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Summary

The purpose of this study was to assess the frequency and severity of motion sickness in personnel during a field exercise in the Command and Control Vehicle (C2V). This vehicle contains four workstations where military personnel are expected to perform command decisions in the field during combat conditions. Eight active duty military men (U.S. Army) at the Yuma Proving Grounds in Arizona participated in this study. All subjects were given baseline performance tests while their physiological responses were monitored on the first day. On the second day of their participation, subjects rode in the C2V while their physiological responses and performance measures were recorded. Self-reports of motion sickness were also recorded. Results showed that only one subject experienced two incidences of emesis. However, seven of the eight subjects reported other motion sickness symptoms; most predominant was the report of drowsiness, which occurred a total of 19 times. Changes in physiological responses were observed relative to motion sickness symptoms reported and the different environmental conditions (i.e., level, hills, gravel) during the field exercise. Performance data showed an overall decrement during the C2V exercise. These findings suggest that malaise and severe drowsiness can potentially impact the operational efficiency of C2V crew. However, a number of variables (e.g., individual's sleep quantity prior to the mission, prior experience in the C2V, etc.) were not controlled for in this study and may have influenced the results. Most notable was the fact that subjects with previous experience in the C2V all occupied seat 4, which was anecdotally reported to be the least provocative position. Nonetheless, it was possible to determine which factors most likely contributed to the results observed. It was concluded that conflicting sensory information from the subject's visual displays and movements of the vehicle during the field exercise significantly contributed to motion sickness symptoms observed in both this study and the earlier study at Camp Roberts. The objectives of this study were successfully met. The use of three converging indicators, (1) physiological monitoring, (2) subject self-reports of symptoms, and (3) performance metrics, was an effective means of evaluating the incidence of motion sickness and the impact on overall crew operational capacity within the C2V. It was recommended that a second study be conducted to further evaluate the impact of seat position or orientation and C2V experience on motion sickness susceptibility. Further, it was recommended that an investigation be performed on behavioral methods for improving crew alertness, motivation, and performance and for reducing malaise.

Introduction

This technical report describes the results of a study conducted within an Interagency Agreement between Ames Research Center, Space Life Sciences Division, Gravitational Research Branch, and the U.S. Army Program Executive Office for Ground Combat and Support Systems, Project Managers Office, Bradley Fighting Vehicle System, (PM-BFVS), Tank–Automotive and Armament Command (TACOM). The purpose of this project was to use NASA technology to assist the U.S. Army in the assessment of motion sickness incidences in the Command and Control Vehicle (C2V).

Results from a previous study by the Army at Camp Roberts and at the Aberdeen Proving Grounds indicate that after a brief excursion on a cross country course in the C2V crewmembers reported varying degrees of motion sickness (e.g., nausea, blurred vision, etc.). Of the 17 participants in that study only 1 experienced vomiting, but 12 were reported to have been taking anti-motion sickness medication (Dramamine). Two commonly reported side effects of Dramamine are drowsiness and blurred vision, but the effects of this medication on crew performance were not reported. Our own research showed

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that promethazine, another anti-motion sickness medication, significantly degrades performance on specific cognitive and psychomotor tasks and decreases alertness (Cowings et al., 1995). These data suggest that such medications may seriously impair operational efficiency of crewmembers in space or operators within the C2V.

Motion sickness is a physiological dysfunction induced by a real or perceived motion stimulus and characterized primarily by nausea, pallor, cold sweating, and vomiting (Reason and Brand, 1975). Other symptoms include salivation, feelings of warmth, dizziness, depression or apathy, drowsiness, and headache. The currently accepted explanation for motion sickness is the sensory conflict theory (Reason and Brand, 1975). The theory suggests that the brain is constantly receiving information from the visual system and from the vestibular system on the position and movement of the body. Sensors in muscles of the neck, arms, legs, and other parts of the body also provide the brain with positioning data known as proprioceptive information. Motion sickness can occur when the brain perceives these various signals to be in conflict with normal motion cues.

Physiological responses during motion sickness can be used to objectively evaluate symptom severity and individual differences in susceptibility. In a study conducted on 127 people, all given the same motion sickness stimulus, a rotating chair, subjects showed consistent changes in heart rate, peripheral vasoconstriction, and skin conductance (Cowings et al., 1986). Changes in these physiological responses were directly correlated with subjective symptom reports which were scored using a standardized diagnostic scale. Standardized diagnostic scales reduce individual variability in the accuracy of reports because they contain the complete constellation of motion symptoms (not just the presence or absence of nausea); they enable assessment of symptom severity (mild, moderate, or severe); and they allow comparisons across different experimental or stimulus conditions. However, subjective reporting alone is insufficient because subjects may over- or underestimate symptom severity, forget specific symptom elements, or simply "misreport" their symptoms (Stout and Cowings, 1993).

Decrements in performance associated with motion sickness have been widely examined, and results are controversial, dependent on the nature of the stimulus (chronic or acute) and the performance measurements used (Abrams et al., 1971; Gal, 1975; Hettinger, 1973; Parker, 1969; Reason and Brand, 1975). Graybiel reported, however, that under conditions of chronic or sustained vestibular stimulation where military personnel spent several days within a slowly rotating room, observations of drowsiness, lethargy, and apathy predominated (Clark and Graybiel, 1961). The impact of these symptoms was such that subjects often refused or were unable to perform assigned tasks, spending much of their time sleeping or lying down.

As part of a research program to develop a treatment for space motion sickness, NASA investigators have determined that the best method for assessing the incidence and severity of motion sickness episodes involves the combination of three distinct measures: (1) subjective self-reports utilizing a standardized diagnostic scale, (2) standard cognitive and psychomotor performance tasks, and (3) monitoring of physiological responses (Stout and Cowings, 1993). This approach has been used to evaluate motion sickness in a variety of Earth-based conditions (Cowings, 1990), including airsickness in military pilots flying high performance aircraft (Cowings and Toscano, 1994), and space motion sickness in astronauts and cosmonauts (Toscano and Cowings, 1994).

The objectives of this study were:

1. To document the incidence and severity of motion sickness in the C2V and thereby determine measures necessary to increase the safety and operational efficiency of crewmembers.
2. To obtain physiological data of crewmembers during routine field operations in the C2V using an ambulatory monitoring system developed by NASA, the Autogenic-Feedback Training System-2 (AFS-2).
3. To obtain performance data of crewmembers during these field operations using a computer-based task battery.

Methods

Subjects

Eight men, between the ages of 23 and 29, who were active duty military personnel, participated in this study. All subjects were in excellent health, and their voluntary participation was obtained after they were briefed on the experiment procedures. Subjects were instructed to refrain from taking anti-motion sickness medication or cold and allergy medication (antihistamines) for 24 hours prior to test conditions. This study was approved by the Institutional Review Board for Human Research at Ames Research Center.

Apparatus

Physiological Measures

The subjects' physiological responses were recorded using the AFS-2, a self-contained ambulatory monitoring system (fig. 1). This system was developed and tested on astronauts during a space shuttle mission in 1992 (Cowings and Toscano, 1993). The AFS-2 includes a garment, transducers, biomedical amplifiers, a digital wrist-worn feedback display, and a cassette tape recorder. The entire instrument is powered by a self-contained battery pack. Data tapes were processed and analyzed at Ames Research Center by NASA investigators. Physiological measures are listed below.

Electrocardiography (ECG): Pregelled Ag-AgCl disposable electrodes were placed on the chest just below the left and right clavicles (distally), and on the left midclavicular line over the fourth intercostal space.

Respiration Rate (RR): Respiratory amplitude and frequency was measured with a piezoelectric transducer attached to the garment with snaps over the chest.

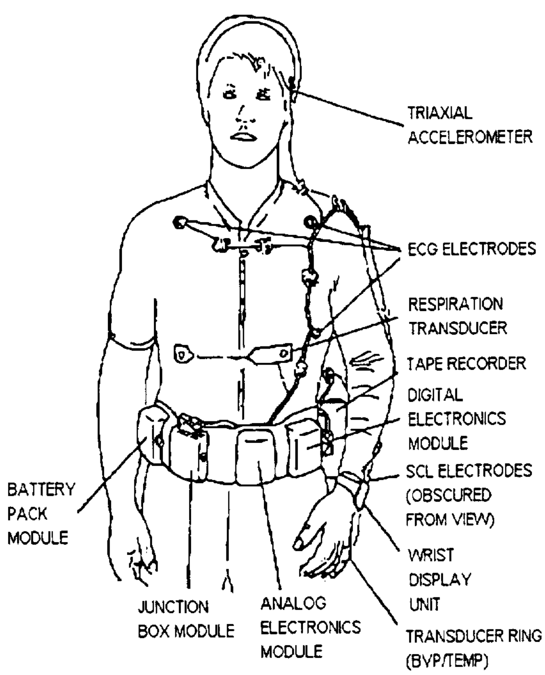


Figure 1. The Autogenic-Feedback System-2 (AFS-2).

Finger Pulse Volume (FPV): A miniature light emitter/diode (photoplythesmograph) was mounted within a ring transducer on the volar surface of the small finger on the left hand, and was monitored and displayed as a relative index of peripheral vasomotor activity.

Skin Temperature (ST): A solid-state temperature transducer (Analog Devices, model AD590) was mounted within the same ring as the FPV transducer. ST was also used as a relative measure of peripheral blood volume.

Skin Conductance Level (SCL): Absolute changes in the electrolytic properties of the skin were monitored from disposable (AMI, model 1650) Ag-AgCl electrodes. These pregelled, self-adhesive electrodes were mounted on the volar surface of the left wrist.

Head Movements: A triaxial accelerometer was attached to the subject's helmet with tape and was used to measure head and upper body movements in the x, y, and z planes.

Performance Tasks

The DELTA human performance measuring system is an upgraded software version of the Automated Performance Test System (APTS), which was developed as an assessment tool for human performance (Kennedy et al., 1985). This test battery has been used extensively to study the effects of environmental stressors, including sleep deprivation, long duration simulated microgravity (DeRoshia and Greenleaf, 1993), and seasickness (Wiker and Pepper, 1978; Kennedy and Bittner, 1978; Johnson and Wendt, 1964). It has also been shown to be predictive of performance on tank gunnery simulators (Bliss, 1990), and of mission specialists (Jeanneret, 1988). Below is a list of the eight subtests used in this experiment, the duration of each test, and a brief description of test procedures.

Reaction Time–Three Choice (60 seconds): This test involves the presentation of a visual stimulus and measurement of a response latency to the stimulus. The subject's task is to respond as quickly as possible with a key press to a simple visual stimulus. On this test, three "outlined" boxes are displayed and one of the three boxes is "filled." A short tone precedes the filling of a box to signal that a "change" in the status of a box is about to occur. The box changes from outlined to filled. The subject scans the boxes for the change and then presses the numeric key corresponding to the box that changes. The test measures response latency between the presentation of the stimulus and the response in milliseconds.

Code Substitution (75 seconds): The computer displays nine characters across the top of the screen. Beneath them, the numbers 1 through 9 are displayed in parentheses. The subject's task is to associate the number with the character above it. This is called the subject's "code." Under the code are two rows of characters with empty parentheses beneath them. The subject responds by pressing the number associated with the character from the code above. When the subject has completed a row, the bottom row moves to the top, and a new row appears below. This is a mixed associative memory and perceptual with visual search encoding/decoding and incorporates memory recall and perceptual speed.

Pattern Comparison (75 seconds): The task involves comparing two patterns of asterisks that are displayed on the screen simultaneously. The subject's task is to determine if the patterns are the same or different and respond by pressing the "S" or "D" key. This is a test of spatial ability which reflects an integrative spatial function associated with the right hemisphere.

Preferred Hand Tapping (10 seconds): The subject is required to press the indicated keys as fast as possible with the fingers from the preferred or dominant hand. Correct responses are based on the number of alternate key presses made in the allotted time. The tapping tests measure manual motor skill and coordination.

Non-Preferred Hand Tapping (10 seconds): The subject is required to press the indicated keys as fast as possible with the fingers from the non-preferred or subdominant hand. Correct responses are based on the number of alternate key presses made in the allotted time. The tapping tests measure manual motor skill and coordination.

Grammatical Reasoning (90 seconds): Stimulus items are sentences of varying syntactic structure (e.g., A precedes B) accompanied by a set of letters (e.g., AB). The sentences are generated from possible combinations of five conditions: (1) active versus passive wording, (2) positive versus negative wording, (3) key words such as "follows" and "precedes," (4) order of appearance of the two symbols within the sentence, and (5) order of the letters in the simultaneously presented symbol set. The subject's task is to read and comprehend whether the sentence correctly describes the sequence of the symbols in the symbolic set which appears to the right of the sentence. The subject responds by pressing the "T" (true) or "F" (false) key. This test measures cognitive reasoning, logic, and verbal ability and assesses an analytic function associated with the left cerebral hemisphere.

Manikin Spatial Transformation Test (60 seconds): This test presents a figure of a sailor on the screen with a box below his feet and a box in each hand. A pattern (XXX or 000) appears in the box below, which matches the pattern in the box in one of his hands. The figure stands either facing away or toward the subject (right-side up or upside own). The objective of this task is to determine which hand (right or left) matches the objects that appear in the box on which the sailor is standing. The subject responds by pressing one of the two arrow keys (i.e., to indicate left or right hand). This test measures the ability to spatially transform mental images and determine the orientation of a given stimulus.

Visuo-Spatial Short Term Memory (75 seconds): This task requires the subject to assess a pair of 6-bar histograms to determine if the histogram presented on the screen is the same or different from the previous histogram. The second histogram in the pair may be 0, 90, 180, or 270 degrees relative to the first histogram. The subject responds by pressing the "S" (same) or "D" (different) key. This test measures short-term memory and the ability to assess spatial orientation.

Motion Sickness Symptom Reports

Subjects within the C2V were asked to report any symptoms they experienced in a diagnostic logbook. The symptoms were evaluated using a standardized procedure referred to as the Pensacola Diagnostic Rating Scale (Graybiel et al., 1968). Figure 2 is an illustration of each page within the diagnostic log book. An array of possible symptoms included salivation (SAL), sweating (SWT), drowsiness (DRZ), and pallor (PAL). The presence or absence and/or strength of most symptoms were assessed subjectively by the subject (mild "I," moderate "II," or severe "III"). Other symptoms were rated as minor or "additional qualifying symptoms," to be scored as mild or moderate levels only. These included increased warmth (TMP), dizziness (DIZ), and headache (HAC). Stomach sensations were evaluated on five levels. Epigastric awareness (EA) is described as not nausea and not particularly uncomfortable, but as an increased awareness of the stomach (e.g., hunger). Epigastric discomfort (ED) was described as not nausea, but becoming increasingly uncomfortable (e.g., lump in the throat, or stomach distended by gas). Nausea was reported when it can clearly be differentiated from ED and EA, as either mild (I), moderate (II), or severe (III). Frank vomiting (VMT) was indicated as either present (I) or absent (no entry). Motion sickness scores between 1 and 4 points represented mild malaise, scores between 5 and 7 represented moderate malaise, scores of 8 or higher represented severe malaise with 16 points scored for vomiting (i.e., frank sickness).

Crew I.D.:__________________ **Time:**______________ **Date:**______________

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

COMMENTS: ____

Figure 2. Motion sickness symptom log book.

Procedures

Subjects were required to participate on two days in this study with a week interval between test days. Each 8-hour day included ambulatory physiological monitoring with the AFS-2, performance testing with the laptop computer, and training in operating the AFS-2 and self-reporting motion sickness symptoms. Two subjects were tested on each day.

Baseline Training–Day 1

Subjects reported to the laboratory in the early morning where they were initially trained on AFS-2 donning procedures and system operation. Performance test battery familiarization and training was initiated with the laptop computers. Each subject was given eight repetitions of the test battery distributed over the day. The purpose of these training tests was to establish stable performance levels for each individual. Subjects were also provided with instructions for self-reporting their motion sickness symptoms during the C2V field exercise.

C2V Field Exercise–Day 2

Subjects reported to the laboratory, donned the AFS-2 system, and initiated data recording. Next, subjects were seated in the vehicle at station 1, adjacent to the rear bulkhead, and station 4, adjacent to the forward bulkhead. Crew seat 1 is set at a 67 degree angle relative to the axis of vehicle movement, while crew seat 4 faces directly forward in the direction of movement. During vehicle movement subjects spent most of their time attending to a computer display video game. The performance test battery was administered only during stationary periods in the vehicle using the same laptop computers as on the baseline day. There were six repetitions of the performance test battery on this day. Table 1 shows a timeline of activities during the field exercise.

Table 1. Timeline of activities during field exercise

Time of day	Activity
07:30–08:50	Stationary period
08:35–08:50	Computer test battery #1
09:05–09:30	Dynamometer (Dyno) course
09:30–10:35	Stationary period
09:30–09:40	Computer test battery #2
10:50–11:15	Level cross country (LXC) course
11:15–12:30	Stationary period
11:15–11:30	Computer test battery #3
12:30–13:00	Tank Hills (HXC) course
13:00–13:20	Stationary period
13:00–13:10	Computer test battery #4
13:20–13:30	Gravel course
13:40–13:50	Computer test battery #5
13:40–15:00	Stationary period—LUNCH
15:00–15:15	Computer test battery #6

Results

Motion Sickness Symptom Reports

Subjects were asked to report their symptoms during each stationary period while in the vehicle. Table 2 summarizes the frequency of symptoms, the number of hours of sleep each subject had on the previous night, and previous experience in the C2V. The severity of each individual symptom (mild, moderate, or severe) was not reported. Consequently, it was not possible to rate motion sickness malaise levels for these subjects.

Only subject 3 reported vomiting (two incidences) during the C2V field exercise. This subject reported nausea on three occasions as well as increased salivation. Two other subjects reported nausea, epigastric discomfort (ED), or epigastric awareness (EA). Subject 6 reported no symptoms at all.

Reports of increased warmth and sweating in subjects 3, 7, and 8 appeared to be unrelated to fluctuations in ambient temperature within the vehicle. The Appendix contains the symptom reports and physiological data of each individual, noting time of day during which symptoms occurred as well as personal comments. Vehicle compartment temperature is plotted with skin temperature for each subject. Only subjects 1 and 2 showed a noticeable change in skin temperature when ambient temperature decreased. For the remainder of that day, and for all other test participants, there was no clear relationship between subjective sensations of warmth, skin temperature, or ambient temperature. For example, subject 3 reported feeling increased warmth, despite ambient temperatures that were below 75°F throughout most of the day.

Reports of dizziness (subjects 3, 5, and 8) and headache (subjects 5 and 7) may have been related to playing a computer video game while the vehicle was moving. It is not known if subjects were constantly attending to their video displays, because they were not visually monitored while the vehicle was moving. Nonetheless, there is a high probability that these types of conflicting sensory cues (i.e., apparent movement of the vehicle and the visual display) are strong enough stimuli to elicit dizziness and possibly disorientation in some subjects.

Table 2. Motion sickness symptoms during the C2V field exercise

I.D.	VMT	TMP	DIZ	HAC	DRZ	SWT	PAL	SAL	NSA	ED	EA	Previous experience	Seat position	Hours sleep
# 1					3							Yes	4	6.5
# 2					2							No	1	4.5
# 3	2	4	3		4	3	1	1	3			No	1	4.0
# 4					1							Yes	4	6.5
# 5			3	1	1				1			No	1	5.0
# 6												Yes	4	4.5
# 7		1		1	4	1		1	1	2	2	No	1	7.0
# 8		2	2		4	1						Yes	4	6.0
Total	2	7	8	2	19	5	1	2	5	2	2			

Previous experience in tracked vehicles is another factor that may have influenced motion sickness tolerance in the C2V. Three subjects (2, 5, and 7) had no prior experience in the C2V or any other tracked vehicle. Two of these subjects reported nausea and other symptoms. Subject 3, who reported two incidences of emesis, had only prior experience in another tracked vehicle, Paladin M09. Four subjects had considerable prior experience in the C2V (subjects 1, 4, 6, and 8). These subjects reported only drowsiness with the exception of subject 8, who reported other symptoms as well, although nausea was absent.

The seat location and angle relative to the axis of vehicle movement are additional factors that may have influenced individual motion sickness susceptibility. During the field exercise, three of the subjects (3, 5, and 7) who reported nausea sat in seat 1, which is located in the rear of the vehicle and positioned at a 67 degree angle relative to the axis of vehicle movement. The other subject who sat in this position, subject 2, reported only drowsiness. The remaining four subjects sat in seat 4, which faced forward and was located in the front of the vehicle. Subject 8 reported drowsiness and other symptoms, subjects 1 and 4 reported only drowsiness, and subject 6 reported no symptoms.

It was not possible to determine from these data whether seat position or prior experience in the vehicle were significant factors influencing motion sickness symptoms observed in these subjects. Nonetheless, seven of the eight subjects reported motion sickness symptoms, with drowsiness being the most frequently reported symptom. Although subjects reported only 4 to 7 hours of sleep on the previous night, there was no relationship between sleep quantity and observed drowsiness or motion sickness in general during the field exercise (table 2).

There is some debate as to whether or not drowsiness per se is a direct symptom of motion sickness or if it is merely a "parallel but distinct phenomena," which is "suggested by its presence in subjects who are otherwise unaffected by the provocative vestibular stimulus, and by its persistence after other ill effects have disappeared through adaptation to the continuing stimulus" (Reason and Brand, 1975). It makes little difference to the sufferer or to a unit commander expecting undiluted workload from soldiers. Prolonged and repetitive vestibular stimulation has an effect very similar to that induced in babies when their cradles are rhythmically rocked. The effect of drowsiness is that it may impair the subject's performance on critical decision making tasks in the field. Exhaustion, neurasthenia (i.e., lack of strength, or debility), lethargy, and apathy are all common elements of motion sickness (Reason and Brand, 1975) and space motion sickness (Myasnikov and Zamaletdinov, 1996).

Physiology

Subject 3, who reported the most symptoms, and subject 6, who was symptom-free, were both tested in the vehicle on the same day. Figure 3 shows the physiological data of each subject plotted over time as 1-minute averages. The different C2V courses are outlined as vertical bars. The top graph shows skin temperature of the hand, a relative measure of vasomotor activity. Finger pulse volume data, another measure of vasomotor activity, was not plotted because of poor signal quality possibly caused by vibrations in the vehicle. Subject 3 showed decreases in skin temperature that were associated with reports of increased malaise, yet this was not the case with subject 6.

One parameter alone does not tell the whole story. Individuals tend to produce a pattern of physiological responses, in which some parameters contribute more than others in response to stressful stimuli. Cowings, Naifeh, and Toscano (1990) have demonstrated that physiological response profiles to motion sickness stimuli are highly idiosyncratic (subject-specific), but are reproducible over repeated tests.

The middle graph is a plot of each subject's heart rate. One characteristic that clearly distinguishes individuals highly susceptible to motion sickness when compared to moderate or low susceptibles is response lability, the tendency for rapid, large magnitude changes in response to stimulation (Cowings et al., 1986). Although subject 6 shows a higher average heart rate than does subject 3, the latter, more susceptible, individual repeatedly showed larger oscillations of up to 30 beats per minute throughout the day.

The bottom graph shows skin conductance levels for both subjects. This response is a sensitive index of physiological and emotional "arousal." Initially, both subjects showed low skin conductance levels, but as C2V course conditions changed, skin conductance levels increased. The response increases (i.e., arousal) beginning several minutes before the Level course probably indicate where the subjects began playing the video game, and/or that the subjects were responding to the vehicle moving to the next course. Subject 3 showed greater increases and longer duration skin conductance responses than subject 6, and his levels never returned to prestimulus levels recorded at the start of the day (i.e., less than 10 micromhos).

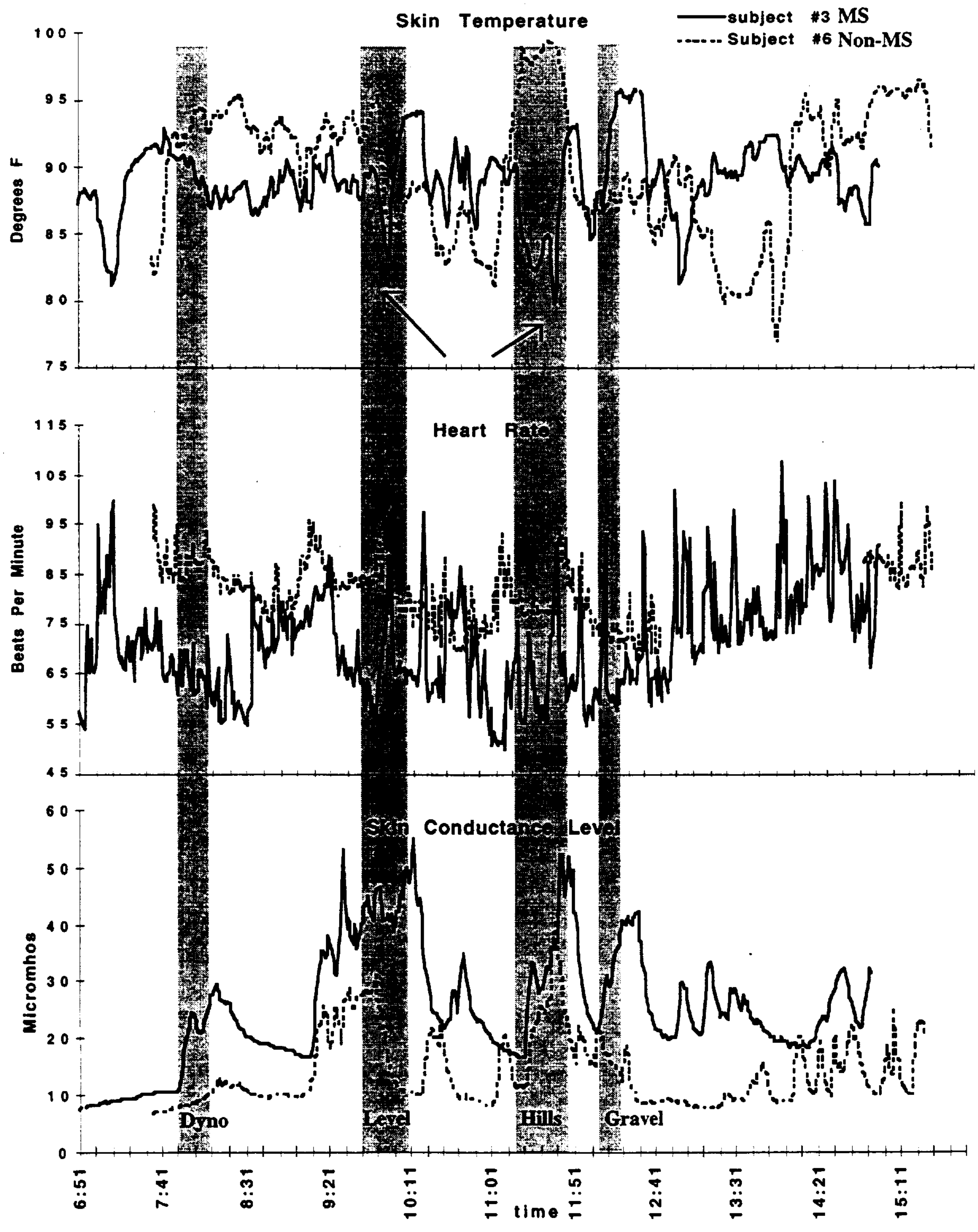


Figure 3. A comparison of motion sickness and non-motion sickness subjects during C2V exercise (arrows indicate time of vomiting episodes in subject 3).

The Appendix includes each individual's symptoms report and graphs comparing the subjects' physiological responses measured during the baseline day (when they were trained on the performance task battery) to responses measured during the C2V field exercise. Data recordings were not made during lunch on the baseline day, and during the C2V day data dropouts were caused by sensor problems (e.g., a cable disconnection or bad electrode; see heart rate of subject 2). In those cases where drowsiness was reported, subjects showed lower heart rate and/or skin conductance level on the C2V day than they did during their baseline day. It is important to note that these symptom reports were made after the vehicle had stopped following each course. The times noted are when the reports were *written*, not when the symptoms actually occurred. Review of the symptom reports and physiology (see Appendix) suggests that the soporific (i.e., drowsiness inducing) effect was most noticeable during the Level course, while the Hills course was perceived as most stressful (higher skin conductance levels). Emesis episodes for subject 3 and reports of nausea for subject 7 occurred under both conditions. Most subjects reported less drowsiness following lunch, which occurred prior to the Gravel course. And nearly all subjects reported feeling better (happier) when the C2V field exercises were completed.

Performance

Performance subtests evaluated for latency were code substitution, pattern comparison, grammatical reasoning, choice reaction time, and Manikin. Latency scores for the five subtests were pooled to establish a composite performance index. To evaluate performance changes during the field exercise independent of practice effects, the training and post-field data were fit by an exponential curve which was then subtracted from the data.

All performance subtest scores stabilized after one training session with respect to subtest variance (Cochran's test for homoscadesticity of variance) and stabilized after four sessions with respect to subtest mean (linear regression slope test) except for the Manikin test latency, which required five sessions for stabilization.

Composite performance latency (fig. 4) shows the expected exponential learning pattern over training trials 1–8 on the baseline training day. On the C2V day, task batteries were administered only when the vehicle was not moving. The vehicle doors were opened and Yuma Proving Ground personnel provided laptop computers for the subjects' use. The periods when the tasks were administered are noted in figure 4 as Stat-1 (first stationary period) through Stat-4. The last point on this graph is the post-field performance test mean, which was conducted on the day following field exercises. There is a performance decrement between the last training trial and the first baseline (prior to vehicle movement, Stat-1) of the field exercise which probably reflects lack of practice over this interval and diurnal performance differences between the last training trial (late afternoon) and the first baseline (early morning). Performance then improved from the first stationary condition (Stat-1) to the Level cross country course (LXC) but deteriorated from the Level through the Hills course (HXC) and the Gravel course. The deterioration is evident in data where the exponential practice curve was subtracted from the data (see fig. 4).

Figure 5 compares the composite latency performance scores of subject 3 and subject 6. Even though subject 6 reported no symptoms, was seated in position 4, and had previous experience in the C2V, he showed an even greater deterioration in performance than did subject 3 (who vomited on two occasions). A t-test comparison of all four subjects seated in position 1 to those seated in position 4 across all epochs (in figs. 4 and 5) showed no significant difference in performance as measured by composite latency scores ($t = -1.54$, $df = 28$, $p = 0.15$). The mean of all subjects ($N = 8$) showed a decrement in performance during field exercise, and the performance of the two subgroups ($N = 4$) was comparable.

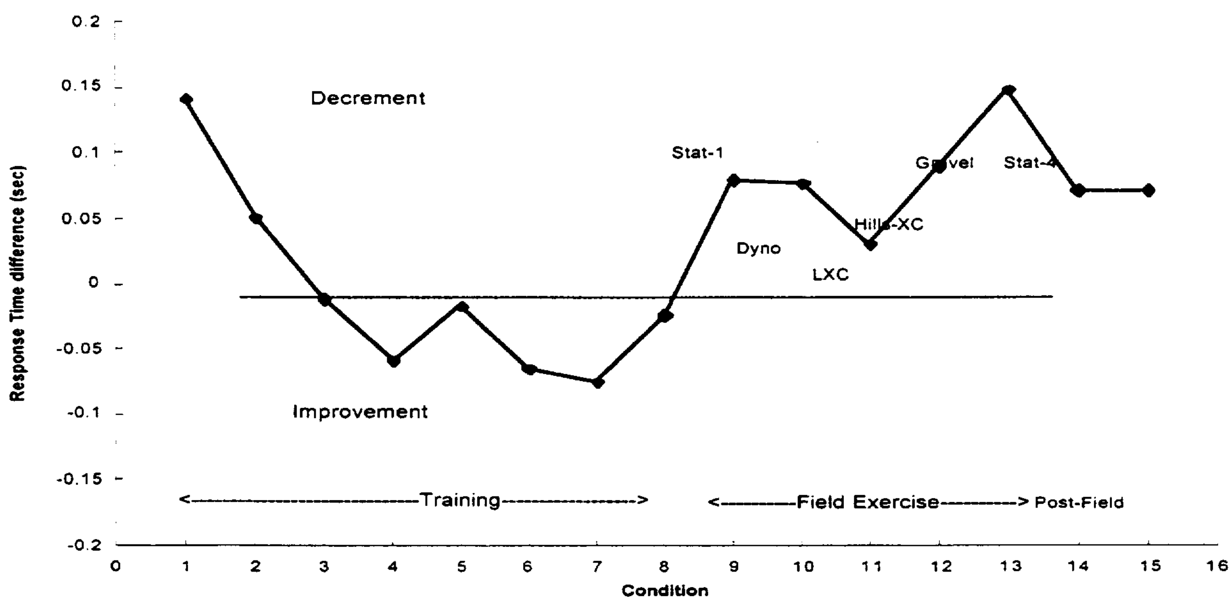


Figure 4. Mean response latency (5 tests): residuals after subtraction of learning curve.

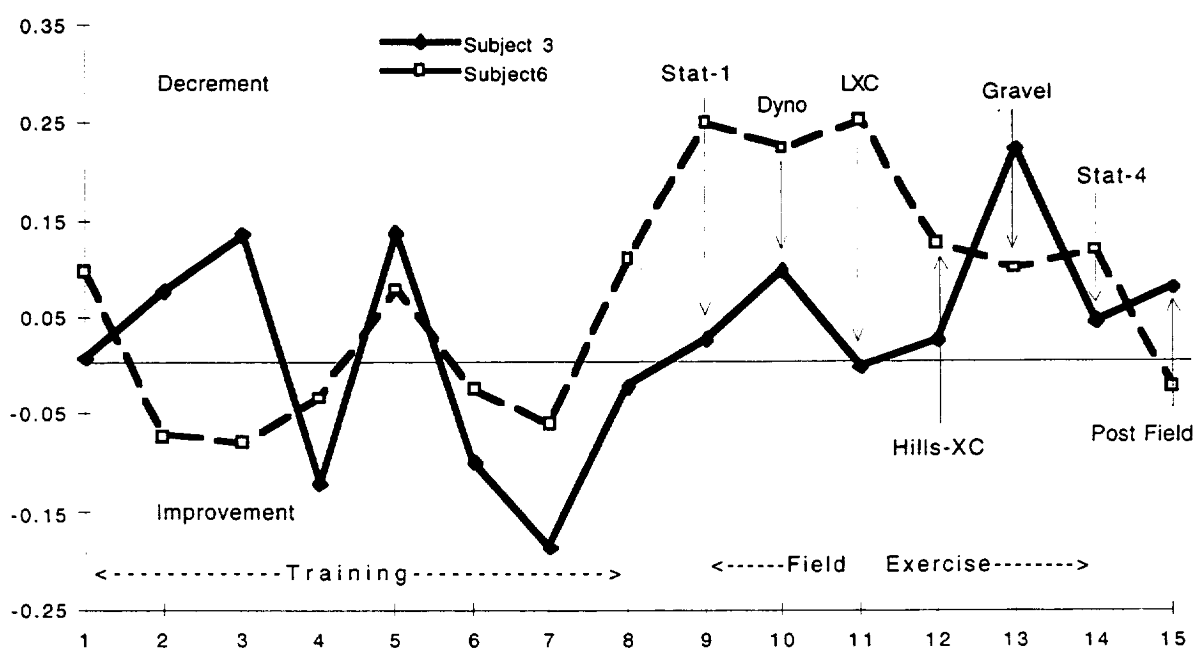


Figure 5. Mean response latency (5 tests), subjects 3 and 6: residuals after subtraction of learning curve.

Discussion

Is motion sickness present in the C2V? Yes.

Physiological data, performance scores, and symptom reports confirm this conclusion. Symptoms of drowsiness, blurred vision, and dizziness cannot be attributed to anti-motion sickness medication (as was a possible conclusion from an earlier study), but is directly attributable to conditions within the C2V. Although only one subject vomited in the present study, seven of the eight subjects reported motion sickness symptoms with the report of drowsiness occurring most frequently, and the composite performance scores showed a progressive decrement during field exercise. The fact that subject 3's performance was better following vomiting episodes (which occurred during the Level and Hills cross country courses) may be a result of two factors. First, subjects often experience a sense of relief after vomiting as the act of emesis is followed by parasympathetic rebound (e.g., a drop in heart rate). Second, because performance tests were performed after the vehicle had stopped (i.e., completed the course) there may have been sufficient time for the subject to recover from the worst effects. Subject 6 reported no symptoms but his physiological responses showed that he did respond to the different field courses, although these changes were of smaller magnitude than those of subject 3. He may have been unaware of the impact of environment on his physiology, as some individuals are unable to accurately perceive such changes (Cowings, 1990). He could tell that he was "better off" than subject 3 and perhaps he thought he should report only *severe* symptoms. Or he may have simply misreported.

What factor contributed most to observed symptoms? Undetermined.

There were several uncontrolled and confounding variables which make verification of the exact cause of symptoms impossible. However, from these data it is possible to rank the probable causes and the relative degree to which specific factors contributed to motion sickness malaise. Significant performance degradation is well documented in response to sleep loss (Naitoh, 1969), and workload fatigue, in which performance degrades because of aversion to effort, increased tolerance for errors, loss of attention to peripheral stimuli (Holding, 1983), or speed-accuracy trade-offs (Hockey, 1986; Rosa and Colligan, 1988). Of the subjects who reported the most sleep, subjects 7 and 8 (7 and 6 hours, respectively), the former reported numerous symptoms, including nausea, while the latter reported drowsiness, headache, dizziness, and increased warmth. Of the subjects with the least amount of sleep, subject 6 (4.5 hours) had no symptoms at all while subject 3 (4 hours) experienced vomiting twice. The performance deterioration between the Level course and the Gravel course occurred in spite of practice effects and diurnal rhythmic influences (Hockey, 1986) which would have been expected to result in progressive performance improvement during a comparable period under controlled conditions. Although both sick and non-sick subjects reported similar amounts of sleep loss on the previous night, it was concluded that the lack of sleep, in general, observed for these subjects did not significantly contribute to the symptoms or composite performance decrements observed in this study.

Ambient temperature changes in the C2V during the field exercise were found to be unrelated to subjective experiences of increased warmth, hence it was concluded that vehicle temperature had a relatively minor impact on motion sickness susceptibility. The potential effect of heat exposure on performance is more difficult to evaluate since it depends on a complex interaction of exposure time, temperature, and type of task (Hockey, 1986; Holding, 1983).

Two variables that may have confounded the results of this study were seat position/angle and previous vehicle experience. Subjects were assigned as test participants on an "as available" basis, and therefore were not preselected on the basis of their experience in tracked vehicles. It is possible that experienced subjects knew (or believed) that position 4 was the "good seat" (i.e., least provocative of symptoms), hence leaving their more naive counterparts to sit in position 1. Or perhaps repeated exposure to the C2V resulted in some degree of adaptation to this environment, leading to diminished symptoms over time which might have occurred regardless of seat position. Nonetheless, when performance metrics of the experienced versus nonexperienced subjects were compared (including seat location), there was no significant difference between the two groups. The group mean ($N = 8$) showed a progressive decrement in performance during field exercises.

It is important to note here that the Level course was not truly flat, but consisted of a series of low hills to be traversed, much like waves for a ship at sea. Cowings found that linear oscillation (0.33 Hz, 0.35 g) produces more pronounced symptoms of sopite syndrome (or sleepiness) than other provocative stimuli (Cowings, 1990). The substantial vibration in the C2V vehicle noted by the experimenter during a test ride may have influenced performance since the vibration tended to induce drowsiness. This vibration may have contributed to motion sickness symptoms since humans are susceptible to low frequency vibrations in the range of 0.12–0.25 Hz

(McCauley and Kennedy, 1976). All subjects experienced vibration to a greater or lesser degree, depending on seat position.

Recommendations

Option 1

Examine specific factors that contribute most to incidences of motion sickness in C2V field operations in a second study, which should include the following:

1. A minimum of eight subjects with previous C2V experience who would be matched for number of hours and exposure to the different field conditions.
2. Subjects would be required to have at least 8 hours of sleep on the nights before baseline training and C2V field tests.
3. Each subject would participate in two field tests in the C2V and be assigned on alternate tests to either seat position 1 or seat position 4. The order of seat position assignment would be counterbalanced for the group.
4. Subjects would be tested with a standard performance battery while the vehicle is in motion. This will provide valuable information for examining etiological factors (e.g., sensory conflicts between the visual display and motion) involved in the development of motion sickness. The DELTA performance task battery is a standard assessment tool which has been used for evaluating motion sickness and performance effects.
5. The field conditions (i.e., Hills, Dyno, Level courses) should be counterbalanced to eliminate order effects. This will help to determine if the drowsiness effects are related to diurnal variations or specific to the type of course.
6. Subjects would be trained to self-report both the frequency and severity of their symptoms using a standard diagnostic rating scale. Significant events (e.g., motion sickness, vehicle breakdowns) would be noted in a written logbook and recorded as "event presses" on the AFS-2.
7. Subjects would be instructed not to take anti-motion sickness medication for 24 hours prior to baseline training and C2V field exercise days.

Option 2

Retest the "experienced" subjects in seat position 1 during the same cross country course. This will at least provide data for evaluating the effects of seat position and angle on motion sickness. An alternative option, if these subjects are no longer available, would be to test other experienced subjects (a minimum of four) in each seat position. These follow-up tests would be more cost effective than any vehicle modifications.

Option 3

Train personnel to control motion sickness symptoms using Autogenic-Feedback Training Exercise (AFTE). This method has been shown to be an effective treatment for motion sickness in a variety of motion sickness inducing conditions (Cowings, 1990) and has the added value of improving crew performance under stressful conditions (Kellar et al., 1993).

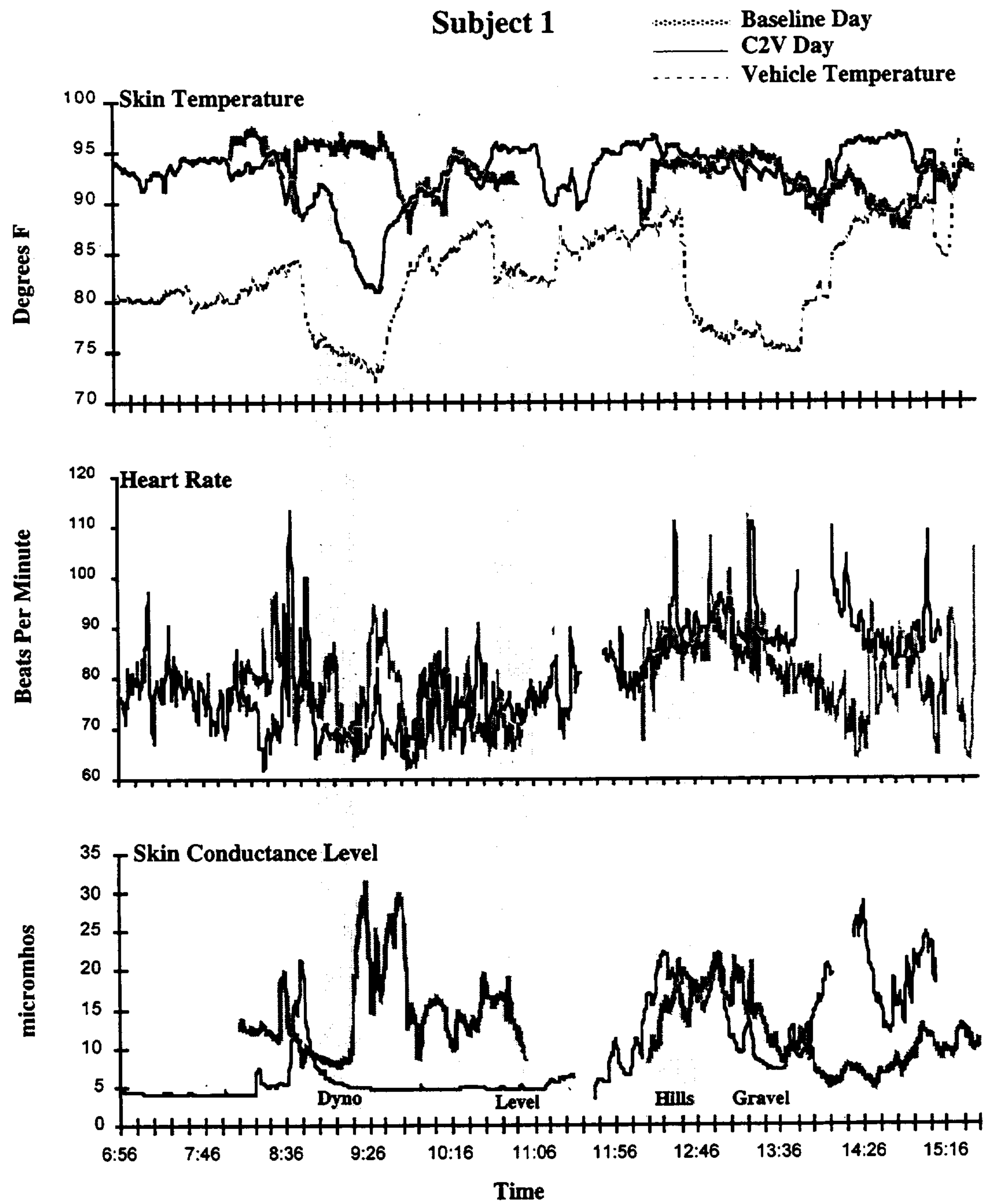
Conclusions

The objectives of this study were successfully met. The use of three converging indicators, (1) physiological monitoring, (2) subject self-reports of symptoms, and (3) performance metrics, was an effective means of evaluating the incidence of motion sickness and the impact on overall crew operational capacity within the C2V. Although several conditions were not properly controlled in this field study, it is possible to determine which factors most likely contributed to the results observed. It is concluded that sensory conflict during C2V operations, while subjects attended to visual screens when the vehicle was in motion, was the most likely cause of motion sickness observed in both this study and the earlier study at Camp Roberts.

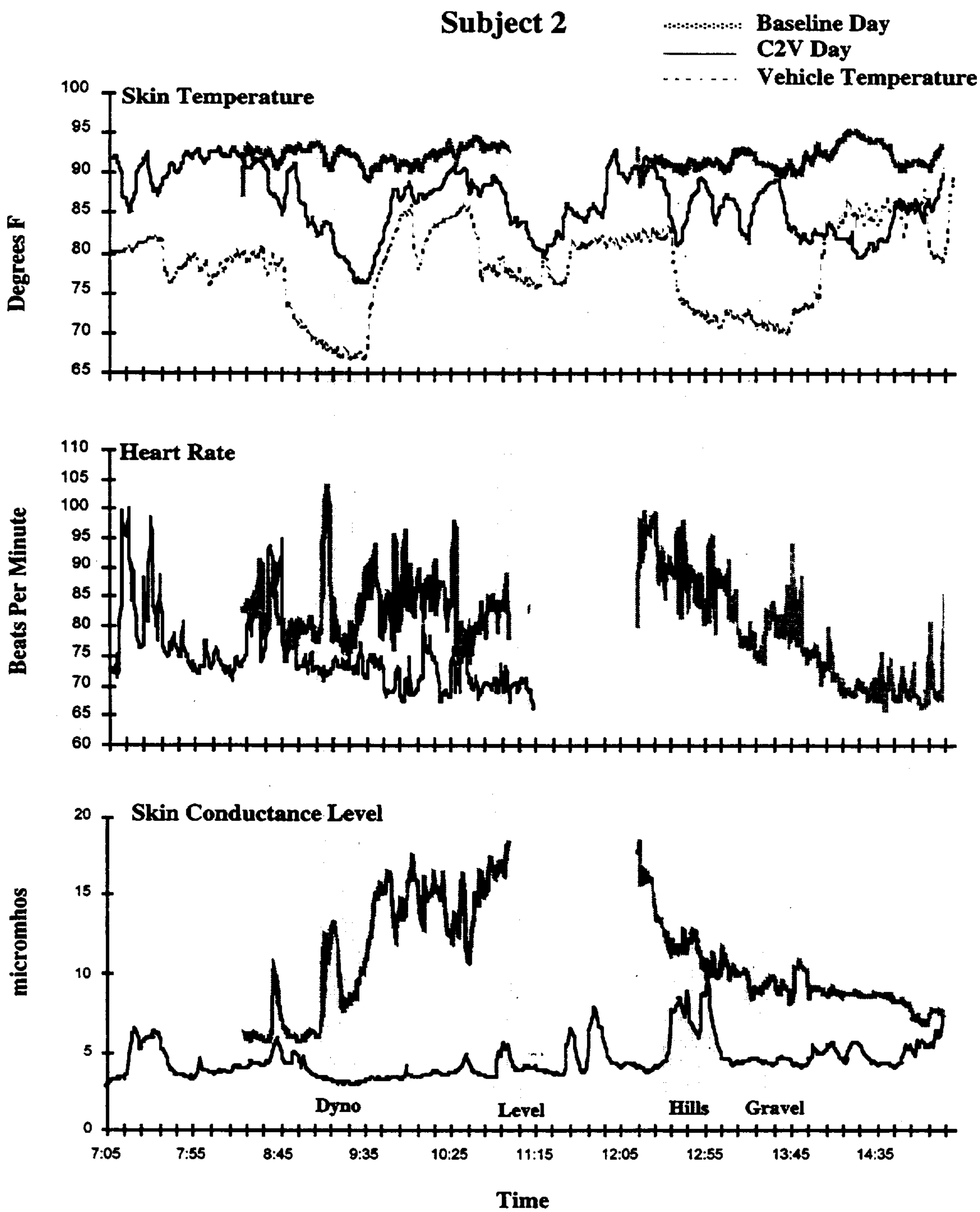
Appendix

Individual Symptom Reports by Timeline and Comments

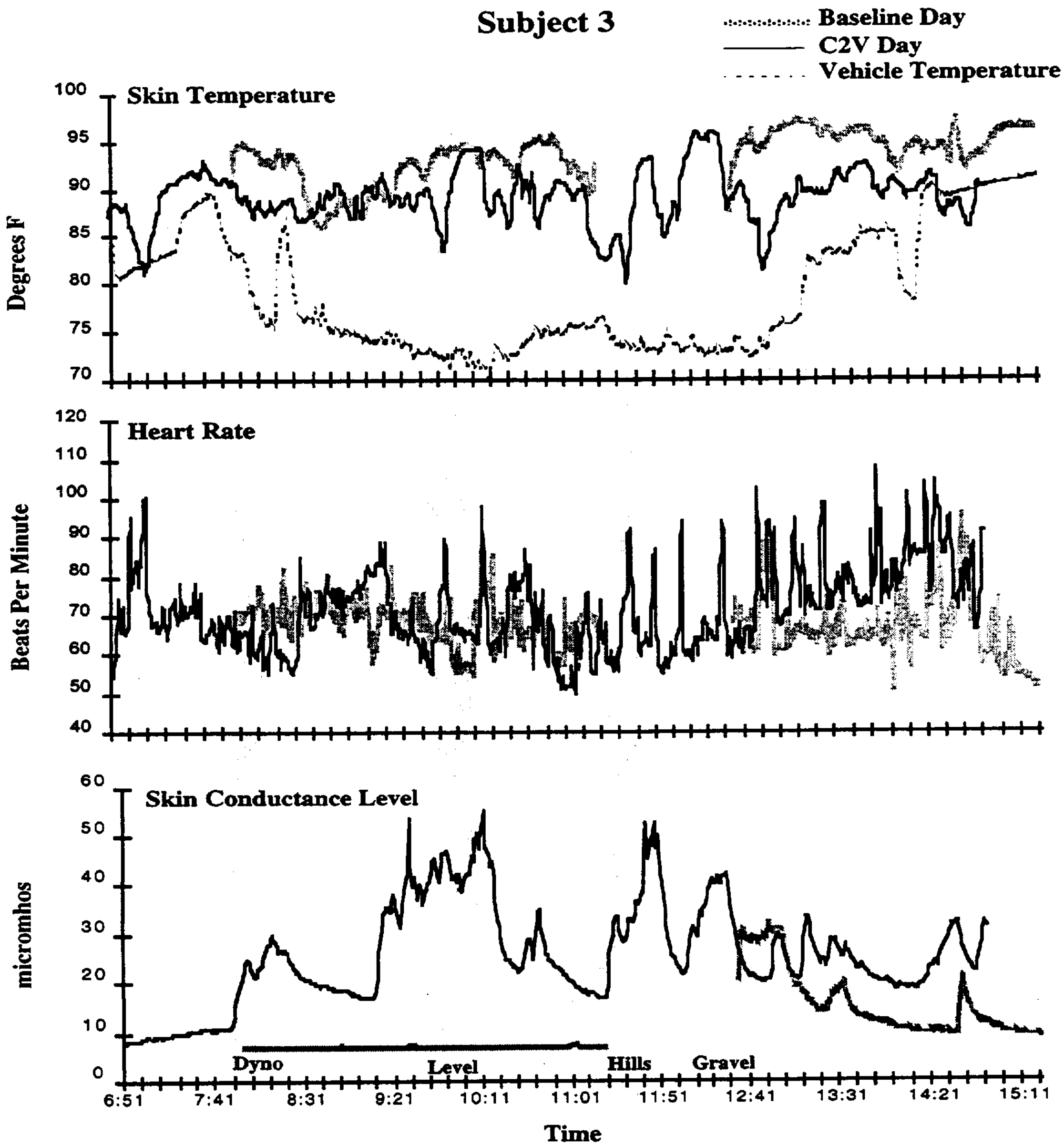
Graphs of Individual Physiological Responses During the Baseline Training Day and During C2V Field Exercises



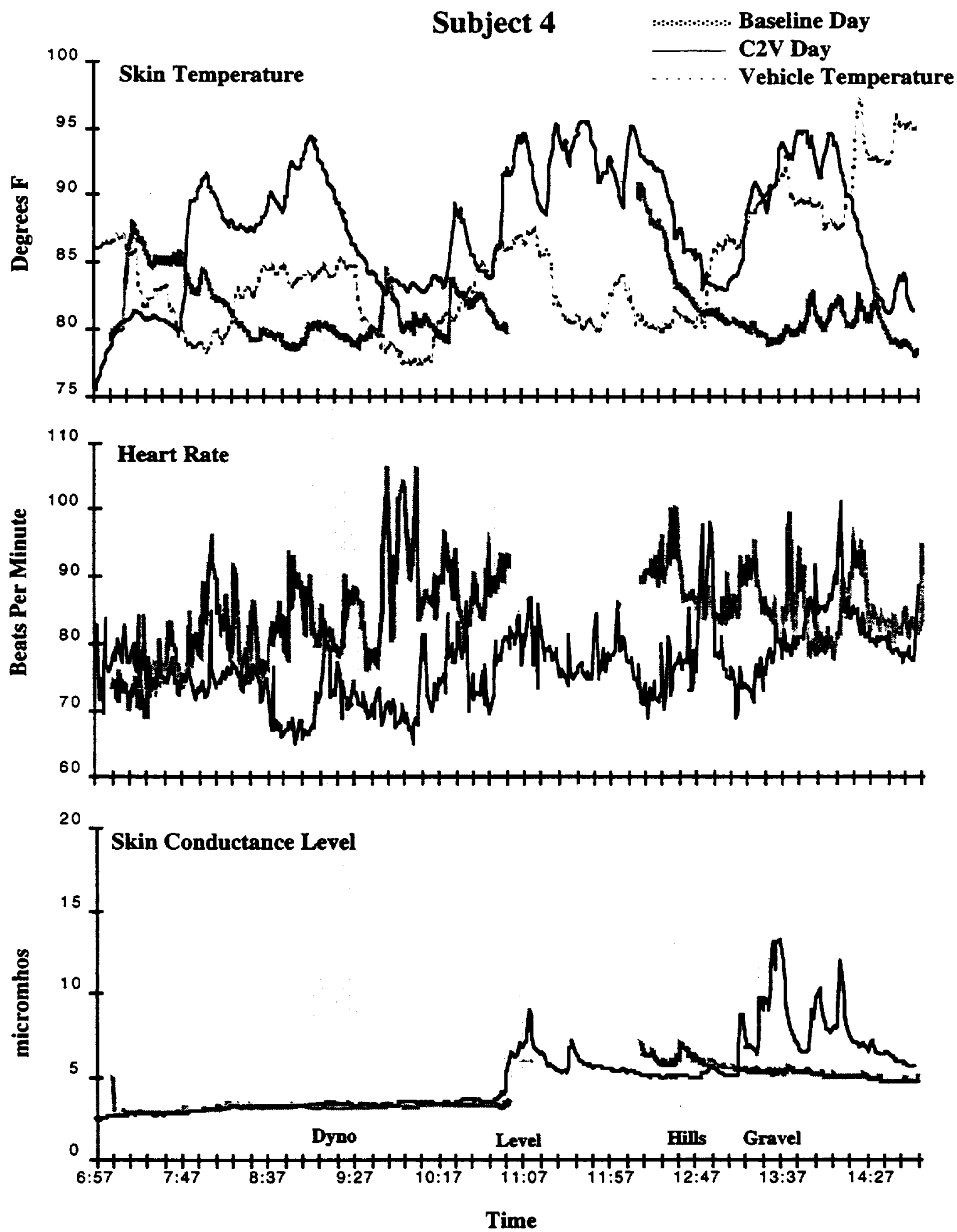
Time	DRZ	COMMENT
8:40	X	No written comments
9:32		
11:17	X	
13:04	X	
13:55		



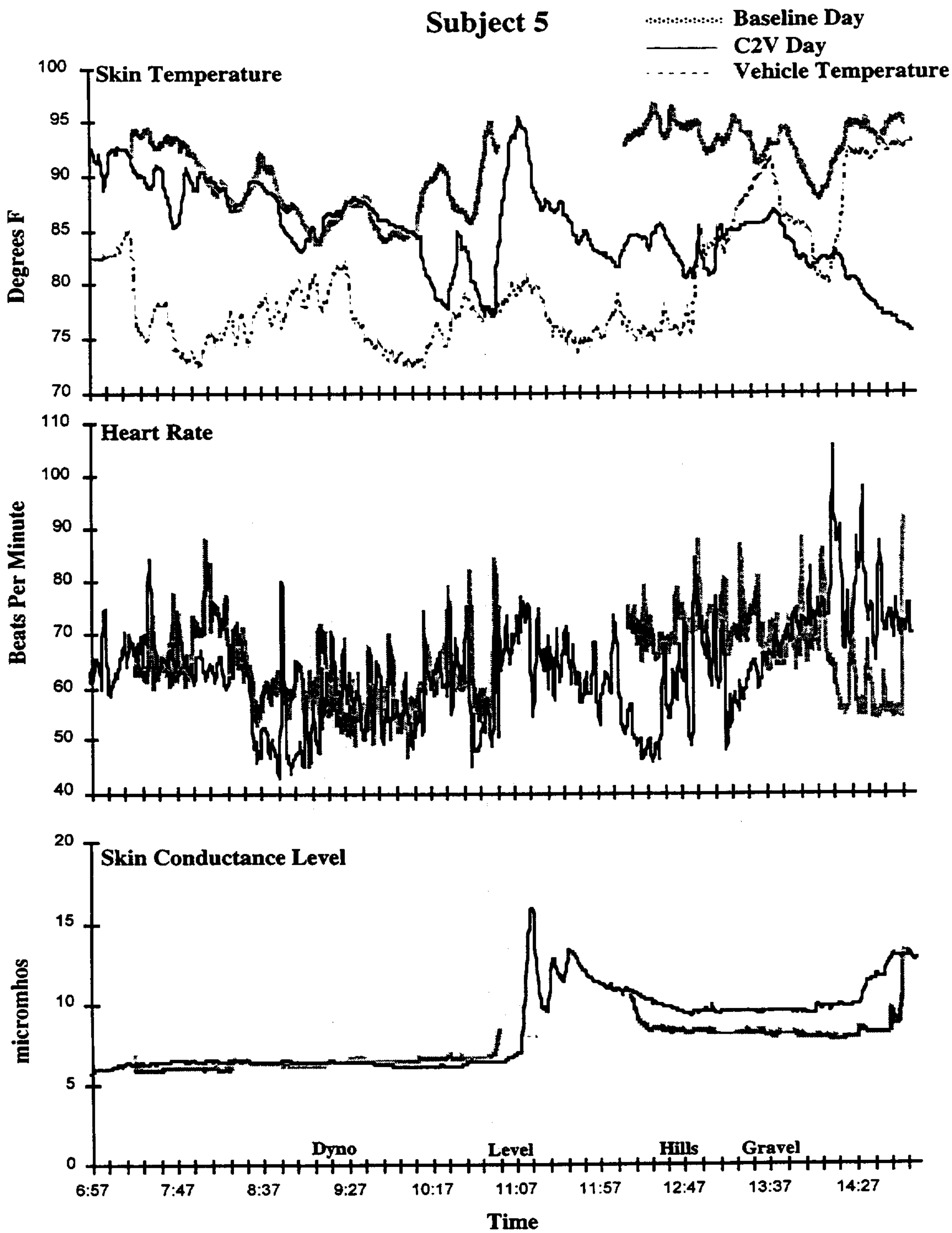
Time	DRZ	COMMENT
8:37	X	
9:30	X	
11:16		
13:19		No problems
13:57		Feeling good



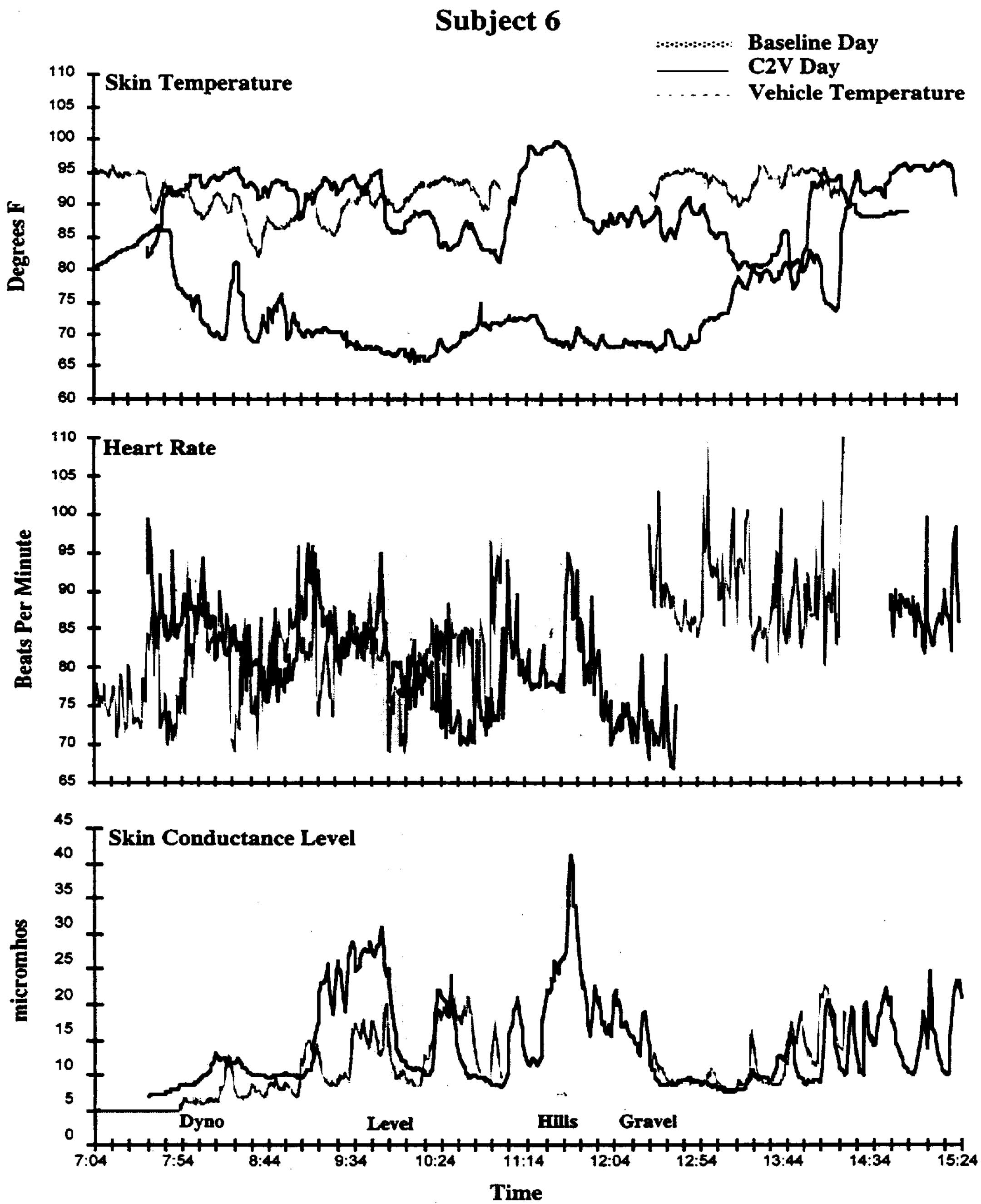
Time	VMT	TMP	DIZ	DRZ	SWT	SAL	NSA	COMMENT
7:49				X				
8:00		X					X	
8:20		X	X	X	X		X	Feeling sick; 8:15 Lost A/C
10:00	X	X	X	X	X		X	Ate some food at 9:15
10:30								At 10:05 sat in cab Okay
11:20	X	X	X	X	X	X		Ate prior to sick, moved to cab
11:55								Laptop test
12:35								No symptoms; test
14:00								No symptoms; last test



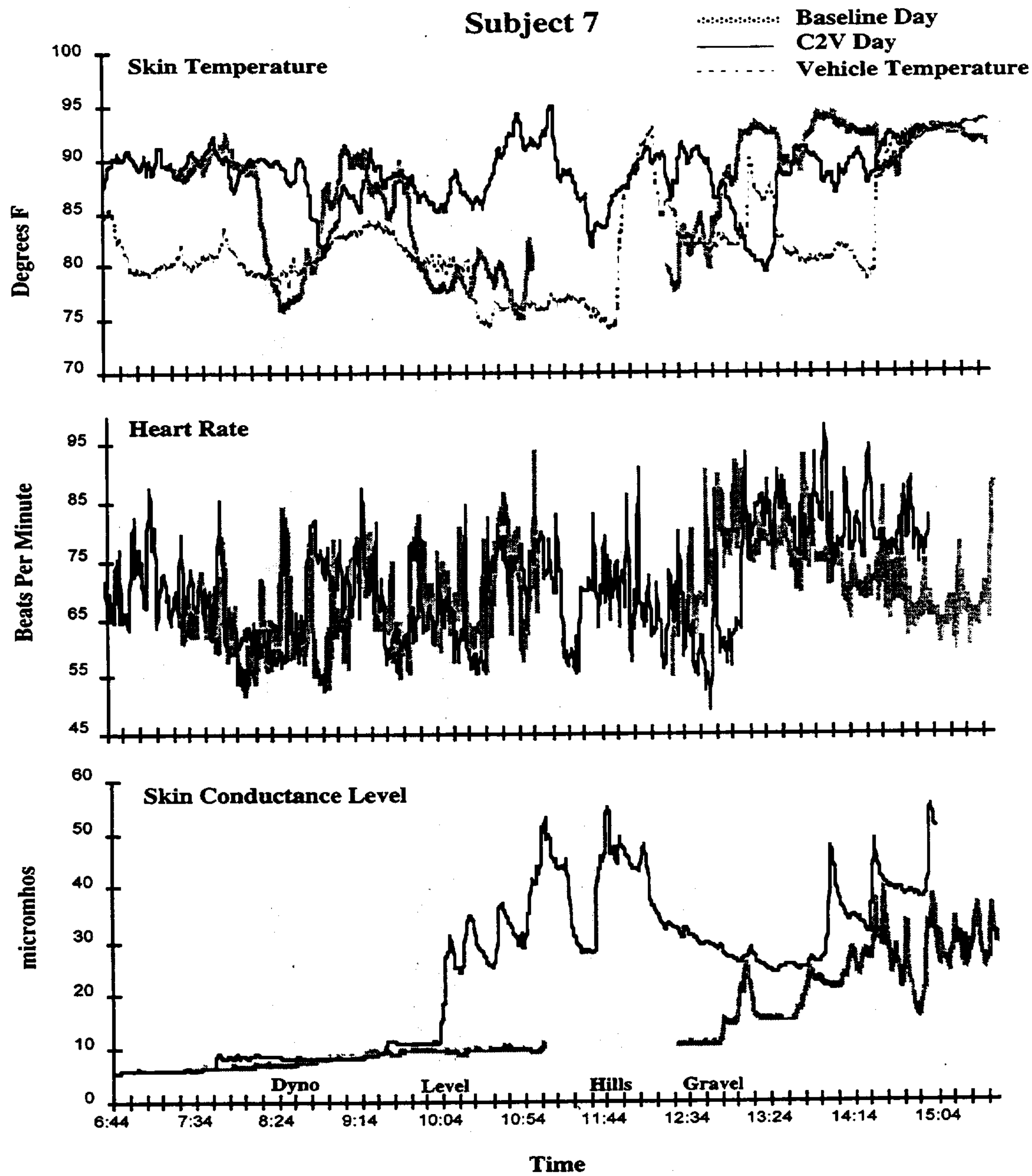
Time	DRZ	COMMENT
8:10	X	No written comments
10:00	X	
11:52		
12:35		
14:00		



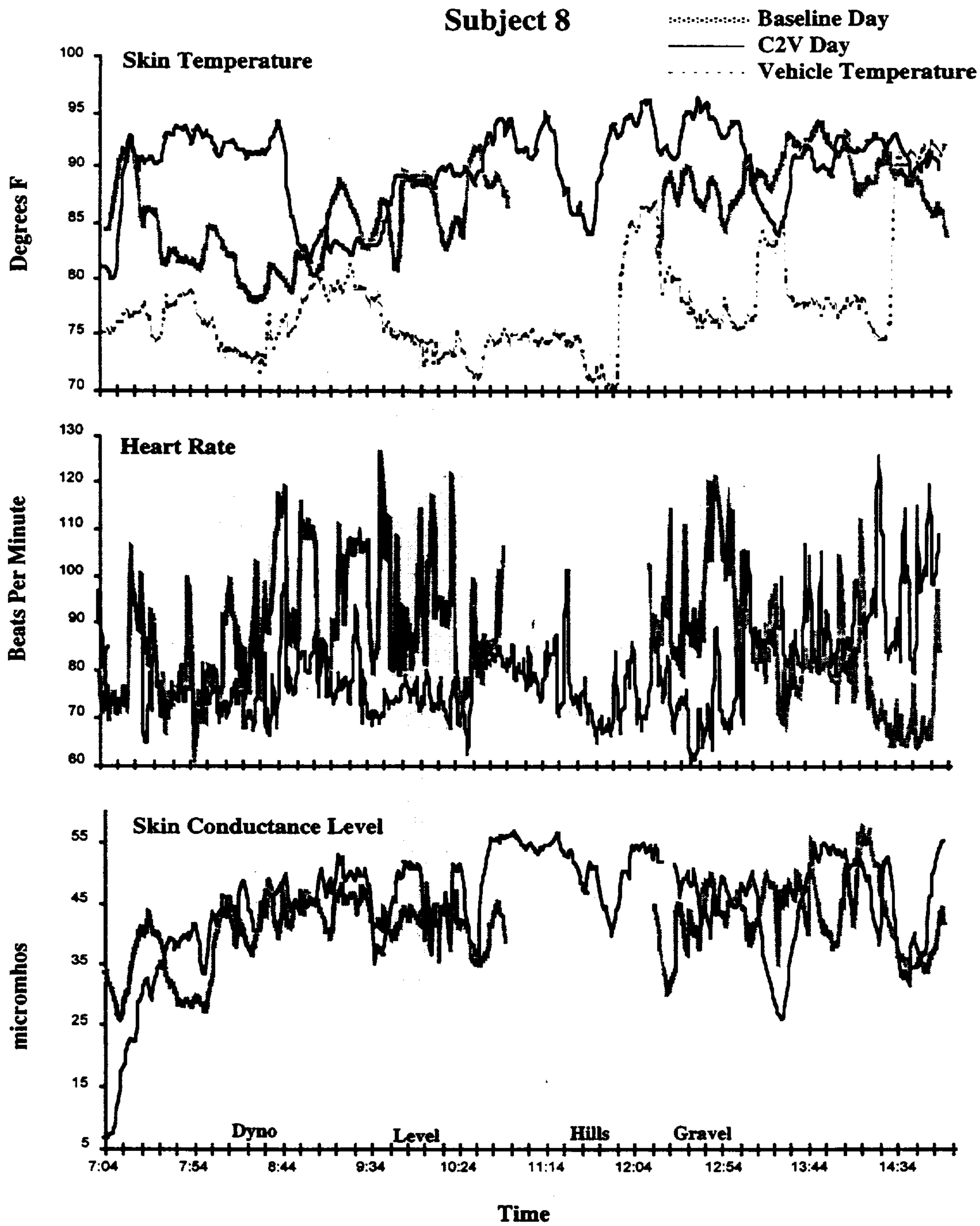
Time	TMP	DIZ	DRZ	NSA	COMMENT
8:12	X	X	X	X	Lot of dizziness, drowsiness, some nausea
10:10	X	X			Dizziness/drowsiness, Bumpy Ride
11:48	X	X		X	little dizziness/nausea
12:35	X				Feel good
14:00					Feel great



Time	NONE	COMMENT
8:25		Feel good; 8:15 lost A/C
10:00		Stop on LXC
11:40		Stop on LXC
11:50		Good/taking laptop test
12:35		Computer test
14:00		Computer test/ate lunch



Time	TMP	HAC	DRZ	SWT	SAL	ED	EA	COMMENT
7:38								
8:36		X	X					Drowsy, headache
10:20			X			X	X	Very drowsy
12:05	X		X	X	X	X	X	
12:58			X					Hard time staying awake
14:15								Feel good!



Time	TMP	DIZ	DRZ	SWT	COMMENT
7:38					
8:37		X	X		
10:26	X	X	X		Too bumpy to play games when riding
12:06	X		X	X	
13:00			X		Very sleepy
14:15					Good to go!

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13. ABSTRACT *(Maximum 200 words)*

The purpose of this study was to assess the frequency and severity of motion sickness in personnel during a field exercise in the Command and Control Vehicle (C2V). This vehicle contains four workstations where military personnel are expected to perform command decisions in the field during combat conditions. Eight active duty military men (U.S. Army) at the Yuma Proving Grounds in Arizona participated in this study. All subjects were given baseline performance tests while their physiological responses were monitored on the first day. On the second day of their participation, subjects rode in the C2V while their physiological responses and performance measures were recorded. Self-reports of motion sickness were also recorded. Results showed that only one subject experienced two incidences of emesis. However, seven out of the eight subjects reported other motion sickness symptoms; most predominant was the report of drowsiness, which occurred a total of 19 times. Changes in physiological responses were observed relative to motion sickness symptoms reported and the different environmental conditions (i.e., level, hills, gravel) during the field exercise. Performance data showed an overall decrement during the C2V exercise. These findings suggest that malaise and severe drowsiness can potentially impact the operational efficiency of the C2V crew. It was concluded that conflicting sensory information from the subject's visual displays and movements of the vehicle during the field exercise significantly contributed to motion sickness symptoms. It was recommended that a second study be conducted to further evaluate the impact of seat position or orientation and C2V experience on motion sickness susceptibility. Further, it was recommended that an investigation be performed on behavioral methods for improving crew alertness, motivation, and performance and for reducing malaise.

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