NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

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REPORT NUMBER 1067

THE EFFECT OF COLD TRAINING AND THE WEARING OF GLOVES on MANUAL PERFORMANCE IN THE COLD: A COMPARISON OF PURE ABILITY AND OPERATIONAL TASKS

by

William H. ROGERS

Naval Medical Research and Development Command
Research Work Unit MR0410106A-0003

Released by:

C. A. HARVEY, CAPT, MC, USN
Commanding Officer
Naval Submarine Medical Research Laboratory

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SUMMARY PAGE

THE PROBLEM

Military cold weather operations suffer due to decrements in performance of motor tasks. Guidelines for safe bare-handed performance in the cold need to be established and general methods of reducing the manual performance decrements associated with cold temperatures need to be found. Previous results based on 'pure-ability' tasks need to be tested on operational tasks.

FINDINGS

A rule of thumb for duration of bare-handed cold exposure with no risk of cold injury is to add five to the ambient temperature in degrees Fahrenheit to determine the safe exposure limit in minutes. For example, one can safely perform tasks with bare hands for 15 minutes at an ambient temperature of 10°F. Gloves are an effective means for reducing the threat of cold-injury without adding to cold-induced performance decrements for some tasks. However, neither gloves nor temperature-specific training are effective means of reducing cold-induced manual performance decrements. Results based on 'pure-ability' tasks appear to be applicable to operational tasks hypothesized to require the same motor abilities.

APPLICATION

Military commanders can plan exposure times for performance of tasks requiring bare-hands based on these results, and they can identify the types of tasks which can be performed with gloves without any detrimental effect. It appears, tentatively, that all results from the series of experiments performed under this work unit are applicable to real military tasks. Further research is needed to determine the composition of different operational tasks in terms of the pure-abilities required to perform them.

ADMINISTRATIVE INFORMATION

This investigation was conducted as part of Naval Medical Research and Development Command Work Unit MR0410106A-0003. The present report is Number 3 on this work unit. It was submitted for review on 16 October 1985, approved for publication on 14 November 1985, and designated as NavSubMedRschLab Report No. 1067.

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ABSTRACT

Cold-induced manual performance decrements pose a serious problem for military cold weather operations. A series of experiments conducted at the Naval Submarine Medical Research Laboratory, Groton, CT, has been based on the notion that the amount of decrement, and possibly the best means for reducing that decrement, depend on the specific motor abilities required to perform a given task. Based on this notion, experiments have been performed using a battery of 'pure-ability' tasks so that ultimately results could be generalized to any task.

The study conducted here had the following goals: (1) to complement the previous studies in terms of the cold temperatures tested, and obtain profiles of performance decrements and cold-injury dangers across a range of cold temperatures; (2) to assess the wearing of gloves and temperature-specific training as potential methods of reducing or eliminating cold-induced manual performance decrements; and (3) to validate and compare results previously and currently obtained using 'pure-ability' tasks with those obtained using operational tasks.

A battery of five pure ability and four operational tasks were administered to six four-man groups of U.S. Marines. Three groups practiced the tasks at room temperature on the first of three training days and at -10°C on the other two training days, while the other three groups practiced at room temperature on all three days. On the test day tasks were performed at room temperature and effective temperatures of -5° and -14°C. Practice and test sessions were performed both while wearing wool gloves and with bare hands.

The cold temperatures tested in this study did not pose an injury threat for 20 to 25 minutes of bare-handed exposure. The results of this study combined with those from the previous studies in this series suggest the following rule of thumb for duration of bare-handed cold exposure with no risk of cold injury: add five to the effective ambient temperature in degrees Fahrenheit to determine the safe exposure limit in minutes. For example, one can safely perform tasks bare-handed for 15 minutes at an ambient temperature of 10°F.

Performances of six of nine tasks were degraded by the cold. While there were no performance differences between the two cold temperatures tested in this study, the combined results of the series of studies suggest that cold-induced performance impairments generally increase as the ambient temperature decreases.

Neither gloves nor temperature-specific training reduced or elinimated cold-induced performance decrements for any tasks. Gloved performance was comparable to bare-handed performance for three tasks tested however, indicating that for some tasks the wearing of gloves allow less cold-injury

risk without increasing cold-induced performance decrements.

Similar results, in terms of the effects of cold and gloves, were generally obtained for the pure-ability and operational tasks hypothesized to require the same motor abilities. This tentatively suggests that quantification and remedy of cold-induced performance decrements based on pure-ability tasks are applicable to operational tasks requiring the same abilities.

THE EFFECT OF COLD TRAINING AND THE WEARING OF GLOVES ON MANUAL PERFORMANCE IN THE COLD: A COMPARISON OF PURE ABILITY AND OPERATIONAL TASKS

Military cold-weather operations are usually impeded by decrements experienced in the performance of manual tasks (McCarroll, Denniston, Pierce, & Farese, 1977; Young, Jackson, Bynum, Wolfe, Philo, Fay, & White, 1976). These decrements have been attributed to a variety of physiological and environmental factors, including ambient temperature (Teichner, 1957; Dusek, 1957b), wind chill (Teichner, 1957), rate of hand cooling (Clark & Cohen, 1961), and hand-skin temperature (HST) (Dusek, 1957a; Clark, 1961). While the factors affecting manual performance in the cold have been well-documented, there seems to be little consistency reported across studies in the magnitude of the cold-induced decrements found. Further, adequate, generally applicable solutions to reducing these decrements have not been found.

A series of studies at this Laboratory was designed to overcome these shortcomings and, ultimately, to lead to practical solutions to the cold-induced manual decrement problem. Previous studies in this series (Rogers, Noddin & Moeller, 1982; Rogers & Noddin, 1984) were based on the premise that the inconsistent results of past research were due, in large part, to the task-specificity of cold-induced manual performance decrements. It appears that the amount of decrement, and possibly, the best means for reducing that decrement, depend on the manual abilities required for performance of a given task (Fox, 1967; Vaughn, Higgins & Funkhouser, 1968). The strategy here was to use a battery of nine tasks to identify and quantify cold-induced manual performance decrements specific to different 'pure' abilities and to assess various means for reducing the decrements. Each of the tasks hypothetically measured a single 'pure' motor ability (Fleishman, 1967).

There were four main goals of the series of studies conducted: (1) determination of which pure abilities are deleteriously affected by the cold; (2) identification of the temperature and time limits for bare-handed manual performance without risk of cold-injury; (3) test of methods for reducing the cold-induced manual decrements; and (4) analysis of the composition of various operational tasks in terms of the pure abilities required to perform them. The first goal was achieved in the previous studies of this series. The present experiment focused on the last three goals. The methods for reducing cold-induced manual decrements concentrated on means which do not encumber Marines with more gear than they now carry or require extensive time to realize.

The results of the Rogers, et al. (1982) and Rogers and

Noddin (1984) studies indicated that four of the nine pure ability tasks were deleteriously affected by the cold. Those four pure ability tasks were included for test here.

The Rogers and Noddin (1984) study tested performance at ambient temperatures equivalent to -18°, -10°, and -1°C in terms of cooling effect (accounting for a five miles per hour wind). It was concluded that it would be impractical to perform tasks bare-handed at -18°C for more than a few minutes because of the cold-injury threat. The cold-injury threat at -10°C was minimal for bare-hand exposure times of up to 20 minutes. The study reported here tested performance at ambient temperatures equivalent to -5°C and -14°C without wind, in terms of cooling effect, to complement those temperatures tested previously.

One method for reducing the cold-induced manual performance decrements assessed by Rogers and Noddin (1984) was the wearing of gloves. The basic notion was that for certain tasks, the decrement due to the wearing of gloves might be less than the decrement due to performing tasks with cold hands. Two of the tasks affected by the cold, plus one other, were deleteriously affected by the wearing of gloves. Gloves did not enhance performance for any task, relative to bare-handed performance, but six tasks were performed comparably with and without gloves. The implication of this finding is that for these tasks (and others requiring the same abilities) there is no reason to take off one's gloves. This gloved-hand, bare-hand performance trade-off was further investigated in the present study using the three pure ability tasks from the Rogers and Noddin (1984) study which were affected by the wearing of gloves.

A second potential performance enhancing procedure evaluated in the present study is temperature-specific training. There is modest evidence (Clark & Jones, 1962) indicating that subjects given brief training in cold temperatures will perform better when subsequently tested in the cold than subjects given the same amount of training at room temperature. Both the wearing of gloves and brief temperature-specific training, if found to be successful in reducing cold-induced manual performance decrements, would provide simple, practical remedies to the manual performance problem.

The present study also began the assessment of the pure ability composition of selected operational tasks. The four pure ability tasks for which Rogers and Noddin (1984) found no cold or glove effects were replaced by four operational tasks which were hypothesized to require the pure abilities affected by cold or gloves. Correlations among task performances and comparison of the effects of cold temperatures, gloves, and temperature-specific training between pure ability and operational tasks will give a preliminary indication of the generality of findings based on pure ability tasks and will also begin to provide the empirical data base required to validate the pure ability composition of several operational tasks.

METHOD

Subjects

Twenty-four male U.S. Marines stationed at the Marine Barracks, Subase, Groton, CT, volunteered for this experiment. All were 18- to 25-years old with a mean age of 20.2 years. None had military cold-weather training or cold-weather experience. Subjects were rune in six four-man replications.

Tasks

The task battery consisted of five pure ability tasks and four operational tasks. The five pure ability tasks were those of the original nine that showed either a glove effect or cold temperature effect in the previous studies (Rogers, et al, 1982; Rogers & Noddin, 1984). Those tasks and the pure abilities they measure are: (1) O'Connor Finger Dexterity Test, finger dexterity, (2) Minnesota Manual Dexterity Test, two-handed manual dexterity; (3) Rotary Pursuit Test, control precision; (4) Steadiness Test, arm-hand steadiness; and (5) Pencil and Paper Tapping Test, wrist-finger speed. The specific versions of the tasks used here are described by Rogers, et al (1982).

The operational tasks used were ones suggested by local Marine Corps personnel experienced in cold weather combat (Korea) or training. Some of the tasks were modified for purposes of standardization and performance measurement. Those chosen for test appeared, intuitively, to require the pure abilities affected by cold temperatures or involved equipment that might be difficult to use with gloves. The four tasks, and the pure abilities they were hypothesized to require were: (1) repairing an engine, finger and/or manual dexterity; (2) loading a M-16 magazine, finger and/or manual dexterity and arm-hand speed; (3) reading a compass, arm-hand steadiness and control precision; and (4) operating a calculator, aiming. Each of these tasks will be described separately.

Engine repair. In this timed task an automotive distributor cap was replaced. The distributor cap was fastened to a base plate with two screws. The subject unscrewed the cap, removed the screws from the cap, put a new distributor cap in place on the base plate, and then used the same screws to fasten the new cap back down. A clock started when the first screw was unscrewed enough to break contact with a plate beneath the base plate, and stopped when the last screw was screwed in enough to make contact with that plate.

Magazine load. In this timed task, subjects loaded a M-16 rifle magazine with blanks. Subjects were given 30 seconds to load as many blanks as possible. Subjects were instructed to pick up the blanks one at a time from a table. The score was the number of blanks loaded.

Compass read. In this task each subject took as many compass readings as possible of designated targets in a 60-second time period. On a verbal command to start, the subject took a compass out of it's case, opened it into it's operating position, and began sighting designated targets located randomly on the walls of the cold chamber. Subjects were required to record each compass reading on a data sheet, and then sight the next target. The score on this task was the number of correct readings within the 60 seconds. The readings were taken in half compass points (1-64), and a reading was considered correct if it was within one-half compass point of the correct reading.

Calculator operation. This task simulated use of a calculator in Marine Corps combat operations to enter gun data. The primary concern was the ability to use the buttons of the calculator in cold weather, so the task was simple addition and subtraction requiring many button pushes. Subjects were given a sheet of paper containing the math problems and were told to solve each problem using the calculator. This required adding two three-digit numbers together, and then subtracting a third three-digit number. Subjects wrote down the answer on the paper containing the problems, and then entered the next problem on the calculator. Subjects were given 60 seconds to solve as many problems as possible, and they were scored as follows: Each correct answer was given a total of three points, reflecting the fact that three three-digit numbers were entered correctly. A point was given for each three-digit number entered correctly for the last problem attempted, if that problem was not completed before the time limit.

Materials

Training and testing was done in a 4.6 m long by 3.7 m wide by 2.7 m high cold chamber located at the Naval Underwater Systems Center, New London, CT. A fan produced a five miles per hour wind which was somewhat attenuated by room geometry at two of the four test stations. The average wind speed made the test temperatures equivalent to -5° and -14°C still air temperatures and the cold training temperature equivalent to -10°C still air temperature in terms of cooling effect.

Hand skin temperatures (HST's) were measured by Yellow Springs Instruments surface temperature probes (No. 409a) fastened to the back of the hand and the proximal phalanx of the second (index) and the fifth (pinky) fingers of each subject's non-preferred hand. Subjects wore standard-issue Marine

Corps cold weather gear, and the wool insert glove liners usually worn inside leather glove or mitten shells were worn for the gloved condition.

The apparatus for the 'pure ability' tasks are described in detail by Rogers and Noddin (1984). All were off-the-shelf items available through the Lafayette Instrument Co. A standard issue Marine Corps compass was used for the compass task, and the targets to be sighted were 10 x 10 cm black numbers written on white tape. The ammunition magazine for a M-16 rifle and 30 M-16 blanks were used for the magazine loading task. A distributor cap from a 1978 Dodge Omni was screwed down to a circuited base plate and connected to a stop clock for the engine repair task. A Texas Instruments TI-59 programmable calculator comparable to standard Marine Corps issue was used for the calculator task.

Procedure

All subjects were trained for three days and were tested on the fourth day. On the first training day, subjects were given a briefing on the general purpose and procedure of the study, followed by verbal instruction and demonstration of the proper procedure for performance of each task. Three replications of four subjects practiced the tasks on all three training days at room temperature. The other three replications practiced the tasks at room temperature on the first training day and at a still air temperature equivalent of -10°C on the second and third training days.

The battery of tasks was performed four times each practice day, twice bare-handed and twice with gloves. Subjects performed the battery of tasks six times on the test day, once with gloves and once bare-handed at room temperature and at still air temperature equivalents of -5°C and -14°C. On the test day the room temperature session was completed first for all replications and the order of the two cold sessions was counterbalanced across replications. The order in which subjects performed with gloves or bare-hands was counterbalanced within each session.

The four subjects comprising a replication were tested simultaneously at four test stations. The order of rotation of subjects through the test stations was fixed, but the starting position for each subject changed each session. The cold sessions were carried out in the following manner: All subjects entered the chamber wearing gloves and HST's were immediately recorded. After five minutes in the cold, two subjects removed their gloves and HST's were recorded again. Subjects then remained in the cold another 8 minutes to assure that HST's were relatively stable before testing began. HST's were measured mid-way through the 8-minute soak period and immediately before and after testing. Subjects were required to leave the chamber or don their gloves if any HST dropped to 3°C. Subjects were also instructed of their right to de-volunteer at any time during the experiment. Each cold session, including soak periods and testing, took approximately 25 to 30 minutes. Intersession intervals were at least 20 minutes, but no session started until all subjects' HST's had risen to at least 27°C.

RESULTS

Analyses of variance (ANOVA's) were computed on the first day's practice data (room temperature) to assess any differences in baseline performance of the two groups and to determine the effect of gloves on initial performance of the tasks. There were two significant baseline differences due to group: The cold-training group performed the engine repair task significantly faster ($p < .01$) than the warm-training group (means of 70.5 and 85.1 seconds to complete the task, respectively) and the warm-training group performed the finger dexterity task significantly better ($p < .05$) than the cold-training group (means of 10.2 and 9.4 holes filled, respectively). These differences were assumed to be random sampling differences. There were significant baseline performance decrements due to wearing gloves for the following tasks: finger dexterity ($p < .001$), manual dexterity ($p < .001$), pencil and paper tapping ($p < .05$), magazine load ($p < .001$), and engine repair ($p < .001$).

On the test day, all subjects completed all testing at -5°C and all but two subjects completed all testing at -14°C. Those two subjects were required to leave the chamber during the bare-handed session at -14°C because their HST's dropped to 3°C before completion of the tests. One other subject donned his gloves between tasks during the bare-handed -14°C session even though his HST's were not dangerously low. For test day analyses of variance, cell means for bare-handed performance of those tasks not completed by all subjects were estimated from the data of those completing the tasks.

Separate analyses of variance (ANOVA's) were computed for the test day data for seven of the nine tasks. Analyses of covariance were computed for the test day data for the engine repair and finger dexterity tests, with the mean of each subject's Day 1 practice scores used as the covariates. All analyses included hand-state (bare-handed versus gloved) and temperature (room, -5°C, -14°C) as within-subject variables, and group (cold-training versus warm-training) as a between subject variable. There were significant main effects of group for the engine repair ($p < .05$) and manual dexterity ($p < .01$) tests, and a Group x Temperature interaction for the rotary pursuit task ($p < .01$). Both main effects were due to the warm-training group performing better than the cold-training group. The group effect for the engine repair was based on means adjusted for the covariate, that is, Day 1 scores. The interaction is shown in Figure 1; a test of the simple effects of group for each temperature showed that the warm-training group performed significantly

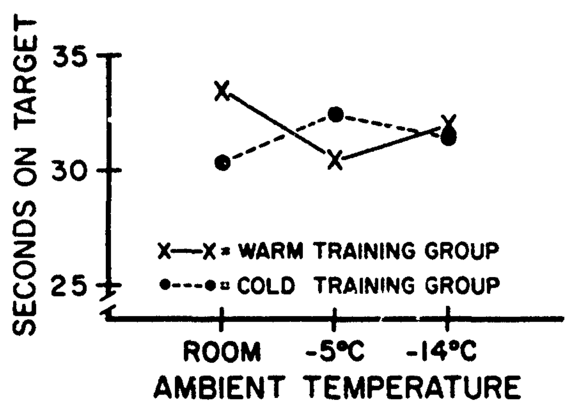


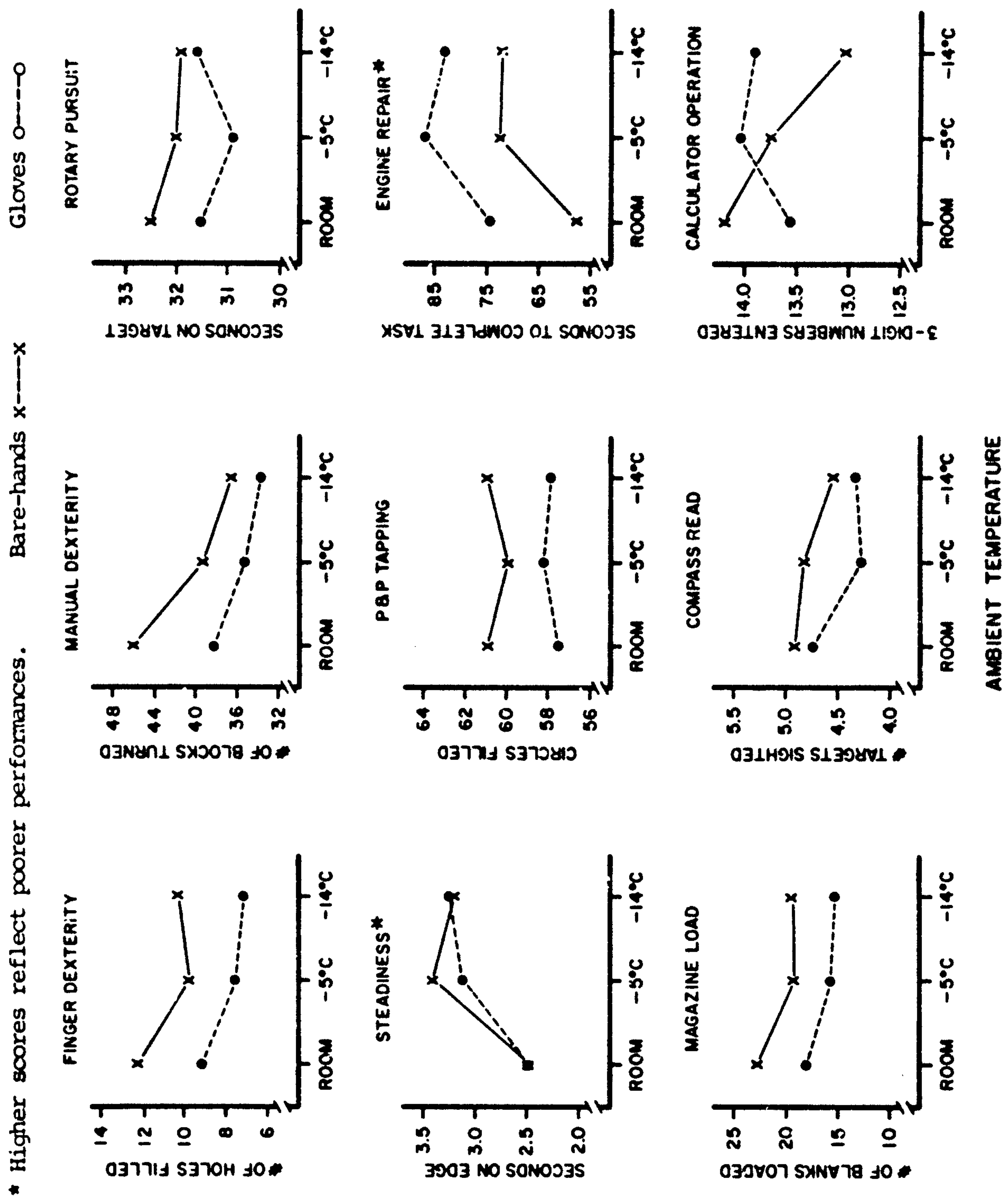
Figure 1. Group x Temperature interaction for the Rotary Pursuit Task.

better ($p < .01$) than the cold-training group at room temperature, but that the differences between the groups at the two cold temperatures were not significant.

The mean test day scores for each task for the three temperatures and two hand-states are shown in Figure 2. Performances of the finger dexterity ($p < .001$), manual dexterity ($p < .005$), magazine load ($p < .005$), and engine repair ($p < .001$) tasks were significantly affected by ambient temperature. Performance of the steadiness test was marginally ($p < .10$) affected by temperature. Newman-Keuls tests showed that the significant effect of temperature for each task was due to better performance at room temperature than at the two cold temperatures ($p < .05$); performance did not deteriorate further between -5° and -14°C. The wearing of gloves significantly degraded performance of finger dexterity ($p < .001$), manual dexterity ($p < .001$), pencil and paper tapping ($p < .001$), magazine load ($p < .001$), engine repair ($p < .001$), and compass read ($p < .05$). Gloves marginally ($p < .06$) degraded performance of the rotary pursuit task. There was also a significant Hand-state x Temperature interaction for the manual dexterity test ($p < .01$). A test of the simple effects of hand-state for each temperature showed that bare-handed performance was significantly better than gloved performance at all three temperatures ($p < .01$ for room temperature, $p < .05$ for the two cold temperatures). It is evident from the manual dexterity plot in Figure 2 that the interaction was due to the fact that the magnitude of the advantage decreased as the ambient temperature decreased.

Correlations using bare-handed scores at room temperature on the test day were computed to assess the relationship among task performances. It was hypothesized that the pure ability tasks required independent manual abilities and hence performances of these tasks would be poorly correlated with each other. It was further hypothesized that the operational tasks would require some of the pure abilities tested by the pure ability tasks and hence performance of these tasks would correlate to some degree with performance of those pure ability tasks requiring the same abilities. There were six significant ($p < .05$) correlations: Pencil and paper

Figure 2. Mean test day scores for each task for three temperatures with gloves and bare hands.



tapping with steadiness and compass reading; finger dexterity with calculator operation and compass reading; manual dexterity with rotary pursuit; and steadiness with calculator operation. None of the hypothesized operational task-pure ability relationships were substantiated by the correlations.

Correlations were also computed on bare-handed task scores and HST's from the -5°C test session. Index finger temperatures immediately before and after testing were used for these correlations. There were no significant correlations between any task performances and HST's. The correlation between HST's before and after testing was also non-significant ($r = .34$). While others (Dusek, 1957a; Clark, 1961) have found a significant relationship between HST's and cold-weather task performances, the negative findings here reproduce those of Teichner (1957) and Rogers and Noddin (1984). The correlations among task performances at -5°C yielded four significant ($p < .05$) relationships: Engine repair with finger dexterity, compass read, and magazine load; and manual dexterity with magazine load.

DISCUSSION

One goal of this research was to determine the temperature and time limits for safe bare-handed manual performance. The fact that only 2 of 24 subjects did not complete testing at -14°C indicates that this temperature is generally safe for brief periods of bare-handed manual performance. Twelve of 24 subjects in the Rogers and Noddin (1984) study did not complete testing at -18°C using the same procedure. The findings from the two studies suggest that a critical temperature for brief (15-20 min), safe, bare-handed performance lies between -14° and -18°C. HST's were below 5°C for over half the subjects at completion of the -14°C temperature session, indicating that subjects were very close to the safe limit in time and temperature for bare-handed performance during this session. Using the aggregate of results from the studies completed in this laboratory, we suggest that a safe, conservative rule of thumb for bare-handed performance would be to limit the time of exposure in minutes to the still air temperature equivalent (accounting for wind) measured in Fahrenheit plus five. Thus for an ambient temperature of 10°F with no wind, most people could safely perform bare-handed for 15 minutes.

A second goal of these studies was to find simple practical ways to reduce cold-induced manual performance decrements. The temperature-specific training hypothesis, that is, subjects who receive training at cold temperatures perform better in the cold than subjects who receive an equal amount of training at room temperature, was not supported by the data. A Group x Temperature interaction with the warm-training group performing better at room temperature and the cold-training group performing better at the cold temperatures would indicate a temperature-specific training effect. The only Group x Temperature interaction found was for the rotary pursuit task, and it actually seemed to favor the warm-training group. The expected warm-training group advantage held for room temperature but there was no cold-training group advantage for performances at the two cold temperatures. The main effects of group also favored the warm-training group, even when tested in the cold. On the test day the warm-training group performed the engine repair (adjusted from Day 1 scores) and manual dexterity tasks significantly better than the cold-training group.

One possible ad hoc explanation of these negative findings is that training under ideal conditions (room temperature) gives subjects more opportunity to improve the required skills; in the cold, subjects must cope with the adverse conditions as well as with learning the tasks. Hence any advantage of temperature-specific training might be more than offset by training in a more ideal learning situation. A procedure used by Clark & Jones (1962), in which they alternated the training temperature between room temperature and a cold temperature for one group of subjects, might allow the advantages of both conditions to manifest themselves.

The use of gloves was a second method investigated for ameliorating the effects of cold on manual performance. 'Common-sense' suggests gloves would result in a constant performance impairment, independent of temperature, while cold-hands would impair performance to a greater and greater degree as the temperature decreased. Thus at colder temperatures the impairment due to cold-hands might be greater than the impairment due to gloves. This was not realized for any of the tasks studied. The only task producing effects remotely like those expected, manual dexterity, showed gloved performance deteriorated less than bare-handed performance with decreasing temperatures. Bare-handed performance of this task was still significantly better than gloved performance at the coldest temperature tested, however. There were no decrements due to gloves for the calculator operation, steadiness, and rotary pursuit tasks. These tasks and ones using the same abilities should be performed with gloves on since performance is comparable to that with bare hands and the risk of cold-injury is less.

The findings discussed above indicate that neither the wearing of standard gloves nor temperature-specific training are effective means for reducing manual performance decrements. Gloves can reduce the threat of cold-injury without increasing the cold-induced performance decrement on some tasks. A training regime which includes some cold training in addition to ample training at room temperature, and specially designed gloves which allow greater dexterity while still providing some insulating value, might be worth further investigation.

A third goal of this study was to begin assessment of the pure ability composition of operational tasks and to determine whether results obtained using the pure ability tasks were applicable to certain operational tasks. The correlations computed on room temperature performances generally did not support the hypotheses concerning the pure abilities required by the different operational tasks, but the correlations computed on -5°C performances generally did. Perhaps so many variables affect performance at room temperature that correlations of manual abilities are obscured, but under adverse conditions the primary variables affecting performance are ability and the adverse conditions. The correlations must be interpreted with some caution at this point, in light of the limited number of subjects and the restricted range of some of the task scores.

That temperature and gloves affect different tasks differently confirmed previous findings (Rogers & Noddin, 1984) concerning pure ability tasks, and support the generality of findings from the pure ability tasks as they apply to the operational tasks. The two operational tasks hypothesized to require finger dexterity and/or manual dexterity, i.e., engine repair and magazine load, were significantly affected by cold and gloves just as the finger and manual dexterity tasks were. Performance of the calculator operation task was not affected by cold or gloves, consistent with the negative findings for aiming (Rogers & Noddin, 1984), the ability hypothesized to load on the calculator task. I thought that it might be difficult to accurately push the calculator buttons with gloved hands, but this was not supported empirically. The compass task showed a glove effect but not an effect due to cold; both of these findings contradict the a priori notion that the compass task required arm-hand steadiness and control precision, two abilities affected by cold but not gloves. It could be that sighting the targets with the fairly lenient accuracy criterion used here did not require substantial arm-hand steadiness and control precision, but that if exact readings were demanded, those abilities would have been required.

Assessment of the relationship between various classes of operational tasks and pure ability tasks needs much more study. A much more vigorous, formal componential analysis of the pure abilities required for operational tasks is needed if the goal of identifying general methods for alleviating cold-induced decrements is to be achieved.

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Cold-induced manual performance decrements pose a serious problem for military cold weather operations. A series of experiments conducted at the Naval Submarine Medical Research Laboratory, Groton, CT has been based on the notion that the amount of decrement, and possibly the best means for reducing that decrement, depend on the specific motor abilities required to perform a given task. Based on this notion, experiments have been performed using a battery of 'pure-ability' tasks so that ultimately results could be generalized to any task.

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The study conducted here had the following goals: (1) to complement the previous studies in terms of the cold temperatures tested, and obtain profiles of performance of decrements and cold-injury dangers across a range of cold temperatures; (2) to assess the wearing of gloves and temperature-specific training as potential methods of reducing or eliminating cold-induced manual performance decrements; and (3) to validate and compare results previously and currently obtained using 'pure-ability' tasks with those obtained using operational tasks.

A battery of five pure ability and four operational tasks were administered to six four-man groups of U.S. Marines. Three groups practiced the tasks at room temperature on the first of three training days and at -10°C on the other two training days, while the other three groups practiced at room temperature on all three days. On the test day tasks were performed at room temperature and effective temperatures of -5° and -14°C. Practice and test sessions were performed both while wearing wool gloves and with bare hands.

The cold temperatures tested in this study did not pose an injury threat for 20 to 25 minutes of bare-handed exposure. The results of this study combined with those from the previous studies in this series suggest the following rule of thumb for duration of bare-handed cold exposure with no risk of cold injury: add five to the effective ambient temperature in degrees Fahrenheit to determine the safe exposure limit in minutes. For example, one can safely perform tasks bare-handed for 15 minutes at an ambient temperature of 10°F.

Performances of six of nine tasks were degraded by the cold. While there were no performance differences between the two cold temperatues tested in this study, the combined results of the series of studies suggest that cold-induced performance impairments generally increase as the ambient temperature decreases.

Neither gloves nor temperature-specific training reduced or eliminated cold-induced performance decrements for any tasks. Gloved performance was comparable to bare-handed performance for three tasks tested, however, indicating that for some tasks the wearing of gloves allow less cold-injury risk without increasing cold-induced performance decrements.

Similar results, in terms of the effects of cold and gloves, were generally obtained for the pure-ability and operational tasks hypothesized to require the same motor abilities. This tentatively suggests that quantification and remedy of cold-induced performance decrements based on pure-ability tasks are applicable to operational tasks requiring the same abilities.