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Effects of Mild-to-Moderate Ambient Cold and Chemical Protective Clothing (MOPP-IV) on Cognitive Performance of Male and Female Soldiers: An Addendum to Technical Reports T11-85 and T7-88

**U S ARMY RESEARCH INSTITUTE
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Previous reports from this Institute describe two studies in which ambient heat (32.8°C, 61% rh) was found to affect the mental performance of male and female soldiers wearing chemical protective clothing (MOPP-IV). In the first study (T11-85), impairment of the performance of males was found after 4-5 hours. In the second study (T7-88), female soldiers, under identical conditions, showed impairment within three hours and fewer were able to sustain performance for the entire seven-hour exposure. A "MOPP-Control" condition was included in both studies to assess performance in MOPP-IV without heat stress. The ambient temperature for this condition (12.8°C) was determined by calculating its thermal comfort equivalence with another control condition in which only the Battle Dress Uniform (BDU) was worn (21.1°C). The matching of the two conditions for thermal comfort enables differences between them to be attributable to aspects of the MOPP system other than its insulation. Key points					
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Large decrements in performance, not easily accounted for by any aspects of the MOPP system, were found for both males and females when in the MOPP-Control condition. To further understand these decrements, data from both studies have been reviewed. It was discovered that a metabolic rate for active (150 watts) rather than inactive (100 watts) personnel was used in determining the appropriate temperature for the MOPP-Control condition. Revised calculations, which assume metabolic rates of 100 watts for men and 85 watts for women, estimate ambient temperatures of 16.3°C and 19.2°C for males and females respectively, as the appropriate MOPP-Control subjective comfort matches for the BDU-Control condition.

The new information suggests that, in both studies, personnel were exposed to a mild to moderate cold stress while in the MOPP-Control condition. This may account for a significant portion of the decrements in performance noted. The results suggest potentially serious operational problems for mental performance in MOPP-IV in mild to moderately cold environments as well as in the heat.

Effects of Mild-to-Moderate Ambient Cold and Chemical
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BERNARD J. FINE



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EXECUTIVE SUMMARY

Previous reports from this Institute (T11-85 and T7-88) describe two studies in which mental performance of males and females was found to be poorer in heat (32.8°C;61%rh) in MOPP-IV than in an optimal climate (21.1°C;35%rh) in Battle Dress Uniform ("BDU-Control"). In both studies, an additional experimental condition ("MOPP-Control") measured the impact of MOPP-IV on performance exclusive of any heat load it imposed on the wearer. This was accomplished by determining a temperature for this condition (calculated as 12.8°C) which was the thermal comfort equivalent of the optimal BDU-Control condition (21.1°C). Given thermal comfort equality, performance differences between the two conditions presumably were attributable only to non-thermal aspects of the protective clothing.

Large decrements in performance occurred in the MOPP-Control condition in both studies. These were thought to be due to stress imposed by the "novelty-of-the-situation." However, the threefold increase in errors on some tasks greatly exceeds what is expected of experienced personnel in a novel situation. Our continued concern with this matter has led to a complete review of both studies in search of additional explanation.

As a result of the review, we report here the discovery of an error which appears to explain the results discussed above and which also suggests the possibility of operational problems with troops in MOPP-IV in climates not heretofore considered to affect mental performance.

The error was in using a metabolic rate for active rather than inactive personnel in the formula for calculating thermal comfort equivalence between MOPP- and BDU-Controls. This resulted in an inappropriately low ambient temperature for the MOPP-Control condition. In addition, the somewhat lower metabolic rates characteristic of women were not taken into consideration in the female study. Amended calculations indicate that instead of 12.8°C, ambient temperatures of 16.3°C and 19.2°C, for males and females, respectively, are the appropriate MOPP-Control equivalents of the BDU-Control condition. In both studies, then, personnel in the MOPP-Control condition were exposed to a mild-to-moderate cold stress and their performance probably was related to that fact.

Scientific explanations of how cold affects mental performance are lacking. Our experience with the tasks suggests that the decrements are not due to direct physical effects of cold, e.g., cold hands limiting manipulation of tools. Research is planned to explore the problem further. Meanwhile, commanders should be alerted to the possible impact of hot and cold environments on mental performance of troops in MOPP-IV. Particular care should be taken to insure that communications to or from personnel in MOPP-IV are verified for accuracy and completeness. This is particularly important when personnel are in situations requiring intense, sustained concentration wherein we have noted mental lapses and substantial increases in errors of omission.

INTRODUCTION

In this report, new information is presented which modifies interpretations of some of the research results previously published in two technical reports (T11-85 and T7-88) from this Institute. Both reports dealt with the topic of mental performance in hot environments in chemical protective clothing.

A synopsis of the two reports is presented, followed by an addendum describing the new information and recommendations for its implementation.

SYNOPSIS OF TECHNICAL REPORTS T11-85 AND T7-88

In two studies using identical designs, procedures and tasks, the mental performance of both male (Fine & Kobrick, 1985; T11-85) and female (Fine, 1987; T7-88) soldiers, clad in chemical protective clothing (MOPP-IV), was found to be significantly poorer in a hot environment (32.8°C; 61%rh; "MOPP-Heat-Stress" condition) than in a comfortable environment (21.1°C; 35%rh) while clad in the Battle Dress Uniform (BDU; "BDU-Control" condition).

Males, as a group, began to show impairment after approximately 4-5 hours of exposure to heat, whereas females, as a group, showed impairment within 3-4 hours. Of greater importance, only 7 of 17 females, compared to 18 of 20 males, were able to endure the entire 7-hour heat exposure.

A third condition, referred to as "MOPP-Control," was included in each study to assess possible effects of the protective clothing itself on performance, that is, apart from any heat load it might impose on the wearer. To accomplish this, the appropriate ambient temperature for the MOPP-Control condition for comfort equivalence between it and the BDU-Control condition was calculated using the method of Breckenridge & Goldman (1977). An ambient temperature of 12.8°C was determined to be equivalent in subjective comfort when in MOPP-IV to an ambient temperature of 21.1°C when in BDU. This equivalence of subjective comfort presumably enables one to attribute any

differences in performance found between the two conditions to aspects of the protective clothing other than insulation.

In both the male and female studies, the MOPP-Control condition, when compared with the BDU-Control condition, was found to have significantly larger adverse effects on performance than expected. Substantial impairment occurred for both genders within the first hour at 12.8°C, and was significantly greater for females. The performance of the male group improved substantially over the 7-hour exposure while that of the female group did not.

In the study of males (Fine & Kobrick, 1985), four explanations were considered for the performance decrements in the MOPP-Control condition: (a) discomfort or anxiety associated with being encapsulated in the protective ensemble, (b) limitations in maneuverability, perception and/or dexterity imposed by the suit, gloves or mask, (c) stress associated with being in a novel situation, in MOPP-IV, faced with a grueling 7-hour exposure, and (d) random occurrence.

Because all participants had undergone a substantial amount of training on the tasks while wearing BDU as well as when in MOPP-IV, it was possible to compare performances in the two conditions, both by observation and with practice scores. Since no evidence of anxiety about encapsulation in MOPP-IV was noticed and we found no instances of the MOPP ensemble interfering with performance, alternatives (a) and (b) were discounted as plausible explanations.

Later, the results from the MOPP-Control condition of the female study (Fine, 1987) were found to corroborate those of the male study. This reduced the likelihood of random occurrence as a feasible explanation for the decrements in performance and "novelty-of-the-situation" remained as the reasonable alternative.

ADDENDUM TO TECHNICAL REPORTS T11-85 AND T7-88

The magnitude of the decrements in performance found in the MOPP-Control condition of both studies has been a source of continuing concern. For the female

group, in particular, the threefold increase in errors that occurred with the Codebook and Codewheel tasks over the entire 7-hour exposure is much greater than one would expect to be due to the novelty-of-the-situation.

In search of additional explanations for the decrements in performance, all aspects of both studies have been reviewed. While all computations of data were found to be correct, an error in the formulation of the appropriate temperature for the MOPP-Control condition has been discovered. The discovery at once helps to explain the performance decrements in that condition and suggests the possibility of operational problems with MOPP-IV in climates not heretofore regarded as particularly stressful for performance of mental tasks.

The error occurred in determining comfort equivalence between the BDU- and MOPP-Control conditions. In both studies, equivalence had been computed using the metabolic rate for physically active men (150 watts). Because the troops in both studies performed primarily sedentary tasks, a metabolic rate for physically inactive persons should have been used. Thus, the two conditions, in fact, were not equivalent in subjective comfort as had been supposed. In addition, in the female study, the somewhat lower metabolic rates characteristic of women should have been taken into account.

Revised calculations (Gonzalez, 1990), which assume metabolic rates of 100 watts for men and 85 watts for women, estimate ambient temperatures of 16.3°C and 19.2°C, for males and females respectively, as the appropriate MOPP-Control subjective comfort matches for the BDU-Control condition (21.1°C), rather than the ambient temperature which was actually used (12.8°C). (It should be noted that these are estimated group average metabolic rates and that the rates of individual participants may have deviated from them.)

In both studies, then, participants, while in the MOPP-Control condition, appear to have been exposed to a mild-to-moderate cold stress. The male group performed in an ambient temperature approximately 3.5°C below its revised subjective comfort level (16.3°C) and the female group at an ambient temperature about 6.4°C below its revised level (19.2°C). This factor appears to be a reasonable explanation of the decrements in performance, particularly since it can account for the comparably poorer performance of the women, their having been exposed to a subjectively colder

environment. Since there was no true MOPP-Control condition, due to the error discussed above, whether cold exposure replaces or only augments novelty-of-the-situation or encapsulation as an explanation for the poor performance remains to be determined.

Specific mechanisms by which the cold stress could have operated to cause decrements in performance are not clear. We have already indicated that the types of errors that occurred were errors of omission, e.g., missing incoming messages, rather than errors of commission, which would have been expected if the cold had interfered with manual dexterity, for example. While it is possible that discomfort associated with feeling cold could have interfered with attentional processes, leading to decreased attention and errors of omission, it is notable that only a few males and no females complained about feeling cold or uncomfortable during the exposure.

There is little additional explanatory help to be had from the very sparse literature on the effects of cold on cognitive performance. To clarify the results, further research using the same performance scenarios in conjunction with non-intrusive physiological measures is needed and is being planned.

RECOMMENDATIONS

Pending the acquisition of further information on the subject, commanders should be aware of possible decrements in mental performance in troops in MOPP-IV who are exposed to either hot or mildly-to-moderately cold environments. Precautions should be taken to insure that communications to or from personnel in MOPP-IV are repeated one or more times or are otherwise emphasized, particularly when personnel are in situations requiring intense concentration, such as monitoring radio messages, video displays, etc. We have noted mental lapses and substantial increases in errors of omission in such circumstances.

It would be extremely helpful if personnel who monitor troops performing mental tasks in MOPP-IV would communicate their observations of such activities, to include instances of successful and/or failed performance, as fully documented as possible, to

the author. Please specify the environmental and other conditions in which the work was performed. All comments and suggestions are valued. Send to:

Commander

US Army Research Institute of Environmental Medicine

ATTN:SGRD-UE-HP/Dr. Fine

Natick, MA 01760-5007

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