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Contralateral effects of thermal stimuli on manual performance capability

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CLARK, R. ERNEST, AND CHARLES F. FLAHERTY. *Contralateral effects of thermal stimuli on manual performance capability.* J. Appl. Physiol. 18(4): 769–771. 1963.—The performance capability of one hand was studied as a function of its surface temperature and that of the contralateral hand. Three findings were determined to be statistically reliable for the subject sample tested: *a)* when the performing hand itself was cooled to a surface temperature of 40 F, performance decrements appeared which were independent of the temperature of the contralateral hand; *b)* when the performing hand was kept warm, cooling of the nonperforming hand resulted in an average reduction of 33% in the time typically needed for the completion of the manual task; and *c)* the surface temperature of a hand not exposed to the cold was found to fall an average of 2 F below its normal level when the contralateral hand was cooled to surface temperatures of 55 F or lower.

ALTHOUGH THE DATA of Hunter and Whillans (1), and Hunter, Kerr, and Whillans (2) strongly imply that the effect of cold exposure on manual activity is mainly local to the specific finger joints of which motion is required, there are data suggesting that psychophysiological changes in an unexposed hand may be associated with the thermal state of the contralateral-exposed hand. Wagoner and Haverman (3), for example, found a rise in the absolute threshold for cold sensation in one hand when the other was cooled, and Nafe and Wagoner (4) observed signs of contralaterally induced vasoconstriction. It was the purpose of the present investigation to determine whether the thermal state of one hand may contralaterally influence the manual capability of the other, and, if so, whether this influence tends to be mainly psychological (e.g., associated with changes in manual effort), mainly physiological (e.g., associated with changes in skin temperatures of the performing hand), or some combination of both types of effect.

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METHODS

The relevant control conditions, including food and sleep requirements, smoking and alcohol restrictions, clothing worn during exposure, etc., were identical to those reported elsewhere (5–9). Therefore, only those details needed for a clear exposition of the present methodology will be mentioned again.

Sixteen nude enlisted men were exposed to a constant ambient temperature of 70 F dry bulb (DB), and 60 F wet bulb (WB) while either one or both of their hands were cooled in 10 F DB still air within a precision cooling unit. Hand skin temperatures (HSTs) were monitored with copper-constantan thermocouples, one on each of the subject's fifth fingers. Criterion HST levels at which the subject was to perform were calculated as the arithmetic averages (5) of these two thermocouple readings in all cases that the hands were subjected to identical exposure conditions. When the hands were exposed differentially, the individual HST measurements were, of course, not combined.

The manual performance task was like that used previously by Clark et al. (5–9) with two exceptions: *a)* only one hand (subject's preferred) was used to tie knots in the present study, and *b)* the number of knots tied in the task was reduced from 15 to 5 in order to reduce fatigue, and to limit the time period for one-handed performance to approximately the duration known to be required for two hands.

Practice (days 1–6). During practice, the subjects tied 50 sets of 5 knots each day. Thus, prior to the exposure periods (*days 7–10*), each subject had completed the task 300 times, and had tied a total of 1,500 separate knots. It was determined through a "least-squares" fit of the practice data that the subjects were very close to their asymptotic performance levels just prior to the experiment proper, and that the average postpractice improvement should be approximately .08 sec./day (.6% improvement) in the time required to complete the task. This small potential bias in the experimental performance data was eliminated as such by a latin-square counterbalancing of the exposure variables over *days 7–10*.

TABLE 1. *Comparison of "warm" hand HSTs measured during experimental PC condition with those measured at an equivalent elapsed time during practice*

HST of Cooled Hand, F	Mean HST of PC "Warm" Hand, F	Mean Equivalent Elapsed Time, min	Mean HST of Practice "Warm" Hand, F
55.0	85.6	4.2	86.9
45.0	84.9	7.7	86.7
40.0	84.4	11.9	87.2

TABLE 2. *Mean performance time (sec) re: BW performance*

Cooling Condition	Hand Skin Temp., F			
	90	55	45	40
BC	3.45	3.28	4.25	10.50
PC	2.87	3.87	2.73	6.35
NPC	2.47	−1.38	−2.47	−2.98

Experimental exposures (days 7–10). During the last 4 days of the study, the hands of each subject were treated experimentally in each of four ways: *a*) control—both hands kept warm (BW); *b*) both hands cooled (BC); *c*) performing hand cooled, other hand warm (PC); *d*) nonperforming hand cooled, other hand warm (NPC).

Regardless of the particular day's routine to which a given subject had been assigned, his HST was raised from basal level to a starting temperature of 90 F with the aid of an electrically heated muff. This is the HST level used consistently by Clark et al. to denote warm hands. In the present paper, however, the term warm will have two meanings: *a*) warm, without quotes surrounding it, will mean the usual 90 F HST; and *b*) "warm" will refer to the HST of the noncooled, nonperforming hand. This latter definition was added because of the desire for a warm-hand reference for HST that was free to vary as a function of contralateral hand cooling rather than being held at 90 F.

During the experimental days, manual performance, regardless of exposure condition, was tested inside the cooling unit where the air temperature was maintained at 10 F DB. This was done to insure that differences between warm- and cold-hand performance could not be accounted for in terms of differences in the cold-induced stiffness of the cords involved in the knot-tying task.

Performing hand warm, nonperforming hand "warm" (BW). The subjects tied one set of five knots at each of the following times: *a*) immediately after the HST of both hands had been raised to a mean of 90 F, and the performing hand had been inserted into the cooling-performing unit; *b*) after 10 min had elapsed from the initial entrance of the performing hand into the cooling box; *c*) after 20 min; and *d*) after 30 min. These intertrial periods corresponded roughly to the expected average times required to cool to the criterion HSTs (55, 45, and 40 F HST) at which performance was to be measured during the three other exposure conditions of the study.

Immediately after completing the task at each of the above times, the performing hand was withdrawn from the cooling unit. Subsequently, and just prior to the next attempt on the task, the HST of this hand was readjusted to the 90 F level. This rewarming procedure was used to prevent an accrual of the small amounts of hand cooling resulting from each 10–15 sec cold exposure that occurred during the BW performance measurements. The HST of the hand not engaged in performance under this condition was always "warm."

Both hands cooled (BC). Subjects tied one set of five knots at each of the following HST levels: *a*) at the starting HST of 90 F (this trial was identical to the first BW trial); *b*) after cooling to an average HST for the two exposed hands of 55 F; *c*) 45 F, and finally *d*) 40 F.

Performing hand cooled (PC). This procedure was the same as that for the BC condition with one exception, the nonperforming hand was "warm."

Nonperforming hand cooled (NPC). The NPC procedure was like PC except, of course, for the selection of the hand to be cooled, and the fact that the performing hand was maintained warm as in the BW condition.

RESULTS AND DISCUSSION

A Bartlett's test (10) indicated that the variances of the distributions of performance scores for the respective exposure conditions were heterogeneous. To correct this, and thereby satisfy the homogeniety assumption underlying the procedures of analysis of variance, the data of four excessively variable subjects were excluded (one from each of the latin-square subject groupings). The findings to be described were based on the data of the remaining 12 subjects.

Any error in statistical reliability established by this elimination procedure should be substantially attenuated in the manual performance data by the very high significance levels obtained. The HST data, however, must be considered more cautiously.

Hand skin temperature data. The possible effects of contralateral hand cooling on the HST of a "warm" hand were studied through comparisons of the temperatures of the "warm" hand in the PC condition at each of the three criterion HSTs of the cooled hand with the respective temperatures of the same "warm" hand at exactly the same elapsed time during the last day of practice. That is, experimental "warm" HSTs measured during contralateral hand cooling were compared with practice "warm" HSTs measured at the corresponding elapsed time when the contralateral hand was "warm." Differences between these "warm" HSTs are assumed to be related to the surface temperature of the contralateral hand since all other factors of known, or presumed, relevance were held constant.

Table 1 summarizes these findings in terms of group mean data. An analysis of variance indicated statistically reliable differences between the two sets of HSTs ($F = 6.36$; df $= 1/8$; $P < .05$), but no systematic effects of contralateral hand temperatures between 55 and 40 F ($F < 1$), and no significant interaction between the variables ($F < 1$). In general, cooling of the contralateral hand to at least 55 F HST resulted in a 2 F lowering of the surface temperature of the nonexposed hand. Further contralateral cooling appeared to be superfluous.

It is quite likely, considering the earlier findings of Nafe and Wagoner (4), that cooling of the performing hand in the PC condition resulted in slight vasoconstriction in the nonexposed hand, and that this vasoconstriction was responsible for the reduction in the latter's surface temperature.

Manual performance data. The BC, PC, and NPC exposure conditions were compared in their respective effects on performance after a subtractive correction had been made at each HST level for each subject's performance under the BW condition. Had performance times not varied with the cooling conditions, the corrected data would have been a collection of scores all approximating zero. Table 2 shows this not to be the case.

An analysis of variance for these data indicated a highly reliable interaction between cooling conditions and HST level ($F = 3.96$; df $= 6/128$; $P < .005$). Therefore, the differences between individual pairs of means within the rows (HST effects) and within the columns (cooling condition effects) of Table 2 were evaluated separately by t tests for related measures. The results may be summarized as follows: *a)* with respect to the effects of cooling conditions on performance; at the 90 F HST control level, BC = PC = NPC; at all other HSTs, BC = PC > NPC. *b)* With respect to the effects of HST level on performance: hand cooling above 40 F HST did not reliably hinder performance under the direct cooling conditions of BC and PC; performance was consistently facilitated under the contralateral cooling conditions of NPC, and the extent of this facilitation was statistically constant between HSTs of 55 and 40 F ($t = 4.75$; df $= 34$; $P < .001$).

Recalling that the actual surface temperatures of the performing hands in both NPC and BW conditions were identical (held at 90 F), the NPC effect may be considered largely psychological in nature, probably relating to the general motivational level of the subjects as contributed to by cold exposure, or to each subject's relevant cold experience. Clark and Jones (7) have reported data elsewhere suggesting that subjects may learn to overcome part of the mechanical restraint associated with cold-hand performance by increased effort. In the present study, had contralateral hand cooling elicited increased manual effort in the absence of actual mechanical stiffness of the performing hand, as in the NPC condition, the observed performance facilitation would be expected.

It is not possible to state definitively here the manner in which this facilitation might combine with the earlier mentioned 2 F reduction in "warm" HSTs during contralateral hand cooling. However, it is doubtful that such a change in a "warm" HST could have any direct influence on the performance capability of a "warm" hand since, as reported previously (6, 8), manual performance does not vary reliably with HST until hand temperatures at or below 55 F have been established for the performing hand. The effects of contralateral hand cooling on the performance of an unexposed hand appear to be mainly, if not entirely, psychological.

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