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EFFECTS OF U.S. ARMY COMMAND AND CONTROL VEHICLE (C2V) OPERATIONAL ENVIRONMENT UPON HUMAN PERFORMANCE.

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Purpose. This study was designed to assess cognitive and neuromotor performance in personnel during field exercises in the in the U.S. Army Command and Control Vehicle (C2V). This vehicle contains four computer workstations where crew members are expected to perform command decisions in the field under combat conditions. **Methods.** Eight active-duty U.S. Army male soldiers participated in this study at the Yuma Proving Ground, Arizona. Performance was assessed using seven subtests in the DELTA performance test battery. After subjects had completed eight training batteries in a classroom, performance in the field was measured before and after exposure to four different field course conditions (hills and level cross-country (LXC), paved road, gravel). Motion sickness susceptibility was assessed using the Pensacola Diagnostic Rating Scale. **Results.** Composite performance (mean of subtest z-scores) relative to baseline was degraded by both gravel and road (-6.6 and –4.0 %, respectively, $P<0.05$), but not cross country courses. The pattern comparison performance subtest was degraded by both road and LXC courses (-13.0 and -14.1%, respectively, $P<0.02$). Four subjects reported 4-7 motion sickness symptoms while the other four reported 0-1 symptoms; however, no significant relationship was found between symptom levels and field performance. Subjects averaged 5.5 hours sleep prior to the field exercises. **Conclusions.** The C2V vehicle environment exposes crew members to confinement, vibration, noise, heavy workloads, and induction of motion sickness symptoms. While performance deterioration during vehicle movement can result from impairment in visual perception and manual control skills induced by vehicle vibration and movement, it is likely that the performance deterioration during the stationary phases of the field exercises resulted from the persistent effects of exposure to vehicle vibration, noise, and drowsiness induced by "sopite syndrome", along with the cumulative

effects of prior night sleep loss and workload fatigue during the field exercises.

RATIONALE.

Interagency collaboration between NASA, Ames Research Center Gravitational Research Branch and U.S. Army Tank-Automotive and Armament Command (TACOM)

Mutual U.S. Army/NASA interest in the frequency and severity of motion sickness in personnel during field exercises in the Command and Control Vehicle (C2V): C2V crewmembers reported varying degrees of motion sickness after cross country excursions at Camp Robers and the Aberdeen Proving Ground

Assess the effects of environmental variables associated with C2V vehicle exposure on a variety of cognitive performance skills

- Confinement
- Noise
- Vibration
- Transient heat exposure
- Drowsiness induced by sleep loss and motion sickness
- Workload fatigue
- Prior vehicle experience and seat position

Hypotheses:

- Significant motion sickness symptoms will be induced in the subjects by vehicle pitch and yaw motions
- Significant motion sickness symptoms will be associated with significant decrements in performance task skills
- Experienced C2V crewmembers will manifest significantly fewer performance decrements in response to vehicle movement than inexperienced crew members since less attention to the environment is required in experienced crewmembers and they are more likely to be habituated to repetitive vestibular stimulation
- The hills cross country course should provide more vehicle pitch and yaw motions than the other C2V test courses and should therefore be associated with greater magnitude performance decrements.

Table I. Timeline of Activities During Field Exercise

Time of day	Activity	
06:23 - 08:38	Stationary Period	
07:23 - 08:50	DELTA test battery #1	
07:50 - 09:30	Dynamometer (Dyno) paved road Course	15.8km
08:10 - 09:40	DELTA test battery #2	
08:15 - 10:35	Stationary Period	
09:40 - 11:15	Level Cross Country (LXC) Course	14.8km
10:10 - 11:30	DELTA test battery #3	
10:15 - 12:30	Stationary Period	
11:15 - 13:00	Hills cross country (HXC) Course	12.7km
11:35 - 13:00	DELTA test battery #4	
12:05 - 13:30	Gravel Course	5.5km
12:30 - 13:50	DELTA test battery #5	
13:40 - 15:00	Stationary Period -LUNCH	
13:55 - 15:15	DELTA test battery #6	

Table II. Motion Sickness Symptoms During the C2V Field Exercise

I.D.	VMT	TMP	DIZ	HAC	DRZ	SWT	PAL	SAL	NSA	ED	EA	# Symptoms	Total	Motion Sickness group	Previous Vehicle Experience	# Hrs Sleep	Seat Position
# 1					3							1	3	Low	Yes	6.5	4
# 2					2							1	2	Low	No	4.5	1
# 3	2	4	3		4	3	1	1	3			8	21	High	No	4.0	1
# 4					1							1	1	Low	Yes	6.5	4
# 5			3	1	1				1			4	6	High	No	5.0	1
# 6												0	0	Low	Yes	4.5	4
# 7		1		1	4	1		1	1	2	2	8	13	High	No	7.0	1
# 8		2	2		4	1						4	9	High	Yes	6.0	4
Total	2	7	8	2	19	5	1	2	5	2	2		55		Mean	5.5	

VMT: Occurrence of vomiting
TMP: Increased warmth
DIZ: Dizziness
HAC: Headache
DRZ: Drowsiness
SWT: Sweating
PAL: Pallor
SAL: Salivation
NSA: Nausea
ED: Epigastric discomfort
EA: Epigastric awareness
Mild Malaise: Total= 1-4
Moderate Malaise: Total= 5-7
Severe Malaise: Total> 8

RESULTS: Field test variables

Motion sickness (MS):

- Emesis occurred twice in one subject
- Symptoms were reported in 7/9 subjects; the most frequent was
  - Drowsiness (19 occurrences)
- Two groups of subjects emerged with respect to degree of symptoms
  - High symptoms group: 4-7 symptoms (n=4)
  - Low symptoms group: 0-1 symptoms (n=4)

Seat location:

- Seat #1 (45° to direction of travel, rear of C2V) was anecdotally more
  - Provocative than seat #4 (parallel to direction of travel, front of C2V)
- By chance all four subjects with prior experience in the C2V occupied
  - Seat #4

Drowsiness and sleep loss:

- Sleep loss effects upon performance response latency due to
  - attentional lapses were observed during training
- Prior night sleep duration mean= 5.5hr (2.2 hr less than comparable
  - Age matched group
- No association between prior night sleep duration and reported
  - Drowsiness (r=0.04 NS)

Confinement effects:

- Performance decrements occurred in 8/12 subtest measures in the
  - Stationary C2V vehicle relative to classroom baseline performance
- No significant interactions between performance latency and errors
  - which would be indicative of fatigue effects from training to post-field trials (grammatical reasoning, $F_{7,98}=0.95$, NS)

Workload fatigue:

Performance decrements occurred in 7/13 subtest measures between first and last stationary trials despite practice effects

A subsequent C2V performance study at Ft Hood, TX showed progressive deterioration in several mood state parameter from first to last stationary trials

Ambient temperature changes:

Subjects in the air-conditioned C2V (mean= 79° front/75° rear) were briefly exposed (1-15 min) to ambient temperatures of 85-98° when the rear hatch door was opened and exposed for longer intervals (1.7-4.6 hr) when the air-conditioning units failed on five occasions. There is no evidence that these exposures influenced MS symptoms. The effects of heat exposure upon performance is difficult to evaluate since it depends upon a complex interaction of exposure time, temperature and task type

Vibration and noise:

Field course conditions:

Paved road, gravel: high frequency, intense vibrations, sharp bumps from holes

Level XC: low frequency vertical acceleration changes due to undulating hills

Hills XC: Multi-directional acceleration changes due to turns, climb and descend

C2V vehicle test parameters:

Peak vibrations at 5Hz

Mean rms vertical acceleration: 0.43g

Mean speed: 15mph

RESULTS: Performance tests

Training: All 13 DELTA performance subtest measures stabilized with respect to means and variances in 1-6 trials

Motion sickness (MS) groups: (High-MS symptoms/Low-MS symptoms)

No significant differences between high and low-MS groups during field conditions in composite performance and 12/13 performance measures (exception: reaction time, $F(1,6)= 24.4$, $P<0.003$; however, the two groups differed during baseline training period)

Maximum reaction time increased and non-preferred hand tapping

decreased in the high-MS, relative to the low-MS group (interaction, $F(5,30)>4.2$, $P<0.05$)

No changes in performance were observed in subject #3 in association with two incidences of emesis

Seat position groups: (Seat #1/Seat #4)

No significant differences between high and low-MS groups during field conditions in any performance measures

Composite performance improved in seat #4, relative to seat #1 from pre-field/field/post-field conditions ($F(2,12)=4.6$, $P<0.04$)

Code substitution accuracy improved in seat #4, relative to seat #1 across all field conditions ($F(5,30)=4.2$, $P<0.005$)

Condition trials: (Prefield/Field course trial means/Post-field)

Performance decrements of –5.9 to –9.8% were found in preferred and non-preferred hand tapping and pattern comparison accuracy in field conditions relative to pre/post field ($P<0.04$)

Field course trials: (Stat., paved road, level XC, hills XC, gravel, stat.)

Field course performance changes were found in composite performance and four subtest measures ($F(5,30)>2.6$, $P<0.05$)

Post-gravel course decrements were detected in composite performance (-2.6 to -6.6%, $P<0.05$), relative to stationary trials

Post-paved road (Dyno) course decrements were detected in composite performance and pattern comparison accuracy and latency (-4.0 to –13.0%, $P<0.05$), relative to stationary trials

Post-level XC course decrements in composite performance (-14.1 %, $P<0.01$), relative to stationary trials

Post-gravel course decrement in composite performance (-7.9%, $P< 0.02$) relative to post-hills XC

CONCLUSIONS.

Motion sickness symptoms probably resulted from a combination of vehicle pitch and yaw motions and subject attention to computer video games on the field courses

Motion sickness, vehicle seat position, prior night sleep loss and crewmember prior C2V vehicle experience had no consistent significant effects upon performance levels

The absence of significant motion sickness symptom effects upon performance may reflect relief of malaise in the two emesis incidents, Sufficient subject motivation and coping ability to diminish symptom effects upon performance, or a self-selection process in which C2V duty volunteers may be relatively resistant to motion sickness effects

A confinement effect was observed in which several performance measures Deteriorated in the stationary vehicle relative to a classroom environment. A similar confinement effect was observed in a previous study conducted at Aberdeen Proving Ground, MD and in a subsequent C2V performance study at Ft Hood, TX in which it was attributed to either classically conditioned MS symptoms or distractions created by anticipation of potential adverse effects of the impending field tests

Accumulated workload and vehicle environmental exposure fatigue, possibly enhanced by prior night sleep loss and drowsiness, likely contributed to progressive performance deterioration observed in this study and in a subsequent C2V performance study at Ft Hood, TX

Prior night sleep loss, drowsiness and exposure to ambient temperatures >85° for up to 4.6 hr may have contributed to performance deterioration during the field runs but there is no direct evidence for these relationships

Significant performance decrements induced by exposure to paved road, gravel and level cross country, but not hills cross country courses, indicates:

a) The detrimental effects of these environments upon performance carried over the subsequent stationary trials
b) Differences between the effects of the different courses upon subsequent performance may have resulted from differences in the course road conditions on vehicle vibration frequency and intensity

Performance decrements in response to field conditions were generally greater for measures of performance accuracy (# correct minus # errors) than for performance response latency

Integrative visuo-spatial perception (pattern comparison) was the performance subtest skill most significantly affected by the differences in the field test courses

REFERENCES.

NASA ARC-U.S. Army Yuma Proving Ground, AZ study

1. Cowings, P.S., W.B. Toscano and C.W. DeRoshia An Evaluation of the Frequency and Severity of Motion Sickness Incidences in Personnel Within the Command and Control Vehicle. Ames Research Center, Moffett Field, CA: NASA Technical Memorandum 112221, 28 p., 1998.

2. DeRoshia, C.W., P.S. Cowings and W.B. Toscano. Effects of U.S. Army Command and Control Vehicle (C2V) operational environment upon human performance. Aviat. Space Environ. Med. 71: 306, 2000.

NASA ARC-U.S. Army Ft. Hood, TX study

1. Cowings, P. S., W.B. Toscano, C. DeRoshia and R.Tauson. Effects of Command and Control Vehicle (C2V) Operational Environment on Soldier Health and Performance. Ames Research Center, Moffett Field, CA: NASA Technical Memorandum 1999-208786, 40 p., 1999.

2. Cowings, P.S., W.B. Toscano, C. DeRoshia and R. Tauson. Motion sickness in the Command and Control Vehicle (C2V) – Space technology applied on earth. Aviat. Space Environ. Med. 71: 334, 2000.

NASA ARC: Human Performance in Space Analog Environmental studies utilizing the DELTA performance test battery subtests

1. DeRoshia, C.W. The effect of habitability and selection upon human performance and mood during head down bed rest. In: Exercise Countermeasures for Bed-Rest Deconditioning (1986): Final Report, Greenleaf, J.E. (ed.), Ames Research Center, Moffett Field, CA: NASA Technical Memorandum 103987, pp. 117-132, 1993.

2. DeRoshia, C.W. and J.E. Greenleaf. Performance and mood-state parameters during 30-day 6^{o} head-down bed rest with exercise training. Aviation Space and Environmental Medicine 64: 522-527, 1993.

DeRoshia, C.W., Y. Kawai, G. Murthy, D.E. Watenpaugh, G.A. Breit and A.R. Hargens. The effect of head-down tilt induced changes in cerebral blood flow upon human performance. Aviat. Space Environ. Med. 65(5): 466,1994.

3. Cowings, P.S., C. Stout, W.B. Toscano, S. Reynoso, C. DeRoshia and N.E. Miller. The Effects of Promethazine on Human Performance, Mood States, and Motion Sickness Tolerance. Ames Research Center, Moffett Field, CA: NASA Technical Memorandum 110420, 24 p, 1996.

4. Cowings, P.S., W.B. Toscano, B. Taylor, L. P. Kornilova, I.B. Koslovskaya, S.V. Sagalovich, A.V. Ponomarenko, C.DeRoshia and N.E. Miller. Control of autonomic responses during long-duration spaceflight - two case studies. . Aviat. Space Environ. Med. 71: 344, 2000.