R58-42

Reprinted from JOURNAL OF APPLIED PHYSIOLOGY
Vol. 12, No. 3, May, 1958
Printed in U.S.A.

Effects of Localized Hand Cooling Versus Total Body Cooling on Manual Performance

HENRY F. GAYDOS AND EDWIN R. DUSEK. *From the Psychology Branch, Environmental Protection Research Division, QM Research and Engineering Center, Natick, Massachusetts*

ABSTRACT

GAYDOS, HENRY F. AND EDWIN R. DUSEK. *Effects of localized hand cooling versus total body cooling on manual performance.* J. Appl. Physiol. 12(3): 377–380. 1958.—Subjects were tested on complex manual performance tasks under two different environmental conditions. Under one condition, only the subject's hands were cooled while the rest of his body was exposed to a comfortable ambient temperature. In the other experimental condition the subject worked *in toto* in a low ambient temperature. The tests were given, in both cases, when finger skin temperatures reached certain predetermined levels. No significant differences were found between performances obtained under the two conditions of exposure; however, the results indicate that performance was impaired when finger skin temperature dropped. The finger temperature seems to have been the primary determinant of manual performance decrement.

ALTHOUGH it seems fairly well agreed that exposing the body to low temperatures has a detrimental effect on manual performance, the precise nature of the factors producing the decrement is still open to question. LeBlanc (1) concluded that exposing the hand to cold increased the viscosity of the synovial fluid in the finger joints and impaired the efficiency of the activating muscles. However, the movements he studied were very simple and discrete, and the results do not appear applicable to the more complex forms of manual behavior. Teichner (2) tested subjects in the cold with the Minnesota Rate of Manipulation Test, but he was unable to relate performance decrement directly to skin temperature; however, he did conclude that at least part of the performance decrement was related to the distracting influence of the low ambient temperatures.

Although the above-mentioned test has been shown to have a high degree of validity and reliability, it does allow the subject to compensate for the handicaps imposed by environmental conditions by altering his manipulative technique. Actually, the test can be performed quite efficiently with a minimum of finger movement. In a subsequent study Dusek (3) employed tasks requiring finer manipulations and found marked decrements with lowered ambient temperature. Unfortunately, the controlled variable was ambient temperature rather than finger skin temperature and the confounding of these two variables negated any clear cut indication of the primary factor producing the decrement. What is needed to clear up some of this ambiguity is a study in which finger skin temperature and ambient temperature surrounding the body can be controlled independently of each other while the subject performs a relative complex manual task. It would be of further advantage if the task were performed without the aid of vision, so that compensatory adjustments mediated through this sensory modality would not obscure any effects produced by changing temperatures on the tactual-kinesthetic-motor system. Thus, in the present study an attempt was made to determine whether any differential effect would occur on complex manual performance when: *a*) only the hands and wrists were cooled while the rest of the body was exposed to a comfortable ambient temperature, and *b*) the subject, fully clothed except for bare

Received for publication November 4, 1957.

hands, performed *in toto* in a cold environment.

METHODS

Sixteen white male enlisted men volunteered for this experiment. A controlled temperature hand-cooling box with ports to accommodate both hands and sufficient space inside to permit manipulation of the test apparatus was used for the hand cooling condition. A dummy hand-cooling box with the same physical shape and dimensions as above, but without cooling equipment, was used in a controlled-temperature room when the entire body was exposed to lowered ambient temperature. Finger skin temperatures were obtained through the use of thermocouples and a Brown Flight Recorder. An interval timer and signal lights were used to control the presentation time of the tests.

Performance Tests. *a) Knot tying.* Three coils of 1/8-inch diameter braided cotton cord, each about 8 feet long, were suspended from pegs within easy reach of the subject. The subject grasped one end of the cord in his nonpreferred hand and, at a given signal, he proceeded to tie knots as rapidly as possible for a 30-second period. The knots tied were of the type known as 'over hand knot and bight.' Three trials were given at each session, with about 1 minute elapsing between trials.

b) Block stringing. The blocks used were 1-inch cubes of wood with 3/16-inch holes drilled through the center of each face. The stringer consisted of a blunted needle, 2½ inches long by 1/16-inch diameter, with a length of string passed through the eye. The subject held the stringer in his preferred hand, and at a given signal, he threaded blocks as rapidly as possible for a 30-second period.

Procedure. To control learning effects, all subjects were required to practice both tasks for 6 days, performing three consecutive trials per task each day with about 1 minute elapsing between trials. Practice sessions were alternated between the hand-cooling box and the dummy hand-cooling box to insure familiarity with each condition. All practice trials were carried out under normal temperature conditions of approximately 70° to 80°F.

For the test sessions, the controlled-temperature room was set at +15°F; the hand-cooling box was set at +5°F with the room temperature outside the box at 70° to 80°F. Subjects performed once under each of the two conditions with a lapse of 1 day between sessions. The test session itself consisted of: *1)* three trials on each task immediately upon entering the controlled-temperature room or placing the hands in the cooling box (T_1); *2)* three trials when the skin temperature of fifth finger of the left hand dropped to 65°F (T_2); and *3)* three trials when this temperature dropped to 50°F (T_3). Actually, it was not possible to control the skin temperatures exactly. For all practical purposes the skin temperature ranges were 70° to 90° at T_1, 60° to 65° at T_2 and 50° to 55° at T_3. A continuous recording of finger skin temperatures was taken during the experimental periods.

Half the subjects performed first in the controlled-temperature room, and the other half performed first with the hand-cooling box. Subjects wore the standard Army wet-cold uniform, except for being barehanded, while working in the controlled-temperature room. When working with the hand-cooling box they wore only the field jacket over the fatigue uniform.

Under the conditions of this experiment the subjects were unable to see what they were doing, and had to rely entirely upon their sense of touch. However, the absence of visual cues was desirable since one uncontrolled variable was thereby eliminated.

RESULTS

Figure 1 shows the mean performance scores of the group plotted for 6 successive days of practice, and for test conditions T_1, T_2 and T_3. Each trial was scored on the basis of the number of knots tied or number of blocks strung, according to the respective task, in the 30 seconds allowed. Points shown on the graph represent the sums of the scores of the three trials for each practice session and for each of the three periods of measurement during the test session.

Although subjects alternated between the hand-cooling box and the dummy cooling box during the practice period, no significant difference was found between the practice scores obtained under these two conditions. There-

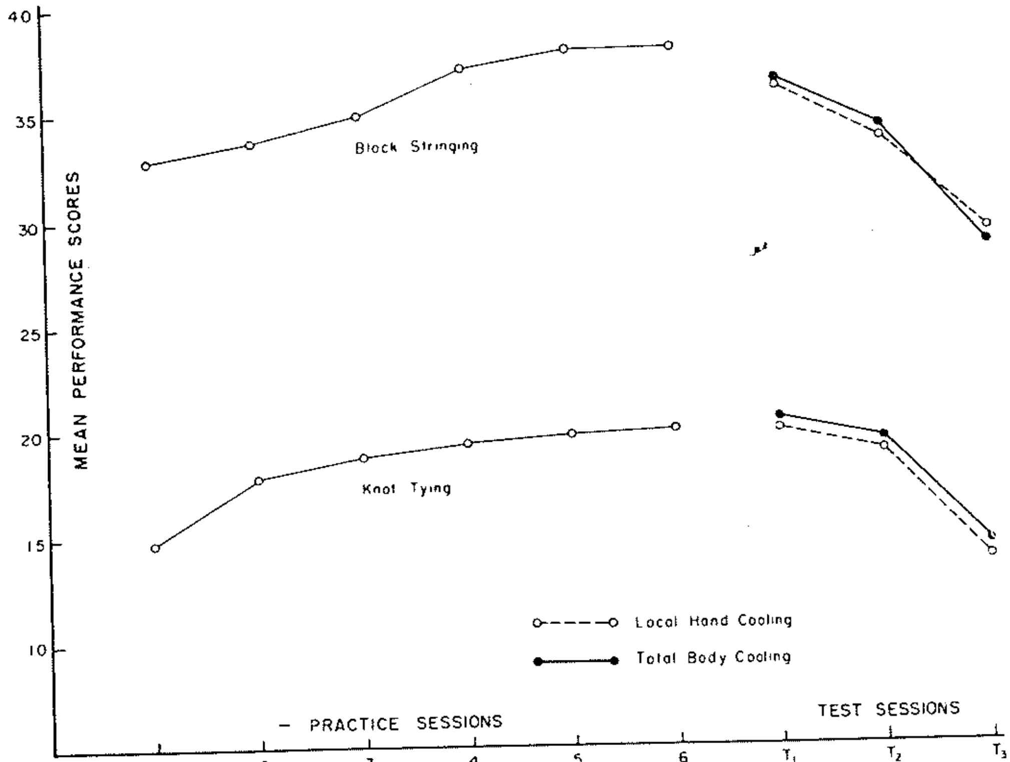

FIG. 1. Comparisons of mean performance scores during the practice sessions and during the experimental sessions.

fore practice scores on the graph are differentiated only in terms of chronology.

The direction of the curves on the 5th and 6th days indicates that a peak in performance was probably reached, with little or no further improvement to be expected. This level is maintained at T_1 for the knot tying task, while a slight drop in performance score occurs for the block-stringing task. However, since the block-stringing task was always the second one to be given, the cooling of the hand during the administration of the knot-tying task probably accounts for this difference. At T_2 and T_3 the performance decrements are quite marked relative to T_1, with approximately 5% and 9% loss at T_2, and 27% and 23% loss at T_3 for the knot-tying and block-stringing tasks, respectively.

An analysis of variance was performed on the data for both tests. No significant differences were found between performances under the two experimental conditions. The effects of finger skin temperature were significant beyond the .01 level on both the knot-tying and block-stringing tasks.

DISCUSSION

Before drawing any final conclusions from the data presented above, it would be well to point out certain uncontrollable variables which may or may not have affected the results. First of all, it was difficult to control the exact skin temperature at which the tasks were administered during the test session. In the controlled-temperature room, T_1 ranged from 67°F to 85°F, with the mean for the group at 77.5°F. In the hand-cooling box, T_1 ranged from 71°F to 94°F, with a mean of 83.6°F.

At T_2 the tests were to begin when the skin temperature of the subject dropped to 65°F. However, in six cases (three under each experimental condition) the cooling rate was so rapid that the 65° point was passed before the second series of tests could begin. Nevertheless, in only two cases did the temperature at T_2 fall below 60°F.

T_3 posed another problem in that nine of the subjects were unable to reach the 50°F skin temperature level even after relatively prolonged exposure in the controlled temperature room. Of these, however, only two began the tests with skin temperatures higher than 54°F. Generally speaking, the cooling rate was somewhat more rapid in the hand-cooling box than in the controlled temperature room, but individual cooling rates are affected by so many variables that no attempt was made to exercise precise control over this factor.

One important unknown is the extent of the true difference between experimental conditions. In the session involving the hand-cooling box the subject's body, excluding the hand and forearms, was exposed to a comfortably warm environment. It might be argued that even though the ambient temperature of the controlled temperature room was 15°F, the clothing worn by the subject still provided his body with a comfortably warm environment. To some extent this is true. However, there is little question about the fact that with the hands, forearms and face exposed, and breathing 15°F air, the subject presents more bare surface area to the cold than under the conditions imposed by the hand-cooling box where only the hands are exposed to cold. If this is the case, then—subject to further verification—the following tentative conclusions may be drawn: *a*) the performance of the complex manual tasks employed in this study was adversely affected by lowering the temperature of the hands; *b*) the decrement of performance appears to have been a function of local hand and forearm temperature alone, regardless of the thermal environment surrounding the rest of the body; *c*) on the basis of the data obtained, it appears that provision must be made to maintain hand temperatures at normal or near normal levels to insure optimum efficiency of manual performance. It is not enough to keep the body comfortably warm while allowing the hands to cool down.

REFERENCES

1. LeBlanc, J. S. *J. Appl. Physiol.* 9: 62, 1956.
2. Teichner, W. H. *J. Appl. Physiol.*, 11: 333, 1957.
3. Dusek, E. R. EP-68, Q M R & E Center, Natick, Mass., 1957.