118 ☐ thoughtful
119 ☐ timid
120 ☐ tormented
121 ☐ understanding
122 ☐ unhappy
123 ☐ unsociable
124 ☐ upset
125 ☐ vexed
126 ☐ warm
127 ☐ whole
128 ☐ wild
129 ☐ willful
130 ☐ wilted
131 ☐ worrying
132 ☐ young

APPENDIX C

LEVEL OF ASSOCIATION BETWEEN COGNITIVE CONSTRUCTS AND CCAB TESTS

LEVEL OF ASSOCIATION BETWEEN COGNITIVE CONSTRUCTS AND CCAB TESTS

[1 = Low; 2 = Medium; 3 = High]
[LR = Logical Relations , IP = Information Purchase , RP = Route Planning , and MI = Missing Items.]
Adapted from Samet, Marshall-Mies, and Albarian (1987)

		CCAB Tests			
Cognitive Complexity Categories	Cognitive Construct Measured	LR	IP	RP	MI
I. Responding to Data	Attention to Detail	1	2	1	2
	Perception of Form		1	2	2
	Memory Retrieval	1	1		
	Time Sharing		1		
II. Going Beyond Data	Comprehension	3			
	Concept Formation	1	1	1	3
	Verbal Reasoning	3			
	Quantitative Reasoning	2	2	1	3
III. Taking Action Based on Data	Planning		2	3	
	Situation Assessment		3	2	1
	Decision Making		3	1	
IV. Creating Data or Solutions	Communication			2	3
	Problem Solving	1	1	2	2
	Creativity				

APPENDIX D

SUBJECTS' COMMENTS

SUBJECTS' COMMENTS

1) Training & Practice:

- " Training- Good I got up to a comfortable level of proficiency before we went on the vehicle. Had no problem on the vehicle."

- "GOOD - Practice was sufficient"

- " The TNG. was adequate for the testing. I was well prepared for the test."

- "Also need [an next step to look at Tach & Staff Dynamics.] Noise was great improvement. Was able to talk to person next to me. GOOD JOB".

- "Training for test was appropriate and necessary".

2) C2V Comments

a. Vehicle:

- "Overall, a well thought out comfortable vehicle."

- "Did not test with inside of vehicle configured for field ops - no LCE, manuals, maps, other equipment. Vehicle would be more crowded in actual environment. Need sterile test environment - mechanics moving about or washing vehicle - distracting. Swap person from #1 position to #2,3, 4 for comparison."

- "Showed on a generic and basic level the degradation of productivity."

- "The activity of data gathering was generally extremely well planned and executed, in eye of a testee. Operation of vehicle did not detract from data testing. This was commendable".

- "Lack of sleep intuitively more severe degradation than vehicle movement."

- "Test seems easily affected by extraneous variables- i.e. CVC helmets, talking/disruptions during the test, computer malfunctions, etc. (But so is CP operations)."

- "Consider having distracting radio chatter during test."

- "Need grab irons around work station for holding - on during violent pitch/ roll of the vehicle".

- " Good leg room at front workstation - I could recline . . . possibly sleep during road march,"

- " Need to be able to dim lights inside vehicle."

- " Need holders for clipboard, map, CEOI, etc. at work station."

- "I would like to comment on the placing of some of the items, such as the power source for computers, very hard to get to, especially on the move. Also room could become a factor work stations."

- " As far as comfort, and being able to operate on the move, I would say the vehicle is fully capable. Very quiet, very tight."

- " Rear seat probably the best, but no one sitting to the left [?].Very comfortable seat."

- "Headset didn't work for commo."

- "Install shoulder straps on seats. Replace helmet with a good Quality headset."

- " Straps from ceiling should be above all seat to allow operators to stretch their arms."

- "ECU (air conditioner) individual vents to control air flow. "

- " Could not control air vents. Would like to be able to control the vents like in a POV."

- " Seat suspension - was not firm enough. Need the capability to adjust firmness."

- [Intercom]"could not be heard intelligibly while vehicle was traveling up at full speed. Need better ear seal."

- [AC] "-is great."

- "Really spend some time thinking where each soldier will put his duffel bags, ruck, rations, etc. Provide a slide-in slide-out name tag holder to label each radio net'bn. cmmd' etc. provide metal plates , pre-lettered with 'BN CMMD', 'BN O&I' etc".

- "Reduce interior noise volume."

- "Suspension felt pretty good on all types of surfaces and at all speeds."

- [Seats]- "great seats. Things to keep on the seats: Air shocks, swivel, recline, arm rests(rotating), degree of firmness of cushion, adjustment in/ out from workstation. Add a mesh bag to seat back for rations, etc.".

- "Seat 4 gets cold when AC is on ."

- "Consider adding audio input and voice response (possibly via radio) portions to the test."

- "The '1' position is still a 'swivel chair' operation. Not sure there is a solution."

- "Seats are comfortable. Suspension of the vehicle needs work. Computers & monitors were adequate for the test."

- "I was located in position four. Vibration caused metal to metal contact was intense. Could a simple thing like placing a rubber pad between chair mount and floor lessen vibration."

- "I became motion sick during the morning Cross Country. It was the result of both the frequency of the ups and downs as well as height/ magnitude."

- " Seats are great. Material for seats is excellent. It prevents slipping, sliding etc. It is comfortable. Will be difficult to beat."

- " Need to test specific software/ functions to assess impact i.e. analyst trying to fill out a SALUTE [?]RPT, plot a current situation on a map. Seats[need] elevated foot rest."

- " Leaving the air conditioner off just to decrease comfort may be worth the effort in a test."

- " Seats were outstanding. It's a non-problem that the seats compensate and the screens move with the vehicle."

- " The environment was too comfortable. We can take worse."

- " Space for tunnel door to open is wasted space - Open door into tunnel. Move generator forward. Add storage space near rear door."

- "Seats - can't swivel seat when seat belts in use. #1 position feels isolated. Need more table space for #1 position. Lots of glare on monitor when rear door open (s), What about overhead hatches? Heat affected performance."

- "Leap and bounds, better than the M-577 Command Carrier, please, please, lets get the C2V."

- "No voice interaction during trials- this appears to me to be an area for further exploration."

- "The different subtask, worked well, though I would like to see the task interfaced with, infantry, and artillery, MOS's, TOC personnel, combat MOS's."

- "Should consider issuing good quality head sets that are light weight, passive noise protection, and active noise reduction. Helmet is too heavy and is not necessary."

b. <u>Computers:</u>

- "Open hatch (Top side) washes out display- open back door does same thing."

- " Cannot hear computer's audio feedback."

- " Flat panel display needs to turn 270 deg. Helmets uncomfortable. Keyboard and monitor at front station can't line up - operator is off-set. . . had to move keyboard to operate. Operation during X-country is difficult. With problems, possible to miss something on display or type wrong data. Vehicle was comfortable temperature wise. Seats goods.[?] No writing space."

- "Computers kept on locking up. Prob.[with] mouse, however resolved. Small letters not as good. All computers in training should have large letters on screen." [Key pads]- " should be moveable instead (of) permanently mounted." [Workstations]- "Need to have adjustment provisions to allow operator to position the keyboard in an optimal position. Must further have the ability to stow the keyboard to free writing surface."

- "Go to flat panel displays for workstations , but keep the screen same place it is now and put stowage behind the flat panel. Soup up the computer > or = to pentium. Enter key on 2 keyboards prone to slight sticking."

- "Put an on-off switch for computer on the table top."

- "Lots of glare on workstation #1 (near vehicle front) if back hatch open. Don't lose any more leg-room than you currently have but protect the computers from kicking feet, etc."

- "Need room for paper, pencils, reference materials at 'work station'."

- "Computer software[CCAB]needs to be more user friendly - i.e. don't immediately accept / score an answer. Allow operator to check his answer, make sure that[?] what he wants to send, then hit 'enter' button."

- "In the future - screen display must be similar to ATCCS displays."

- "Need to have PM's of ATCCS [s?ais?] start thinking about adjustable font. They will need to."

- " Strongly suggest using objective software in shake test (not in vehicle) to help verify screen font/ graphics while on move."

- "Board layout needs work to allow workspace. Mouse won't work in CC - perhaps in Secondary road? Monitor needs to be brought up to eye level. Fout[?] should have been same as objective system to verify readability - Note in report. Motion had wave . across. [?] . Recommend flat screen be checked out." was similar, however , the frequency varied."

- "A couple of time trial(s) did not give enough time to read statement before timing out - logical relationships only."

3) ROAD CONDITIONS

a. <u>Idle:</u>

- "No problems- better than training class."
- " Shut the door @ the idle."
- " O.K. but a lot of noise."
- "Idle may or may not need to happen."
- " More could take place during the idle session - i.e. purposely added distraction noises."
- "What's different between idle and stationary?"

b. <u>Road March:</u>

- "No major problems."
- " Had no problem on secondary roads.
  [RM/ CC]: Definite effect on processing visual information."

<u>Cross Country</u>

- [CC] "Some nausea- No big prbs in the keyboard, however prbs in concentrating/ focusing on screen."
- " X Country was not tortuous enough."
- " Increase speed of RM and CC." .
- " Rough ride- very nauseating, need more air in vehicle. Looking at monitor caused nausea."
- " However CC was bad. I got sick very badly - problem seemed to occur when I started looking at trip test. I was unable to look out to get my bearings. Not sure if it would have solved problem, but might have helped. Doing CC had continuous rolling motion rather than staggered motion - might have made difficult."
- " Cross Country course in moving was awesome, even at 10 mph. I did vomit because of this. I did not vomit in p.m. for two reasons. a. Course was less rhythmic, slower and less rugged.
  b. Dramamine was used, to lessen effects."

APPENDIX E

ANALYSIS OF VARIANCE RESULTS FOR CCAB DATA

ANALYSIS OF VARIANCE RESULTS FOR CCAB DATA

Variables
- Between Subjects
  - Seat - Seat position (Front, 2nd or 3rd seat, Rear seat)
- Within Subjects
  - Time - Morning, Afternoon
  - Road Condition - Idle, Road March, Cross Country
  - Presentation - First or Second Presentation of that road condition at that time of day

Logical Relations

Source	SS	DF	MS	*F*	*p*
Seat	1028269.95	2	514134.97	1.38	0.30
Error	3732273.62	10	373227.36		
Time	163403.33	1	163403.33	3.98	0.07
Time * Seat	114792.88	2	57396.44	1.40	0.29
Error	410600.56	10	41060.06		
Road Condition	438392.26	2	219196.13	4.94	0.02
Road Condition * Seat	90650.76	4	22662.69	0.51	0.73
Error	887042.11	20	44352.11		
Presentation	8760.73	1	8760.73	0.08	0.78
Presentation * Seat	123255.95	2	61627.97	0.56	0.59
Error	1106935.03	10	110693.50		
Time * Road Condition	6333.62	2	3166.81	0.05	0.95
Time * Road Condition * Seat	123032.65	4	30758.16	0.51	0.73
Error	1215845.34	20	60792.27		
Time * Presentation	6195.36	1	6195.36	0.09	0.77
Time * Presentation * Seat	98875.97	2	49437.98	0.74	0.50
Error	671505.64	10	67150.56		
Road Condition * Presentation	48771.52	2	24385.76	0.82	0.45
Road Condition * Presentation * Seat	501594.62	4	125398.65	4.23	0.01
Error	592522.36	20	29626.12		
Time * Road Condition * Presentation	77771.36	2	38885.68	0.58	0.57
Time * Road Condition * Presentation * Seat	354797.51	4	88699.38	1.31	0.30
Error	1350104.23	20	67505.21		

Information Purchase

Source	SS	DF	MS	*F*	*p*
Seat	32923.45	2	16461.72	0.49	0.63
Error	300213.63	9	33357.07		
Time	2502.81	1	2502.81	0.17	0.69
Time * Seat	3609.23	2	1804.61	0.12	0.89
Error	135569.69	9	15063.30		
Road Condition	20299.96	2	10149.98	1.82	0.19
Road Condition * Seat	28916.91	4	7229.23	1.30	0.31
Error	100257.19	18	5569.84		
Presentation	8723.01	1	8723.01	1.98	0.19
Presentation * Seat	2543.75	2	1271.87	0.29	0.76
Error	39648.41	9	4405.38		
Time * Road Condition	3324.34	2	1662.17	0.26	0.78
Time * Road Condition * Seat	16965.17	4	4241.29	0.66	0.63
Error	116383.69	18	6465.76		
Time * Presentation	3816.88	1	3816.88	2.19	0.17
Time * Presentation * Seat	36915.90	2	18457.95	10.60	0.00
Error	15676.87	9	1741.87		
Road Condition * Presentation	2470.23	2	1235.11	0.17	0.84
Road Condition * Presentation * Seat	13742.51	4	3435.63	0.48	0.75
Error	129399.61	18	7188.87		
Time * Road Condition * Presentation	7700.02	2	3850.01	0.36	0.71
Time * Road Condition * Presentation * Seat	15965.68	4	3991.42	0.37	0.83
Error	194171.95	18	10787.33		

Route Planning

Source	SS	DF	MS	*F*	*p*
Seat	925980.55	2	462990.27	3.92	0.06
Error	1180584.65	10	118058.47		
Time	4688.38	1	4688.38	0.23	0.64
Time * Seat	1614.21	2	807.11	0.04	0.96
Error	200759.21	10	20075.92		
Road Condition	18848.61	2	9424.30	0.27	0.76
Road Condition * Seat	103327.31	4	25831.83	0.75	0.57
Error	689807.69	20	34490.39		
Presentation	220725.09	1	220725.09	5.42	0.04
Presentation * Seat	62479.91	2	31239.96	0.77	0.49
Error	406947.00	10	40694.700		
Time * Road Condition	153562.32	2	76781.16	1.86	0.18
Time * Road Condition * Seat	61383.88	4	15345.97	0.37	0.83
Error	826374.28	20	41318.71		
Time * Presentation	10596.75	1	10596.75	0.21	0.65
Time * Presentation * Seat	74345.36	2	37172.68	0.75	0.50
Error	495400.25	10	49540.03		
Road Condition * Presentation	48644.69	2	24322.36	1.87	0.18
Road Condition * Presentation * Seat	54400.91	4	13600.23	1.04	0.41
Error	260417.99	20	13020.90		
Time * Road Condition * Presentation	33331.10	2	16665.55	0.56	0.58
Time * Road Condition * Presentation * Seat	72091.81	4	18022.95	0.60	0.67
Error	599992.24	20	29999.61		

Missing Items

Source	SS	DF	MS	*F*	*p*
Seat	121516.25	2	60758.13	2.56	0.12
Error	260682.18	11	23698.38		
Time	68222.28	1	68222.28	7.17	0.02
Time * Seat	11966.75	2	5983.38	0.63	0.55
Error	104694.93	11	9517.721		
Road Condition	55550.60	2	27775.30	1.34	0.28
Road Condition * Seat	149345.87	4	37336.47	1.81	0.16
Error	454983.10	22	20681.05		
Presentation	29640.09	1	29640.09	1.02	0.34
Presentation * Seat	83797.82	2	41898.91	1.44	0.28
Error	320193.01	11	29108.46		
Time * Road Condition	125967.07	2	62983.54	2.06	0.15
Time * Road Condition * Seat	173429.37	4	43357.34	1.42	0.26
Error	671859.40	22	30539.06		
Time * Presentation	136.46	1	136.46	0.02	0.90
Time * Presentation * Seat	109354.93	2	54677.46	6.65	0.01
Error	90512.01	11	8228.36		
Road Condition * Presentation	75056.63	2	37528.31	1.45	0.26
Road Condition * Presentation * Seat	34337.42	4	8584.35	0.33	0.85
Error	567668.27	22	25803.10		
Time * Road Condition * Presentation	54732.20	2	27366.10	2.93	0.08
Time * Road Condition * Presentation * Seat	58193.36	4	14548.34	1.56	0.22
Error	205855.09	22	9357.05		

APPENDIX F

UNIVARIATE TEST RESULTS FOR MANOVAS CONDUCTED ON PRE-STRESS AND POST-STRESS PSYCHOLOGICAL MEASURES

UNIVARIATE TEST RESULTS FOR MANOVAS CONDUCTED ON PRE-STRESS AND POST-STRESS PSYCHOLOGICAL MEASURES

Variable	SS	DF	MS	*F*	*p*
Pre-Stress Measures					
MAACL-R					
Anxiety	29.4	2	14.7	.23	.792
Error	2881.7	46	62.6		
Depression	270.5	2	135.3	.63	.537
Error	9875.5	46	214.7		
Hostility	293.8	2	146.9	1.55	.223
Error	4360.9	46	94.8		
Sen. Seek.[a]	28.33	2	14.2	.225	.799
Error	2894.8	46	62.9		
Pos. Aff.[b]	216.9	2	108.5	1.933	.156
Error	2581.8	46	56.1		
Dysphoria	109.1	2	54.5	.314	.732
Error	7889.7	46	173.7		
Subj. Stress[c]	2782.3	2	1391.1	2.807	.071
Error	22799.4	46	495.6		
Post-Stress Measures					
MAACL-R					
Anxiety	486.9	3	162.3	1.445	.238
Error	6964.1	62	112.3		
Depression	748.8	3	249.6	.875	.459
Error	17684.0	62	285.2		
Hostility	635.0	3	211.7	1.223	.309
Error	10735.1	62	173.1		
Sen. Seek.[a]	6.6	3	2.2	.039	.990
Error	3524.8	62	56.9		
Pos. Aff.[b]	879.3	3	293.1	4.696	.005
Error	3869.8	62	62.4		
Dysphoria	299.7	3	99.9	.483	.696
Error	12832.3	62	207.0		
Subj. Stress[c]	6549.2	3	2183.0	5.129	.003
Error	26388.6	62	425.6		

[a]Sen. Seek = Sensation Seeking [b]Pos. Aff. = Positive Affect
[c]Subj. Stress = Subjective Stress Scale

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