UNCLAS

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER M38/84	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Effects of Dehydration and Cold Exposure with Fluid Restriction upon Cognitive Performance		5. TYPE OF REPORT & PERIOD COVERED Manuscript
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) L. E. Banderet, et al.		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Research Institute of Environmental Medicine, Natick, MA 01760-5007		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 54882101011 S10/CA WU-011
11. CONTROLLING OFFICE NAME AND ADDRESS Same as 9.		12. REPORT DATE 22 Oct 84
		13. NUMBER OF PAGES 13
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLAS
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution is unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

DTIC ELECTE APR 0 2 1985 S D E

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

cognitive performance, dehydration, cold, physical work, coding, number comparison, computer interaction, pattern comparison, grammatical

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

See reverse.

85 03 13 187

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLAS

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

AD-A151 973

DTIC FILE COPY

Controlled studies of cognitive performance in cold environments are rare. The present study examined the effects of initial hydration state upon cognitive performance during cold exposure. Five tests (Coding, Number Comparison, Computer Interaction, Pattern Comparison, and Grammatical Reasoning) were used to assess the cognitive performance of 36 male Marine volunteers. Assessment methods and four of the tests were adapted from the Navy's program, Performance Evaluation Tests for Environmental Research (PETER); the Computer Interaction Test was developed at USARIEM. All subjects practiced the tests extensively the 3 days before the cold exposure. Each test was usually given 5 times per day for 4 minutes per administration. Computer Interaction was practiced 5 times per day for 7 minutes.

Two groups of 18 subjects each were studied, 21 days apart, for 10 consecutive days. The second group of subjects was dehydrated by 2.5% of their body weight by severe fluid restriction and exercise-induced sweating the day before the cold exposure; the first group was normally-hydrated. All subjects spent 5 days in an environmental chamber where temperatures during the day were -23 to -25°C with 4 km/h winds and night conditions ranged from -4 to -10°C without wind. In the cold the subjects wore protective Artic Uniforms; afterwards, recovery was evaluated for 27 hours. All cognitive assessment was interspersed with extensive physical work. Subjects exercised vigorously each day by walking, running, and pulling simulated loads on a treadmill. Handware was worn during precold, cold, and recovery testing. The subjects' fluid intake was controlled and limited throughout the study.

The results indicate that dehydration or cold exposure with limited intake of fluids impairs cognitive performance. The five tests assessed different processes and all tests, except Grammatical Reasoning, were sensitive to cold and to 2.5% dehydration at room temperature. Before dehydration, both groups' performances were comparable on the Coding, Number Comparison, and Computer Interaction Tests. The performance of the dehydrated group, before the cold exposure, was 70-90% of the normally-hydrated group (15th testing) and 79-90% of their prior peformance when they were hydrated (6 & 7 testings). These differences were statistically significant, except for Grammatical Reasoning. Both groups' performances were comparable in the cold and 71-81% of the normally-hydrated group's pre-cold performance. Performance in the cold was not affected by the initial hydration state but recovery lagged in the predehydrated subjects. The similarity of performance impairments observed for dehydration at room temperatures and for cold suggests that 2.5% dehydration produces impairments as great as those seen for extreme cold. Both dehydration and cold impaired cognitive performances.

Originator Supplied Keywords include:

Accession For
NTIS GRA&I ☒
DTIC TAB ☐
Unannounced ☐
Justification
By
Distribution/
Availability Codes
Dist | Avail and/or Special
A-1

See DD1473

Effects of Dehydration or Cold Exposure and Restricted Fluid Intake Upon Cognitive Performance

L.E. Banderet, Ph.D., SP4 D.M. MacDougall, B.S., D.E. Roberts, Ph.D.
US Army Research Institute of Environmental Medicine (USARIEM)
Natick, MA 01760
D. Tappan, Ph.D., M. Jacey, MS, & Lt. P. Gray, MC
Naval Submarine Medical Research Laboratory
Groton, CT 06340

ABSTRACT

Controlled studies of cognitive performance in cold environments are rare. Unfortunately, few cold studies include hydration as an independent variable, and some studies confound performance and handware effects. The present study examined the effects of initial hydration state upon cognitive performance during cold exposure. Five tests (Coding, Number Comparison, Computer Interaction, Pattern Comparison, and Grammatical Reasoning) were used to assess the cognitive performance of 36 male Marine volunteers. Assessment methods and four of the tests were adapted from the Navy's program, Performance Evaluation Tests for Environmental Research (PETER); the Computer Interaction Test was developed at USARIEM. All subjects practiced the tests extensively the 3 days before the cold exposure. Each test was usually given 5 times per day for 4 minutes per administration. Computer Interaction was practiced 5 times per day for 7 minutes.

Two groups of 18 subjects each were studied, 21 days apart, for 10 consecutive days. The second group of subjects was dehydrated by 2.5% of their body weight by severe fluid restriction and exercise-induced sweating the day before the cold exposure; the first group was normally-hydrated. All subjects spent 5 days in an environmental chamber where temperatures during the day were -23 to -25°C with 4 km/h winds and night conditions ranged from -4 to -10°C without wind. In the cold the subjects wore protective Artic Uniforms; afterwards, recovery was evaluated for 27 hours. All cognitive assessment was interspersed with extensive physical work. Subjects exercised vigorously each day by walking, running, and pulling simulated loads on a treadmill. Handware was worn during precold, cold, and recovery testing. The subjects' fluid intake was controlled and limited throughout the study.

The results indicate that dehydration or cold exposure with limited intake of fluids impairs cognitive performance. The five tests assessed different processes and all tests, except Grammatical Reasoning, were sensitive to cold and to 2.5% dehydration at room temperature. Before dehydration, both groups' performances were comparable on the Coding, Number Comparison, and Computer Interaction Tests. The performance of the dehydrated group, before the cold exposure, was 70-90% of the normally-hydrated group (15th testing) and 79-90% of their prior peformance when they were hydrated (6 & 7 testings). These differences were statistically significant, except for Grammatical Reasoning. Both groups' performances were comparable in the cold and 71-81% of the normally-hydrated group's pre-cold performance. Performance in the cold was not affected by the initial hydration state but recovery lagged in the predehydrated subjects. The similarity of performance impairments observed for dehydration at room temperatures and for cold suggests that 2.5% dehydration produces impairments as great as those seen for extreme cold. Both dehydration and cold impaired cognitive performances.

INTRODUCTION

Dehydration can profoundly affect behavior, especially when combined with elevated body temperatures. With marked dehydration heat exhaustion or heat stroke and death may result (1,6,16). Changes in emotion (6), aggression (6), cognitive performance (16), jet fighter crew performance (4), video target acquisition (10), and hand steadiness, dexterity, and coordination (9,13,18) have also been reported. Some studies have also shown negative results. Number Comparison and Choice Reaction Time performance were not affected by 3% dehydration (2) nor were visual reaction times to central and peripheral stimuli for 2.5 or 5% dehydration (12).

Most dehydration studies have examined physiological changes during heat exposure; few have investigated cognitive or psychomotor performance. Studies of dehydration and mental performance in cold environments are even rarer and many studies of cold do not manipulate dehydration as an independent variable. Typically, performance studies in cold investigate tasks which require hand steadiness, dexterity, and coordination, e.g. (13,18).

The purpose of this study was to investigate the effects of dehydration upon cognitive performance under normal and cold temperature conditions. Cognitive performance was evaluated by five tests, which were sensitive to 4600 m simulated high altitude in one of our prior investigations.

METHODS

Thirty-six active duty, male Marine Corps personnel from Camp LeJeune, NC, were the subjects of this study. All were fully informed volunteers. Their average age was 22.0±4 (SE) years and weight 76.54±1.12 (SD) kg.

Our investigation was part of a larger collaborative study with personnel from the Naval Submarine Medical Research Laboratory, Groton, CT, and other personnel from USARIEM in which dehydration indices (17), physical work performance (14,17), hand cooling (17), and map plotting performance were evaluated. Two groups of 18 subjects each, were studied 21 days apart. Each group was studied over 10 consecutive days in a large climatic chamber at the US Army Natick Research and Development Center, Natick, MA, where subjects were exercised and tested during the day and housed at night. In the first group studied subjects were fully hydrated before the cold exposure; the second group was dehydrated 2% by body weight. For our purposes, these groups were regarded as normally-hydrated and predehydrated.

Testing on days 1-3 of each study was at 20 to 27°C and was used to establish baselines. On day 3 subjects in the predehydrated group lost 3% of their body weight by severe fluid restriction and sweat losses over 10 hours. In the evening they were rehydrated to 2%. On days 4-8 all soldiers wore the protective Arctic uniform and were challenged with -23 to -25°C and 4 km/h winds from 0700 to 1530 h. During these evenings, conditions warmed to -4 to -10°C and there was no wind. Normal temperature was restored and rehydration was begun on days 9-10. A program of vigorous physical activity was maintained on days 1-8. Subjects were given adequate food but were limited in the fluid intake permitted them.

Five paper and pencil tests of cognitive performance were administered during the study. Each test had 15 alternate forms and sample items are shown (Fig 1). The Computer Interaction Test was developed at USARIEM. The other tests were adapted from items in a publication (5) from the Navy's Program, Performance Evaluation Tests for Environmental Research, i.e. PETER (3). The Coding Test requires that subjects write symbols for different numbers from the legend at the top of the page. This test is similar to procedures for manually encoding sensitive military radio communications. Subjects performing the Number Comparison Test indicate if the numbers in each horizontal pair are the same or different. Such test demands are similar to comparing part numbers, map grids, or numbers on property decals.

The Computer Interaction Test evaluates a person's global transactions with a "computer" system. Subjects use a 12-digit desk top calculator with a liquid crystal display (Radio Shack EC-2004) to solve problems like those in Fig 1. A plastic plate covers several calculator function keys not required during testing. The Computer Interaction Test requires actions like those of some military personnel who use computer keyboard and display systems. In general, information is entered into the calculator, one of six sequential operations is performed, and display information is transcribed onto the test form. The result may require rounding, depending upon the answer's characteristics.

Each Pattern Comparison problem consists of two patterns with the same number of asterisks, i.e. 6, 7, or 8. On some problems, a single asterisk in one of the patterns will be displaced slightly. Subjects indicate if the patterns on each problem are the same or different. Grammatical Reasoning is a test of verbal comprehension in which the subjects decide if a two letter series (sample) is described correctly by a statement. This test evaluates understanding of various grammatical transformations of language, e.g. "A precedes B", "A is preceded by B". Grammatical Reasoning performance evaluates processes similar to those for understanding written information, e.g. orders, technical procedures, and training manuals.

The Arctic chamber and other study activities created a dynamic setting with distractions and special challenges for cognitive testing.

Cognitive testing was interspersed between exercise intervals and the requirements of other investigators. Typically, 9 subjects were tested while the other 9 subjects were exercised. Testing sessions usually began 2-3 minutes after 15 minutes of heavy exercise. We did not attempt to reduce the noise from the two large 5-person treadmills or the extraneous sounds produced by the exercising group during cognitive testing. When subjects were released to other studies, they were tested (if possible) when they returned.

All tests were timed. Computer Interaction was evaluated for 7 minutes per administration; all other tests were evaluated for 4 minutes. Subjects were urged to work as quickly and accurately as possible. No subjects completed all problems on any test in the time allowed. Subjects were instructed formally before each test was given on day 1. To provide individual feedback, data sheets were given to subjects showing their sequential test scores (number of problems attempted and number of errors) on days 1 and 2 and at the end of day 3. If individual error rates were greater than 10% after 8-10 administrations, comments written on the data sheet and/or verbal feedback suggested the subject work slower to reduce errors.

Each cognitive test was practiced several times the first few days to produce stable and near maximal baselines. Both groups were given each test 5 times daily on days 1-3, except group 1 which was tested 4 times on day 1. Subjects were tested twice daily at 0800 and 1300 h during the cold and restricted fluid intake (days 4-8) and recovery (days 9-10) conditions. Subjects wore handware during most cognitive testing. Group 2 wore the Artic mittens with woolen inserts on days 3-9. Group 1 wore military gloves with woolen inserts on days 2, 3, and 4; on days 5-9 they switched to the Artic mittens and inserts after the gloves were found inadequate for the cold. Wooden pencils, 1 cm in diameter, were used to complete the tests.

The mean number of problems correct per minute was calculated to provide a single performance score for each test. A correction factor to penalize for guessing was used with the Number Comparison, Pattern Comparison, and Grammatical Reasoning Tests. On days 4-8, the two daily administrations of each test were averaged to yield a single score.

Body weights were determined at 0600 h daily shortly after awakening and voiding of urine. Subjects were weighed in their briefs in an adjacent room that was heated. On day 3 subjects were weighted nude 3-4 times to document hydration state. Control body weights, i.e. 100% body weight, were the average of day 1 and 2 weights. Percent change from 100% body weight was also calculated. All data were analyzed using 2V repeated measures analysis of variance programs created with BMDP statistical software (7). The statistical significance of individual data points was determined with Tukey's HSD statistic for selected multiple comparisons (15). Statistical significance was specified as $p<0.05$.

RESULTS

Day 3 fluid restrictions imposed in the predehydration group were effective. After 8 hours, the group was 2.1% dehydrated as inferred from changes in body weight; after 10 1/2 hours, the group was 2.9% dehydrated. We assume subjects were dehydrated ~2.5% at 9-10 hours during cognitive testing. In contrast, after 5 hours (before fluids were replaced) the body weight of the normally-hydrated group decreased 1%. After 10 1/2 hours, this group was dehydrated 0.7%.

Performances on the Coding, Number Comparison, and the Computer Interaction Tests are shown in Fig 2. Day 1 and 2 values are the averages for test administrations 2+3 and 6+7, respectively; day 3 data are from the 15th administration. Coding, Number Comparison, and Computer Interaction performances were significantly impaired by 14.2, 10.5, and 30.4% in the predehydrated group ($p<0.01$) at room temperature. Comparable data are shown for the Pattern Comparison and Grammatical Reasoning Tests (Fig 3). Normally-hydrated group values for day 3 were adjusted to compensate for significant ($p<0.05$) group differences (admin. 8) before completing the Pattern Comparision and Grammatical Reasoning analyses. After adjustment, the Pattern Comparison performance of the predehydration group was impaired by 14.6% ($p<0.01$). Grammatical Reasoning performance was not affected by 2.5% dehydration.

Body weight fell during the cold with restricted fluid intake challenge (Fig 4). Before the cold challenge (end of day 3), the normal-hydration group was 0.4% lighter than their 100% body weight values, but they lost 1.7% more during days 4-8 in the cold. All their body weight changes, except day 3, were significantly different from their 100% body weight ($p<0.01$). In contrast, the predehydration group's weight loss was 2.7% just before the cold challenge and they lost but 0.2% more by day 8. Their within-group weight losses were also significantly different than control ($p<0.01$). Because the initial weight loss of group 2 was not restored, between-group weight losses were significantly greater in group 2 on days 4 ($P<0.01$), 6 ($P<0.05$), 7 ($P<0.05$), and 8 ($p<0.05$). After 24 hours of recovery, the body weights of groups 1 & 2 were significantly less, i.e. 1.1 and 1.9%, than their controls ($p<0.01$).

Fig 2 & 3 also show the impact of cold and fluid restriction upon performance. Performance on the Coding, Number Comparison, Computer Interaction, and Pattern Comparison Tests was significantly impaired from baseline ($p<0.01$) for the combination of cold and fluid restriction, with a few exceptions. Coding did not differ significantly from baseline (day 4, normal-hydration group) nor did Number Comparison on days 5, 7, and 8 (predehydration group). Consistent with the 2.5% dehydration data, at no time was Grammatical Reasoning impaired significantly in the cold. Maximal performance decrements on the Coding, Number Comparison, Computer Interaction, and Pattern Recognition Tests during the cold and fluid restriction condition were 28.2, 19.2, 27.1, and 33.6% of the normal-hydration group's control performance.

We also compared the predehydrated group's performance on each test during the cold and fluid restriction condition with their day 3 performance when they were dehydrated. Only once (Pattern Comparison, day 6) was performance in the cold and fluid restriction condition more impaired than that observed on day 3 for 2.5% dehydration at room temperatures ($p<0.01$). On all other occasions, performance impairments for cold and for 2.5% dehydration at room temperature were similar.

When normal temperature was restored and rehydration was begun (day 9), the two groups were compared. After 6 hours, the performance of the normally-hydrated group on the Coding, Number Comparison, Computer Interaction, and the Pattern Comparison Tests was not significantly different than their day 3 control values. Their Grammatical Reasoning performance at 6 hours actually exceeded baseline performance ($p<0.01$). Number Comparison performance in the predehydration group did not differ from the baseline performance of the normally-hydrated group; however, Computer Interaction ($p<0.05$), Coding ($p<0.05$), and Pattern Comparison ($p<0.01$) performances remained impaired. The next morning, 19 hours later, performance on these three tests was equivalent or superior to baseline.

The predehydration and normal-hydration groups were compared at equivalent times during the study for possible group differences. During the cold and fluid restriction condition the performance of both groups on the five tests was remarkably similar, except for the predehydration group's greater performance on Number Comparison on day 7 ($p<0.01$) and day 8 ($p<0.05$). On the other four tests and at all other times during the cold and fluid restriction condition, the groups' performances were similar.

Similar group trends emerged during recovery. After 1 and 24 hours the groups' performances were not different on any of the tests, except the predehydrated group's performance was greater on Pattern Comparison ($p<0.01$). As noted earlier, after 6 hours of recovery the predehydration group had not recovered as fully as the normal-hydration group. Hence, between-group comparisons at 6 hours showed the normal-hydration group's performances exceeded that of the predehydration group on the Computer Interaction ($p<0.01$), Coding ($p<0.01$), Pattern Comparison ($p<0.01$), and Grammatical Reasoning ($p<0.05$) Tests. Performance on Number Comparison did not differ.

The two groups were also compared with data collected before the dehydration manipulation. We only compared administrations 5 and 8 from day 2, but both groups' performances on the Number Comparison and Computer Interaction Tests were similar. Coding performances were similar on administration 5 but the predehydration group had greater scores on administration 8 ($p<0.01$). On Pattern Comparison the predehydration group had greater scores initially ($p<0.01$); later the normal-hydration group did ($p<0.05$). On Grammatical Reasoning the normally-hydrated group's performance was greater ($p<0.01$) on both administrations.

DISCUSSION

Dehydration at normal room temperatures and cold with fluid restriction produced significant performance impairments on the Coding, Number Comparison, Computer Interaction, and Pattern Comparison Tests. The Grammatical Reasoning Test was not affected. The changes observed on the four tests are interesting since the tests require varied processing (e.g., numbers, symbols, patterns, or numbers and words) and have different memory and hand coordination requirements. This finding suggests a range of cognitive processes are affected by dehydration at room temperatures or cold. Our data contrast with earlier studies that showed no effects on Number Comparison Performance after 3% dehydration in 14 subjects (2) or visual reaction times after 2 1/2 or 5% dehydration (12).

Before dehydration was induced, there were performance differences on the Pattern Comparison (admin. 8) and Grammatical Reasoning (admin. 5 & 8) Tests between the predehydrated and normally-hydrated groups. To offset the higher than expected scores for the normally-hydrated group on each test, their scores (admin. 15) were decreased by the group difference observed earlier (admin. 8). Even with this adjustment, Pattern Comparison Performance was significantly impaired after 2.5% dehydration; Grammatical Reasoning was not.

We were surprised that Grammatical Reasoning Performance was not impaired by dehydration. Our previous work at 4600 meters simulated high altitude demonstrated impairments and the test is sensitive to other stressful conditions in the literature. We suspect that our subjects had not received enough training and feedback. This is supported by the fact that Grammatical Reasoning Performance was equivalent in the two groups at the end of the study and our experience has shown Grammatical Reasoning to be one of the more difficult tests that we administer for subjects to understand.

Cold and restricted fluid intake also impaired the same four cognitive tests that were affected by 2.5% dehydration at room temperatures. There were some exceptions such as Coding performance (day 4, normally-hydrated group) and Number Comparison Performance (days 5, 6, and 8, predehydration group). We have no hypotheses or explanations for these nonsignificant data. The fact that Grammatical Reasoning was not affected contrasts with a study reporting enhanced performance during a cold exposure (8).

The literature suggests that performance decriments in the cold are probably due to changes in manual dexterity and distracting stimuli (11). Our test battery emphasizes thinking and processing of information so manual dexterity would be less important for our tests than those that measure psychomotor performance, e.g. (13,18). Our experience in the cold also suggests that competing activities, e.g. moving the hands or feet to keep them warm, are probably also an important factor.

Our data indicate that each group's performances on the four tests were not significantly different during the cold and restricted fluids condition except for days 7 and 8 on the Number Comparison Test. The earlier substantial performance changes observed for dehydration at room temperature and the consistent difference in weight loss, i.e. dehydration, of the two groups in the cold suggest if there are dehydration effects they are probably masked by the effects of cold.

Impairments on the Coding, Number Comparision, Computer Interaction and Pattern Comparison Tests for the cold and restricted fluid intake condition were comparable to those for 2.5% dehydration in comfortable temperatures. This finding suggests 2.5% dehydration at comfortable temperatures can have effects upon cognitive performance which are as great as those observed at −23 to −25°C. A second consequence of dehydration is suggested by our finding that performance impairments were present on three of the four sensitive tests after 6 hours of recovery. This suggests that cognitive performance impairments from dehydration may persist after partial hydration has occurred.

CONCLUSIONS

1. Subjects dehydrated 2.5% of their body weights at room temperature exhibited impaired cognitive performances on the Coding, Number Comparison, Computer Interaction, and Pattern Comparison Tests. The Grammatical Reasoning Test was not affected.

2. Performance also deteriorated on the same four tests during a 5-day cold exposure (−23 to −25°C) with restricted fluid intake.

3. Performance decrements observed for 2.5% dehydration (room temperature) were as large as those observed with cold and restricted fluid intake.

4. Performance during the cold and restricted fluid intake condition was not different in subjects who began normally hydrated or dehydrated 2%.

5. Subjects, dehydrated 2% before cold exposure, exhibited performance decrements longer during recovery on three of the four cognitive tests than the normally-hydrated group.

REFERENCES

1. Adolph, E.F. Physiology of Man in the Desert. Interscience Publishing, New York: 1947.

2. Bijlani, R.L., and K.N. Sharma. Effect of Dehydration and a Few Regimes of Rehydration on Human Performance. Indian Journal of Physiological Pharmacology. 24(4):255-266: 1980.

3. Bittner, A.C. Jr., R.C. Carter, R.S. Kennedy, M.M. Harbeson, and M. Krause. Performance Evaluation Tests for Environmental Research: Evaluation of 112 Measures., Report #NBDL84R006, Naval Biodynamics Lab ., New Orleans, LA, August 1984.

4. Bollinger, R.R., and G.R. Carwell. Biomedical Cost of Low-Level Flight in a Hot Environment. Aviation Space and Environmental Medicine. 46: 1221-1226: 1975.

5. Carter, R.C., and H. Sbisa. Human Perfromance Tests for Repeated Measurements: Alternate Forms of Eight Tests by Computer. Naval Biodynamics Lab., New Orleans, LA, January 1982.

6. Cohen, I., D. Mitchell, R. Seider, A. Kahn, and F. Phillips. The Effect of Water Deficit on Body Temperature During Rugby. South African Medical Journal. 60(1):11-14: 1981.

7. Dixon, W.J., M.B. Brown, L. Engelman, J.W. Frane, M.A. Hill, R.I. Jennrich, and J.D. Toporek. BMDP Statistical Software. University of California Press, Berkeley, CA: 1983.

8. Ellis, H.D. The Effects of Cold on the Performance of Serial Choice Reaction Time and Various Discrete Tasks. Human Factors. 24(5): 589-598: 1982.

9. Enander, A. Performance and Sensory Aspects of Work in Cold Environments: A review. Ergonomics., 27(4):365-378: 1984.

10. Epsteim, Y., G. Keren, J. Moisseiev, O. Gasko, and S. Yachin. Psychomotor Deterioration during Exposure to Heat. Aviation, Space, and Environmental Medicine. 51(6):607-610: 1980.

11. Fox, W.F. Human Performance in the Cold. Human Factors. 9(3):203-220: 1967.

12. Leibowitz, H.W., C.N. Abernethy, E.R. Buskirk, O. Bar-Or, and R.T. Hennessy. The Effect of Heat Stress on Reaction Time to Centrally and Peripherally Presented Stimuli. Human Factors. 14(2):155-160: 1972.

13. Meese, G.B., R. Kok, M.I. Lewis, and D.P. Wyon. The Effects of Moderate Cold and Heat Stress on the Potential Work Performance of Industrial Workers: Part 2. CSIR Research Report 381/2. National Building Research Institute Council for Scientific and Industrial Research. Pretoria, South Africa, 1981.

14. Roberts, D.E., J.F. Patton, J.W. Pennycook, U.S. Army Research Institute of Environmental Medicine, Natick, MA, and M.J. Jacey, D.V. Tappan, P. Gray, and E. Heyder. Naval Submarine Medical Research Laboratory, Groton, CT. Effects of Restricted Water Intake on Performance in a Cold Environment. Technical Report No. T 2/84, May 1984.

15. Steel, R.G.D., and J.H. Torrie. Principles and Procedures of Statistics with Special Reference to the Biological Sciences. McGraw Hill, New York: 1960.

16. Strydom, N.B., C.H. Van Graan, J.H. Viljoen and A.J.S. Benade. Physiological Performance of Men Subjected to Different Water Regimes over a Two-Day Period. South African Medical Journal. 42(5):92-95: 1968.

17. Tappan, D.V., M.J. Jacey, E. Heyder, and P.H. Gray. Dehyration as a Potential Controlling Factor of Fat Loss During Cold Exposures. Naval Submarine Medical Research Laboratory, Groton, CT, May 1984.

18. Wyon, D.P., R. Kok, M.I. Lewis, and G.B. Meese. Effects of Moderate Cold and Heat Stress on Factory Workers in Southern Africa. South African Journal of Science. 78(5):184-189: 1982.

ADDENDUM

Human subjects participated in these studies after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 on Use of Volunteers in Research.

The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation.

FIGURE CAPTIONS

Fig 1 - Sample items from the cognitive tests used in the study.

Fig ~~2~~ 4 - Baseline (100%) and successive body weights during the cold and restricted fluid challenge. Control subjects began the cold exposure normally-hydrated; whereas, other subjects were predehydrated.

Fig ~~3~~ 2 - Cognitive performance on the Coding, Number Comparison, and Computer Interaction Tests for training, 2.5% dehydration at room temperatures, cold exposure with restricted fluids, and recovery.

Fig ~~4~~ 3 - Cognitive performance on the Pattern Comparison and Grammatical Reasoning Tests for training, 2.5% dehydration at room temperatures, cold exposure with restricted fluids, and recovery.

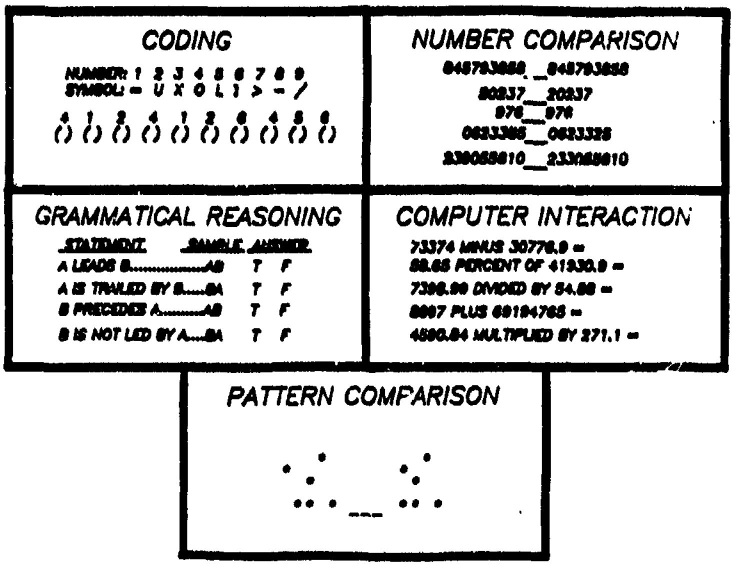
CODING
NUMBER COMPARISON
GRAMMATICAL REASONING
COMPUTER INTERACTION
73374 MINUS 30776.9 =
PATTERN COMPARISON

Fig 1

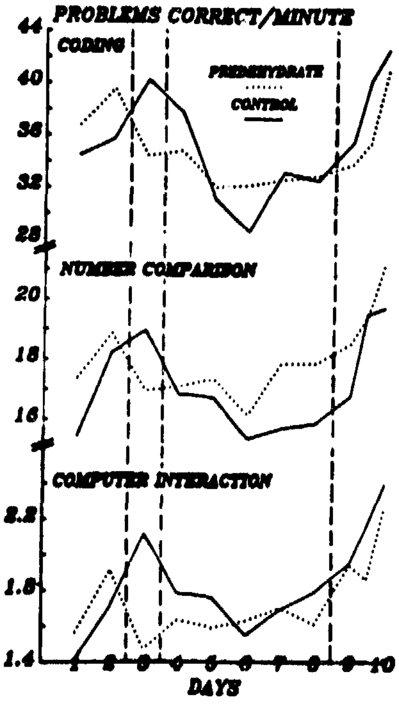
PROBLEMS CORRECT/MINUTE
CODING
PREDEHYDRATE
CONTROL
NUMBER COMPARISON
COMPUTER INTERACTION
DAYS

Fig 2

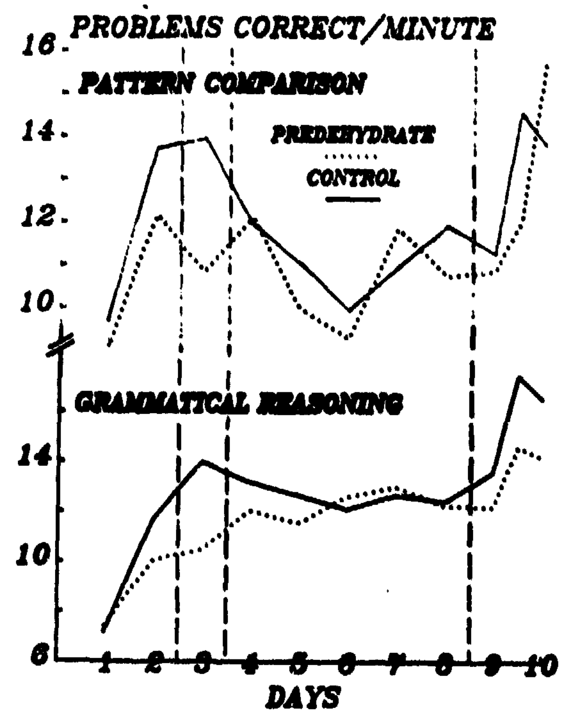
PROBLEMS CORRECT/MINUTE
PATTERN COMPARISON
PREDEHYDRATE
CONTROL
GRAMMATICAL REASONING
16
14
12
10
14
10
6
1 2 3 4 5 6 7 8 9 10
DAYS

Fig 3

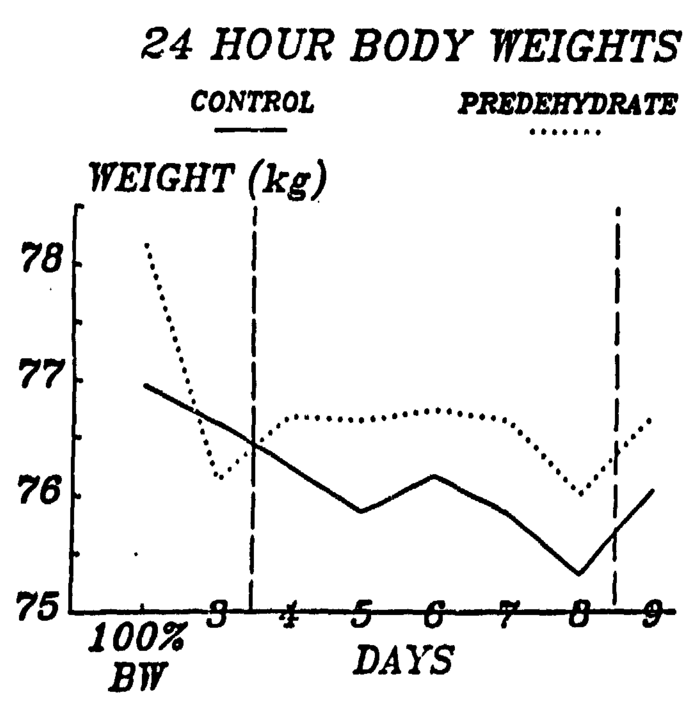
24 HOUR BODY WEIGHTS
CONTROL
PREDEHYDRATE
WEIGHT (kg)
78
77
76
75
100% BW
3 4 5 6 7 8 9
DAYS

Fig 4