AN INVESTIGATION TO DETERMINE THE EFFECTS OF DIFFERENT CONDITIONS OF EXPOSURE TO COLD ON THE PERFORMANCE OF TWO TESTS

A Thesis

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by

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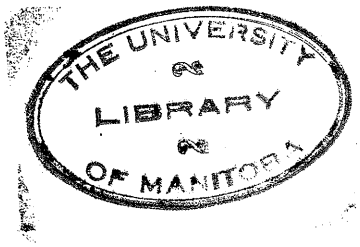

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CHAPTER 1

THE PROBLEM AND A SURVEY OF RELATED LITERATURE

1. INTRODUCTION

The Arctic and sub-Arctic regions have recently taken on added military importance in terms of the present problem of national defence. The problems of adjustment to climate are much greater in time of war. Instead of a house, Man has a vehicle or a foxhole in which to live. Instead of staying in the locality in which he was trained, he is transported to the desert, the tropics or the Arctic. He has no time to learn how to combat the extremes, but can only be briefly instructed and given what forms of protection are available.

As the environment becomes more severe, the more frequently will operations fail because of the inability of the personnel involved to remain efficient. Scott's last expedition to the South Pole and the high casualty rate in the Aleutian Campaign of the last war [1] are two general examples of losses that have resulted from inadequate knowledge of the human factors involved. The result of the severity of the environmental problems which may be encountered has stimulated investigations on the proper functioning of military equipment, both mechanized and personal.

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[1] Pamphlet - Medical Research Council, Report - Aug. 1948 F.P.Ellis.

The literature of Arctic exploration is full of advice on how to keep warm in extremely cold weather. The methods proposed involve properly balancing clothing, shelter, and bodily activity to maintain comfort under prevailing conditions of temperature and wind.

Superimposed on the various environmental stresses to which troops are exposed, is the necessity for performing a wide variety of activities. Aerial gunners exposed to severe cold must often remain inactive in cramped quarters for hours; soldiers must frequently continue forced marches for long periods. It has been established [2] that "in extreme cold no conventional clothing assembly is at the same time warm enough for standing around and sufficiently free of bulk to permit freedom of movement".

Experience has shown that clothing should be reduced in amount or loosened to avoid sweating during periods of hard work. Even when these precautions are taken, moisture which accumulates in the outer clothing makes it stiff with ice and as a result, reduces the insulation provided.

In an attempt to protect members of the Armed Forces from extremely low temperatures, electrically heated suits were developed. "Electrical failures of the gloves and slippers were numerous, and even when failure did not occur the distribution of heat in the garments was

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[2] Advances in Military Medicine - Vol.2Little, Brown and Co-Boston 1948 P. 498 U.S. office of Scientific Research and Development Andrus E.C. Bronk D.W.

unsatisfactory". [3]The proper distribution of heat to different parts of the hands and fingers is an obstacle which must be surmounted. Furthermore, with the mobile unit of to-day, it seems impractical to maintain a source of electrical heat.

In many of the northern areas, fuel is a considerable problem, and, to keep the whole body warm would demand too much fuel. Also as we have seen, attempts to keep the entire body warm have resulted in decreased mobility.

The hands and their adequate protection are of prime importance to a soldier, since they must be used continually and efficiently in the handling and repair of weapons and in the care of personal equipment. Results of previous investigations [4] show that exposure to extreme winter conditions causes deterioration in motor performance and the deterioration appears in the smaller muscles first.

The aforementioned suggests the possibility that, rather than keep the whole body warm, efficiency might be maintained by local applications of heat. While clothing may be adequate to prevent freezing, this does not necessarily ensure maintenance of efficiency. The problem of maintaining efficiency is not simply that of preventing frost-bite, for efficiency is impaired long before the body or any part

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[3] Ibid ., p. 502

[4] J. A. Sunde, " A field Study of the effects of exposure to extreme Winter Conditions on the performance of three motor tests", (Unpublished Master's thesis, The University of Manitoba, Winnipeg, 1950) P.P. 79-80

of it reaches the freezing point. Local application of heat is to be thought of, not in terms of comfort, but in terms of operational efficiency.

While there are distracting factors, other than the specific effects of cold on motor efficiency, attention will be focussed on this one particular aspect. The literature reviewed below deals briefly with the effects of exposure to cold on muscles and on blood circulation.

11. A BRIEF SURVEY OF RELATED LITERATURE

A study was made [5] of the activity of the intact gastrocnemius muscle and its antagonist when exposed to cold. The procedure in securing the data was to make control records from the muscle and then pack the leg in ice. After five minutes cooling, the relaxation time is increased 62%, while the period of contraction and the latent time are increased 21% and 12.5% respectively. This means that relaxation is affected three times as much as contraction and five times as much as the latency of the muscle. Ten minutes of cooling increases the period of relaxation 115%, while the contraction time is increased only 46% and the latency 24%. Under this condition, relaxation is increased 2.5 times as much as contraction and 4.6 times that of the latency. After twenty minutes of cooling, the situation

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[5] The Effects of Decreased Temperature on the Activity of Muscle W.W. Tuttle, PH.D., Iowa City - Journal of Laboratory and Clinical Medicine Vol 26 1940 - 1 - St. Louis, The C.V. Mosby Co. P. 1913:

is similar. Relaxationis increased 172%, contraction 82%, and latency 37.5%. Under this condition relaxation is increased 2.1 times as much as contraction and 4.6 times as much as latency. The results of this experiement seem to justify the conclusion that "cooling a muscle not only affects the relaxation more than any other period of its activity, but also shows this period from two to three times as much as the contraction".

It is a well known fact that cold contracts the arterioles of the skin, drives the blood to the interior and increases oxidation. If exposure to cold is prolonged the temperature of the skin and of the muscles lying beneath is reduced, and either the heat producing processes may be checked and a loss of temperature result or shivering may intervene. In this case muscular contractions and constriction of the blood vessels stimulate metabolism and heat production.

A study [6] of the skin and rectal temperatures of 10 normal subjects exposed to an environmental temperature of 20° C for two hours and of an equal number of subjects at a temperature of 15° C was made. It was found that the skin temperature fell markedly, more rapidly in the first hour and more precipitously at 15°C than at 20°C. It was also observed that the fall was least on the forehead and greatest on the extremities.

Reasons commonly given for the greater fall in the temperature

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[6] Freeman and Nickerson - Skin and Body Temperatures of Normal Individuals under cold conditions, Journal of Nutrition Vol 15, 1938 - The Wistar Institute of Anatomy and Biology, Philadelphia, P. 598.

of the extremities as was shown to happen in the study of Freeman and Nickerson are: lack of adipose tissue, absence of heat, generating organs and the large surface.

When an individual is exposed to a cold environment the sensation of cold often appears to be local. Finger-tips become numb and motor efficiency is impaired. One would suspect that if heat were applied to the hand, operational efficiency might be maintained.

CHAPTER II

THE EXPERIMENTAL PROBLEM AND ITS METHODS

I. THE PROBLEM

Statement of the problem. It was the purpose of this investigation to make an objective evaluation of the effect of different conditions of exposure to cold upon the performance of simple motor tasks primarily to determine if a person's efficiency could be maintained by local application of heat. "Different conditions of exposure" mentioned above, refers to four exposure conditions - namely - warm body - warm hand, cold body - cold hand, warm body - cold hand and cold body - warm hand.

Importance of the study. A considerable amount of research has previously been conducted with the purpose of evaluating the effects of exposure to winter conditions on the performance of motor tasks. No available evidence indicates, however, that investigators have directed their experimentation to the purpose of determining whether operational efficiency could be maintained as the result of the application of heat to a local part.

It has previously been determined [1] that individuals vary markedly in their ability to perform under cold stress. Some men

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[1] M. Bader, J. Mead - Journal of Applied Physiology - Vol 2 #11 May, 1950. P. 608.

seem to be particularly resistant to frostbite, can work with unprotected hands for considerable periods in the cold or withstand relatively long exposure under generalized cold stress without complaint. Others may be incapacitated under the same circumstances. Experience, training, attitude toward the cold and out-of-door-life, mechanical ability, and general co-ordination, intelligence, body build and fat distribution can all conceivably play a part. In addition, there may be significant individual differences in the specific physiological responses of the body to cold which would markedly influence cold tolerance.

Incentives for investigating the human response to excessive cold derive from several sources. Among them is the need for data on the physiological changes resulting from such prolonged exposure as occurs in lifeboats in northern areas, during fighting in semi-arctic terrain, and in the forced landings of planes in the snow.

The present investigation was undertaken as a small segment of the large area of experimentation which must be conducted if the effects of prolonged exposure to cold climatic extremes are to be minimized. It was designed to yield information of practical value concerning the effects of different exposure conditions upon simple motor performance and to act as a guide to future research along similar lines.

II. THE METHOD OF APPROACH

The problem of the effect of various conditions of exposure to cold upon motor performance is one which permits an objective, quantitative approach in the form of a scientific experiment.

The experiment was so designed that the data obtained by means of the experimental procedure would either contradict or confirm the hypothesis formulated - namely - that application of heat to a local part would enable the individual to maintain motor efficiency in spite of exposure of his body to cold. It was possible, also, to make an analysis of the data in order to assess the extent of deterioration due to exposure, and to determine the differential effects of the various conditions of exposure. Hand skin temperatures were recorded during the course of the experiment with the expectation of determining their relation to impairment scores.

The investigation took the form of a cold room experiment composed of simple, realistic motor tests that permitted of controls essential to a scientific experiment.

III. DEFINITION OF TERMS USED

Test. This term refers to either of the two types of test apparatus - the "blocks" or the "bolts" - utilized in the experiment.

Sub-test. refers to either the four bolts and nuts, which are designated as sub-test A, or the three smaller bolts and nuts

designated as sub-test B.

Test-Battery. The blocks test plus sub-test A and sub-test B mentioned above, when carried out consecutively, constituted the test-battery or test group.

Conditions of exposure. This term, as used throughout the thesis, refers to the four conditions experienced by the subjects- namely: warm body, warm hand; cold body, cold hand; warm body, cold hand; and cold body, warm hand. The duration of exposure between the first and last tests on any one day, was approximately seventy minutes.

Trial. Is the term applied to the testing activities carried out during any one day. The trials included three performances of the test-battery, the last two being performed after exposure periods.

Deterioration. For convenience, all changes in test score have been expressed in terms of deterioration, since a study of deterioration was the main object of the experiment. Where improvement occurred, it is expressed as negative deterioration.

Experiment. The full series of four trials - under the four conditions of exposure - constituted the experiment proper.

Organization of the remainder of the thesis. Subsequent chapters of this thesis will embody the following considerations: (a) details of the experiment, including a description of the

nature and administration of each test, and the order and conditions of presentation, (Chap. II). (b) the presentation, discussion and interpretation of the data gathered during the course of the experiment, (Chap. IV): and (c) the conclusions drawn as a result of the investigation, together with suggestions for further experimentation, (Chap. V).

CHAPTER III

THE TESTS AND THEIR ADMINISTRATION

I. INTRODUCTION

The purpose of the present investigation was to obtain a direct measure of the effect of four different conditions of exposure to cold upon the performance of two motor tests.

The two motor tasks selected for the test-battery were both used previously [1] in former investigations. They contain elements approaching a realistic manipulation such as might be encountered in outdoor work, and at the same time they permit a high degree of experimental control. The movements involve only simple motor activities and depend on speed of hand and arm movement rather than on judgement or precision in eye-hand co-ordination.

In an attempt to isolate the effects upon speed of performance which were due to exposure from the effects resulting from series practice and fatigue, a master plan of the order of presentation of tests and conditions of exposure was prepared.

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[1] J. A. Sunde, " A Field Study of the Effects of Exposure to Extreme Winter Conditions on the performance of three motor tests", (Unpublished Master's thesis, The University of Manitoba, Winnipeg, 1950) P.P. 79-80.

Frizell, R.N., "A Field Study of the Effect of Extreme Winter Conditions on a Test of Motor Performance, "unpublished Master's thesis, The University of Manitoba, Winnipeg, 1949.

The present chapter offers a complete description of the two tests selected for the experiment, and of the experimental techniques utilized in their administration.

II. THE TESTS

A. The "Bolts" Test. Two sub-tests involving the turning of nuts on to bolts, the heads of which are embedded in a wooden base.

Nature of the test. The bolts test was included in the test-battery as it was considered to approach as nearly as possible a realistic manipulation, such as might be required of one whose job it is to make minor repairs. At the same time, the simple nature of the task assures good experimental control. Test-retest reliability for Bolts sub-test A (test period 1vs. test period 3) was .80. For Bolts sub-test B = .74.

Description of the test. The test was designed by R.N. Frizell [2] and only slightly modified for the present investigation.

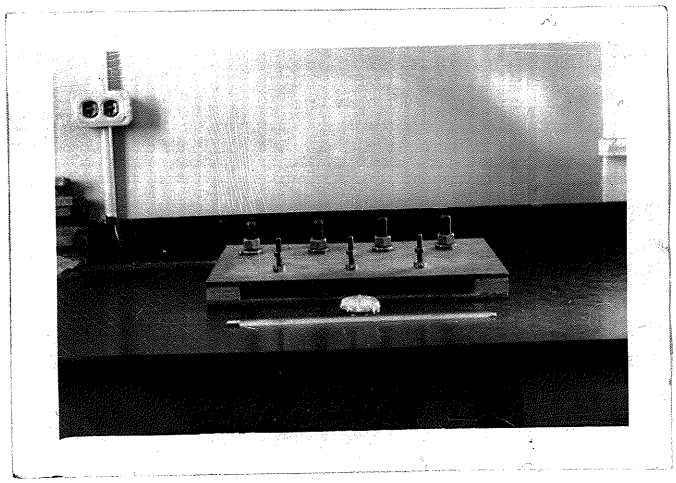

Fig A

[2] "A Field Study of the Effect of Extreme Winter Conditions on a Test of Motor Performance" (unpublished Master's thesis, The University of Manitoba, Winnipeg, 1949).

The bolts used in sub-test A are of five-eighths of an inch in diameter and those in sub-test B are five-sixteenths of an inch in diameter. The nuts fitted to these bolts have the dimensions one inch x three-quarters of an inch for sub-test A and nine-sixteenths of an inch x four inches for sub-test B, and are hexagonal. The nuts and bolts are of the ordinary commercial grade in mild steel, the nuts being of a rather slack fit, turning easily with the hand and at no point requiring forcing.

Both series of bolts are mounted on one frame and are separated by a five inch space. Working clearance i.e. the distance between the nuts when they are placed on the bolts, is two and three quarter inches for the sub-test A series and three and one quarter inches for the sub-test B series.

One deviation from the original test design was that the nuts, instead of initially being placed on the bolts, were arranged in an orderly fashion in front of the bolts on to which they were to be turned. This made the test more difficult and as a result more sensitive, since the pattern of co-ordination required to place the nuts on to the bolts was more complicated. With the nuts placed in this manner, the number of turns required on each bolt of sub-test A is fifty eight and forty six on each bolt of sub-test B.

In an effort to reduce the tendency of the nuts to spin freely while being turned down on the bolts, the latter were coated with glycerine, and the free spinning was entirely eliminated.

Directions for administering the test. The test was begun by having the subject face the board on to which the bolts were attached. In response to the command "Ready? Go", he was instructed to pick up the nut and begin to turn it on to the bolt as fast as he could, using only one hand. He was to employ as far as possible a deliberate turning action, using the thumb and fingers, and to avoid rolling the nut down with the side of his hand. He was told to start with the bolt opposite his preferred hand and continue until he had completed the 4 bolts. As the subjects tested were all right-handed, all proceeded from their left to right in each series. Having completed sub-test A, the subject was then given the same command for sub-test B. Separate time records were kept for both sub-tests.

The experimenter then prepared the test for the next subject by rolling off the nuts and placing them in their appropriate places in front of the bolts.

B. The "Blocks" Test. "Blocks" test was the name adopted during the course of this investigation to denote the Minnesota Manual Dexterity Test.

Nature of the Test. This simple perceptual - motor test depends neither on judgement of differences in size or shape, nor in precise eye-hand co-ordination, but rather on speed of gross hand and arm movements. It measures the speed with which a subject picks up one hundred and sixteen cylindrical blocks, all of the same size, and places them in holes in a board. Test Retest reliability for

the Blocks test was .87.

Description of the test. The blocks test consists of a board with circular holes, and cylindrical blocks of wood to place in these holes. [2]

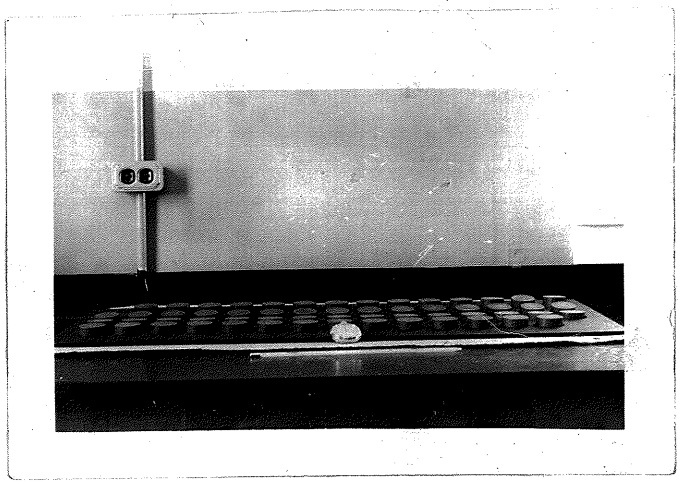

Fig. B

Administration of the test. The board was placed on a table of standard height, with the blocks arranged just beyond the board.

The subjects were instructed to place the blocks into the board as rapidly as they were able. After filling the board the first time, they were to proceed at once to fill it the second time without any aid or instruction from the experimenter.

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[2] A complete description of the test, together with dimensions, appears in W.V. Bingham, Aptitudes and Aptitude Testing, pp.278-9.

A consistent pattern of filling the board was to be maintained throughout. If they filled it in a horizontal sequence the first time, they were to do it in the same fashion for the remainder of trials on the blocks. Similarily, if they filled it vertically on the first trial, the same pattern was to be followed for the remainder of the experiment.

The subject began the performance of the test at the second word of the command "Ready? Go", and it was timed from the word "Go", until the board was completely filled the second time. He was instructed not to pick up any blocks in the event that they were dropped, but to proceed with the task. This instruction was given because the time lost in picking up the blocks would throw off the timing of that particular trial. Throughout the course of the experiment only two blocks were dropped.

III. THE PLAN OF THE EXPERIMENT

The experiment conducted involved one group of sixteen subjects, a test battery comprised of two tests, and four conditions of exposure. The number of factors involved necessitated a careful planning of the experiment in order that the effects of exposure upon motor performance might be isolable.

A master plan drawn up before the actual testing was begun, provided the individual subject with the order of presentation of tests and the special condition of exposure during his four trials.

Before the actual testing was begun, a "dry test" was run through with six subjects and it was found impossible ~~for the~~

for the experimenter unaided to take the nuts off the bolts after each test, time the various subjects, and bring the two tests from the cold to the warm room and vice-versa. An assistant was hence provided.

Order of testing of the subjects . The sixteen subjects who participated in the investigation were all University students. It was very difficult to arrange for the group to meet together for any period of time amounting to two hours or more. At the same time it was desirable to retain the proposed schedule of three presentations of the test-battery on each trial. In order that the testing program should not take too much of the subjects' time on any one day, it was decided to divide them up into two groups -one-half being tested on Friday, the remainder on Monday. The subjects were paired to facilitate testing. The members of these pairs worked together throughout the course of the experiment. The order of testing for each pair of subjects was chosen arbitrarily and is shown in table I on page 19.

Order of presentation of the tests . Nine test scores were obtained for each subject during each of his experimental runs, three scores being obtained from the blocks test and three from each of the two bolts sub-tests. In an attempt to control the series effects resulting from fatigue and practice, the tests were presented in rotation [4].

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[4] T. G. Andrews, editor, Methods of Psychology, (New York, John Wiley and Sons, Inc., 1948), p. 13.

TABLE I

TEST ORDERS AND CONDITIONS FOR INDIVIDUAL SUBJECTS
FOR EACH TRIAL OF THE EXPERIMENT

Day	Condition	Subject	Test order: No. exp.	1st exp.	2nd exp.	Day	Condition	Subject	Test order: No exp.	1st exp.	2nd exp.
I	1		AB	BA	AB	I	2		AB	BA	AB
II	2	1)	BA	AB	BA	II	3	2)	BA	AB	AB
III	3		AB	AB	AB	III	4		AB	AB	AB
IV	4		BA	AB	AB	IV	1		BA	AB	BA
I	3		AB	AB	AB	I	4		AB	AB	AB
II	4		BA	AB	AB	II	1		BA	AB	BA
III	1	3)	AB	BA	AB	III	2	4)	AB	BA	AB
IV	2		BA	AB	BA	IV	3		BA	AB	AB
I	1		BA	AB	BA	I	2		BA	AB	BA
II	2		AB	BA	AB	II	3		AB	AB	AB
III	3	5)	BA	AB	AB	III	4	6)	BA	AB	AB
IV	4		AB	AB	AB	IV	1		AB	BA	AB
I	3		BA	AB	AB	I	4		BA	AB	AB
II	4		AB	AB	AB	II	1		AB	BA	AB
III	1	7)	BA	AB	BA	III	2	8)	BA	AB	BA
IV	2		AB	BA	AB	IV	3		AB	AB	AB

Note: The same test orders and conditions of exposure were used for both groups of eight subjects.

CODE: Conditions 1.- warm body-warm hand
2.- cold body-cold hand
3.- warm body-cold hand
4.- cold body-warm hand

Tests A - bolts
B - blocks

Exp. - exposure

Two orders of presentation of the group of tests were alternated throughout the trials:

1. Blocks-bolts sub-test A-bolts sub-test B
2. Bolts sub-test A-bolts sub-test B-blocks.

In all cases, the bolts sub-test B was performed immediately after that of bolts sub-test A. The length of the bolts tests made it possible for one subject to be performing it while his partner was performing the blocks test.

It was desirable to have the two subjects with warm body-cold hand and the two with cold body-warm hand, perform the bolts test before the blocks because of the differential effects of hand cooling with the bolts. Adopting this method, cooling of the hand at random was eliminated.

The order of presentation of the tests for each subject on each trial appear in Table I on page 19. While the order of rotation is balanced for each condition of exposure, it was impossible to control the series effects within each day's trials.

Conditions of exposure. The first administration of the test-battery to each pair of subjects began as soon as they had entered the testing room and taken their skin temperature. The four subjects who were under the condition of having their body cold, performed the tests in the cold room, whereas the four subjects whose ~~body was~~ bodies were to be kept warm performed in the warm room.

Between the first and second administrations of the test-battery and between the second and third, the members of each pair

of subjects were required to spend periods of from thirty-five to forty minutes under one of four conditions of exposure : 1) body warm-hand warm 2) body cold-hand cold 3) body warm-hand cold and 4) body cold-hand warm.

The condition of exposure for each subject, on each day of the trials is presented on page 19. It will be noticed that the conditions are balanced over the period of the experiment as a whole, but the presentation of the tests to four of the subjects on each day is not balanced. This is due to the fact that the subjects with cold body-warm hands and warm body-cold hands did the bolts test before the blocks test on all occasions.

The condition of warm body-warm hand allowed the subject to sit or walk around in the warm room, the temperature of which approximated 33°C. Under the condition of cold-body-cold hand, the subjects were allowed to walk around in the cold room, the temperature of which was approximately -8°C. If shivering became too severe, they were allowed to throw their coats over their shoulders. The cold body-warm hand subjects sat down at a table in the cold room and placed placed their right hand in between two heating pads. In the event that their bodies became uncom- --- fortably cold, they were also permitted to wear their overcoats. Skin temperatures of the cold hand were recorded every five minutes. The warm body-cold hand subjects seated themselves at a partially open window in the same room as the warm body-warm hand subjects performed their tests. To the

window was attached a cardboard which allowed them to expose their right hands to the cold air, ranging between plus and minus 20°C., but at the same time their bodies were kept warm. Hand-skin temperatures before starting and after completion of the test - battery for this condition of exposure is tabulated in Appendix A, Page 61, under Condition 3.

The experimental procedure was at fault in that no records were taken of the ambient temperature of the hands of subjects under the warm body-cold hand condition. However, despite the fact that ambient temperatures varied, the investigation was primarily concerned with how cold the hand became, rather than the surrounding temperature which brought the skin temperature down to such a level.

IV. FURTHER CONTROLS

A complete explanation has already been given of the controls applied to the order of presentation of the tests to the subjects, the rotation of conditions of exposure between the performances of the test-batteries, and the administration of the tests. There were a number of further controls utilized in an effort to obtain unbiased results.

Clothing. It was impossible to have every subject wear exactly the same clothing every day on which he was tested. They were, however, asked to wear comparable clothing throughout; generally, subjects wore slacks and a sport coat.

Motivation. The subjects were all University students, most of them taking Psychology. They all volunteered and were genuinely interested in the experiment.

Time and Place. The trials were held during the early part of the afternoon on each day. The site of the testing was an Agricultural Research Building, chosen because it had a room which was heated and also an adjacent room which could be used as a cold room. The temperature of the warm room was nearly constant throughout the investigation and the adjacent cold room varied by only two or three degrees.

Apparatus. In an attempt to eliminate the free spinning of the nuts, the bolts were given a uniform coating of glycerine

each day before the trials were begun.

CHAPTER IV

ANALYSIS AND INTERPRETATION OF THE DATA

The raw data recorded during the course of the experiment appears in Appendix A. All calculations appearing in the analysis presented in this chapter are derived from the ungrouped raw data, using the formulae presented in Appendix B.

I. CONDITIONS OF EXPOSURE

A reasonable experimental design appears to demand at least four conditions of exposure in order to determine whether variations of the temperature of a local part produce changes of efficiency independently of the body temperature. Two conditions of exposure, which might be regarded as anchorage points, are that of warm hand and cold hand. These may each have two different combinations- namely, warm and cold body. Therefore, the four conditions of exposure utilized in the present investigation are warm hand-warm body, warm hand - cold body, and cold hand-warm body and cold hand-cold body.

The test battery was administered to each subject three times under each of the four conditions. The first battery was presented to the subjects without any exposure, the second battery was given after thirty-five minutes exposure and the third after seventy minutes. The effects of exposure to a given condition on performance are measured by comparing trials 2 and 3 with trial 1.

Consequently, averages and standard deviations are calculated for each of the test periods under each condition and are shown in Table 6, on page 30.

II. THE EFFECTS OF DIFFERENT CONDITIONS OF EXPOSURE ON TEST PERFORMANCE

Condition 1. Under this condition, the subjects spent the test periods in a warm room. From the data secured this way, we obtain an indication of what level of performance might be expected under optimal conditions.

While it may seem to be desirable that the trials under the condition of warm body-warm hand be used as a standard against which to measure deterioration, there is a real difference between the warm and the cold rooms. The results obtained justify this statement, and these differences seem to cast doubt on such a treatment of the data. When the subjects performed the test battery in the cold room, having been exposed to the cold for only approximately three minutes, the average score for the initial test was higher than it was for the first trial conducted in the warm room. It does not seem reasonable to assume that these three minutes of exposure were the cause of the impaired performance. Factors other than exposure, apparently affected performance. For this reason, the all warm conditions has not been used as the control condition against which deterioration has been measured.

Referring to Table 6 on page 30 it will be seen that the average performance improved as between test periods 1, 2, and 3. The mean score for the blocks was 106.8 seconds in the first test period and was decreased to 101.8 seconds in the third test period. In the initial test period for Bolts sub-test A the mean score was 84.6 seconds and was 82.8 seconds in the third test period. For the Bolts sub-test B, the initial score was 42.8 seconds and 42.5 seconds in the third test period. The differences between the first and third trials for the blocks test are significantly different, indicating that there is an improvement factor operating. This result was substantiated by Sunde's data.

Table 8 on page 33, expresses the deterioration or improvement as percentages. The results may be briefly summarized as follows:

TABLE II

	Blocks	Bolts A	Bolts B
TRIALS	% Det.	% Det.	% Det.
1 & 2	-3.93	-2.37	1.17
1 & 3	-4.68	-2.13	-.70

- indicates a mean improved % score.

Between trials 1 and 2 for the 'blocks' test, 3.93 % improvement in mean score is significant, as may be seen in Table 8 page 33. The same applies for the 4.68% improvement between trials 1 and 3, Bolts sub-test A show a mean improvement of 2.37% between trials 1 and 2, and 2.13% improvement between trials 1 and 3, the former

being significant. Bolts sub-test B however, shows a deteriorated performance between trials 1 and 2 and an improvement of .70% between trials 1 and 3, neither of which is significant. The deterioration shown between trials 1 and 2 for this test may conceivably have been caused by the fact that the individual's finger muscles were tired, since in all cases this test was performed immediately after bolts sub-test A.

It should be noted that the method employed in the thesis to measure deterioration does not take into account the improvement that occurs under 'normal' conditions and the measures of deterioration are therefore probably smaller than they should be.

Condition 2. Table V on page 30 shows that for the blocks test and the two bolts sub-tests there is considerable deterioration between trials. The average performance score on the blocks tests for the first trial was 110.4 seconds which increased to 122.2 seconds after seventy minutes of exposure. Performance on bolts sub-test A increased from 90.9 to 121.4 seconds and bolts sub-test B from 44.1 to 57.9 seconds. The mean deteriorated score is significant in the three cases. The difference in scores between test periods 1 and 3 are significant in each case.

Table 8 page 33 shows the percentage deterioration to be as follows:

TABLE III

	Blocks	Bolts A	Bolts B
TRIALS	% Det.	% Det.	% Det.
1 & 2	5.7	21.01	24.72
1 & 3	10.69	33.55	31.29

It will be noticed that the percentage deterioration is greater between trials 1 and 3 or after seventy minutes of exposure than it is between trials 1 and 2 which was after thirty-five minutes of exposure. The deterioration for bolts sub-tests A and B is considerably higher than that for the blocks test. This is possibly caused by the fact that larger muscles are used in the blocks tests, also, the fingers lose heat to the metal nuts, thus reducing the skin temperature of the hand.

Condition 3. It might be suggested at this point that subjects under condition 1 should have been instructed to seat themselves and keep their right arm elevated at approximately the same angle at which subjects under condition 3 had to keep their arms during the exposure period. If any fatigue was involved in adopting this position, it would have then been equalized for the two conditions. None of the subjects however, mentioned any element of fatigue during the course of the investigation.

Table 6 page 30 indicates there was considerable deteriorations between trials, although not as great as that for condition 2. Performance scores on the blocks test increases from 105.8 seconds for test period 1 to 112.1 seconds for test period 3. Scores on bolts sub-test A increases from 86.1 seconds in test period 1 to 115.2 seconds after seventy minutes of exposure and bolts sub-test B increases from 45.2 seconds to 55.3 seconds in the third test period.

Table 8 page 33 expresses the deterioration in terms of percentages:

TABLE IV

	Blocks	Bolts A	Bolts B
TRIALS	% Det.	% Det.	% Det.
1 & 2	1.70	26.02	15.04
1 & 3	5.95	33.79	22.30

It will be noticed here, also, that deterioration is greatest between test periods 1 and 3 but because it is smaller than that for condition 2, it seems to indicate that the warm body to some extent, countereacted the effects of cold on the exposed hand, despite the fact that is was not sufficient to prevent impairment in motor performance. The fingers were also warming up, which would tend to reduce the difference in impairment between condition 2.

Condition 4. Table 6 page 30 indicates that for the blocks test, performance scores decreased from 110.4 seconds in the first test period to 109.4 seconds in the third test period. For bolts sub-test A the score increased from 89.3 seconds to 91.2 seconds after seventy minutes of exposure and bolts sub-test A increased from 46.7 seconds to 48.4 seconds. However, none of these scores are statistically significant. The deterioration expressed in terms of percentages was as follows:

TABLE V

	Blocks	Bolts A	Bolts B
TRIALS	% Det.	% Det.	% Det.
1 & 2	- .72	3.47	4.92
1 & 3	- .91	2.13	3.64

- indicates a mean improved performance score.

TABLE VI

EFFECTS OF CONDITIONS OF EXPOSURE
ON PERFORMANCE OF THE TESTS

Condition	Test Period	N	Blocks M	Blocks Sd	Bolt Sub-Test A M	Bolt Sub-Test A Sd	Sub-test B M	Sub-test B Sd
Warm Hand	1st	16	106.8	11.89	84.6	12.28	42.8	7.10
Warm Body	2nd	16	102.6	11.96	82.6	11.86	43.3	6.60
	3rd	16	101.8	10.06	82.8	11.79	42.5	5.80
Cold Hand	1st	16	110.4	9.87	90.9	20.92	44.1	8.62
Cold Body	2nd	16	116.7	10.67	110.0	27.30	55.0	9.34
	3rd	16	122.2	16.97	121.4	45.14	57.9	9.43
Cold Hand	1st	16	105.8	9.94	86.1	18.21	45.2	7.80
Warm Body	2nd	16	107.6	9.95	108.5	24.91	52.0	10.67
	3rd	16	112.1	10.90	115.2	25.40	55.3	9.33
Warm Hand	1st	16	110.4	12.74	89.3	12.25	46.7	9.11
Cold Body	2nd	16	109.6	14.13	92.4	16.00	49.0	8.90
	3rd	16	109.4	13.26	91.2	15.20	48.4	6.21

TABLE VII

SIGNIFICANCE OF THE DIFFERENTIAL EFFECTS OF THE EXPERIMENTAL CONDITIONS OF EXPOSURE

Condition	Test N Blocks	Trials	N	D	r	^1D	t	P
Warm Body		1 & 2	16	-4.2	.91	1.35	3.11	.0018
Warm Hand		2 & 3		- .8	.96	.97	.83	.4066
		1 & 3		-5.0	.87	1.55	3.23	.0012
Cold Body	"	1 & 2	16	6.3	.89	1.30	4.85	H Sig
Cold Hand		2 & 3		5.5	.78	2.92	1.88	.0600
		1 & 3		11.8	.56	3.76	3.19	.0014
Warm Body	"	1 & 2	16	1.8	.76	1.83	.98	.3270
Cold Hand		2 & 3		4.5	.81	1.73	2.60	.0094
		1 & 3		6.3	.67	2.27	2.78	.0054
Cold Body	"	1 & 2	16	- .8	.89	1.72	.47	.6384
Warm Hand		2 & 3		- .2	.91	1.57	..13	.8966
		1 & 3		-1	.86	1.83	.54	.5892
	Bolts Sub-Test A							
Warm Body		1 & 2	16	-2	.95	1.02	1.96	.0500
Warm Hand		2 & 3		.2	.86	1.67	.12	.8975
		1 & 3		- 1.8	.80	2.02	.89	.3734
Cold Body		1 & 2	16	19.1	.85	3.87	4.93	V H Sig
Cold Hand		2 & 3		11.4	.93	5.99	1.90	.0574
		1 & 3		30.5	.78	8.49	3.59	.0004
Warm Body		1 & 2	16	22.4	.75	4.40	5.09	H Sig
Cold Hand		2 & 3		6.7	.92	2.69	2.49	.0128
		1 & 3		29.1	.82	3.95	7.37	H Sig
Cold Body		1 & 2	16	3.1	.42	3.98	.78	.4354
Warm Hand		2 & 3		-1.2	.95	1.29	.92	.3576
		1 & 3		1.9	.39	4.10	.46	.6456

TABLE VII (continued)

Condition Test	N	Trials	N	D	r	'D	t	P
Bolts Sub-Test B								
Warm Body		1 & 2	16	.5	.76	1.27	.39	.6966
Warm Hand		2 & 3		-.8	.72	1.26	.63	.5286
		2 & 3		-.3	.74	1.28	.23	.8180
Cold Body		1 & 2	16	10.9	.50	2.40	4.54	H Sig
Cold Hand		2 & 3		2.9	.77	1.70	1.71	.0872
		1 & 3		13.8	.68	1.93	7.15	H Sig
Warm Body		1 & 2	16	6.8	.37	2.87	2.37	.0178
Cold Hand		2 & 3		3.3	.72	2.01	1.64	.1010
		1 & 3		10.1	.42	2.53	3.99	H Sig
Cold Body		1 & 2	16	2.3	.74	1.73	1.33	.1836
Warm Hand		2 & 3		-.6	.89	1.16	.51	.6100
		1 & 3		1.7	.91	1.14	1.48	.1388

TABLE VIII

DETERIORATIONS EXPRESSED AS PERCENTAGES

	TRIALS	BLOCKS % Det.	BOLTS A % Det.	BOLTS B % Det.
Condition 1	1 & 2	3.93#	2.37%	1.17
	2 & 3	.75#	.23	1.87
	1 & 3	4.68#	2.13#	.70%
Condition 2	1 & 2	5.7	21.01	24.72
	2 & 3	4.98	12.54	6.58
	1 & 3	10.69	33.55	31.29
Condition 3	1 & 2	1.70	26.02	15.04
	2 & 3	4.25	7.78%	7.30
	3 & 1	5.95	33.79	22.30
Condition 4	1 & 2	.72%	3.47	4.92
	2 & 3	.18#	1.34#	1.28#
	1 & 3	.91#	2.13	3.64

Despite the fact that the body was allowed to get cold, it would appear that the warming of the hand, although it did not enable the subjects to maintain complete efficiency in terms of what they did under condition 1, nevertheless helped them to keep it near to maximal efficiency.

Figure 1, on page 34a, summarizes the trend of the performance scores from test-period to test-period, for each of conditions of exposure. It indicates that the all cold and the cold hand-warm body conditions of exposure affect performance to a considerable extent, and in a similar direction. The conditions of all-warm and cold body-warm hand affect performance only slightly.

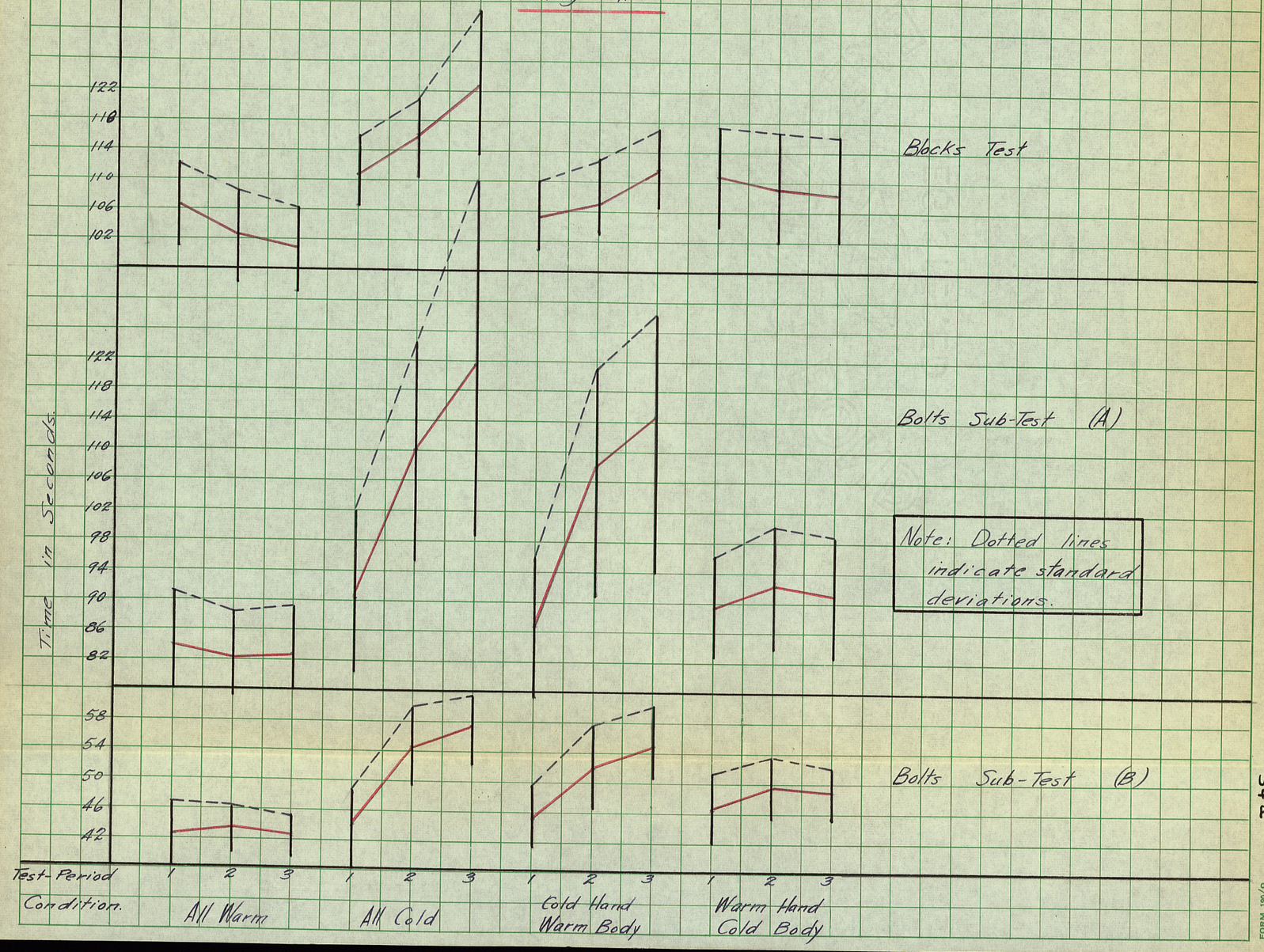
We may conclude that the effects of cold are not wholly local. When an individual is exposed to cold, application of heat to a local part does not suffice to prevent some deterioration in motor performance. It does on the whole, however, enable the subjects to maintain a level which is close to their initial level of performance, but the improvement found under condition 1 is not obtained.

III. PROBLEM OF INDIVIDUAL DIFFERENCES WITH RESPECT TO EXPOSURE EFFECTS.

We have already shown on the basis of group results, that different conditions of exposure result in changes in test performance. If it could be indicated that there is a real difference in the way

The Effects of the Conditions of Exposure upon Test Performance

Fig 1.



that individuals react to these conditions rather than their being affected more or less equally, it would be evident that there is a problem of selection with respect to cold tolerance.

a) Differential effects of exposure to cold.

On the basis of mean differences, the effect of exposure to cold is to increase the time scores on the motor tasks, but are all subjects equally affected? If we correlate scores for blocks test, trial 1 condition 1 with scores for the blocks test, trial 1, condition 2, we have a correlation which is not affected by any possible differential effects of exposure. If we correlate blocks test trial 1 condition 1, with blocks test, trial 3 condition 2. we have a correlation which does take into account any possible differential effects due to exposure. If these two correlations are significantly different, it would indicate that there are real differences with respect to individuals reactions to exposure. [1]

The difference between r's for all warm(1st trial) vs all cold (1st trial) and all warm (1st trial) vs all cold (3rd trial) was tested for significance with the following results:

(i)

Blocks test

All warm (1st trial) vs. all cold (1st trial) $r = .42$ $n = 16$

All warm (1st trial) vs. all cold (3rd trial) - $r = .37$

All warm vs. all cold (1st trial) $-.42 \frac{z}{.448} \frac{N - 3}{13}$

---

[1] In testing for these differential effects, the general method adopted was to calculate the difference between two observed correlations by R.A. Fisher's Method - R.A. Fisher Statistical Methods for Research Workers, (London: Oliver & Boyd, 1938), P. 208.

All warm vs. all cold (3rd trial .37 .388 13

T. Score = .153 P = .8808

(ii)

Bolts Sub-Test A

All warm vs all cold (1st trial) - r = .56

All warm vs all cold (3rd trial) - 5 = .30

T score = .822 P = .4122

(iii)

Bolts sub-test B

All warm vs all cold (1st trial) __ r = .38

All warm vs all cold (3rd trial) __ r = .16

T score = .608 P = .5484

These results indicate that the individuals are not differentially affected by exposure to cold. If the T scores are low for conditions where deterioration is great, it is not likely that we would find differences between the other two conditions where the deterioration is smaller.

In view of the high coefficients of reliability (page 31) one might expect a high correlation between the first trial for the all warm condition and the first trial for the all cold condition, since the only difference between the two is the fact that the tests for the all cold condition (1st trial) were performed in the cold room (with exposure of approximately three minutes), rather than the warm room. The data however, indicates that the results of tests conducted in the warm room are not the same as when they are conducted in the

cold room with approximately three minutes of exposure - the test-retest correlation for blocks' test in warm room was .87 which falls to .42 when the first test periods in the warm room and the cold room are compared. One contributing factor may be the nature of the experimental design.

The rotation method of presenting conditions was employed with the intention of balancing out for the group what practice effects did exist, so that the mean scores would be comparable on the basis of the variable conditions of exposure. While differences between mean scores appear to be well protected against variable practice effects, neverthless they may still affect correlations. Some of the subjects that performed under the all warm conditions would be presumably worse than the subjects that performed under this condition the third or fourth day of the experiment. This also applies to the remaining conditions of exposure. If practice effects are great, the tendency will be to mask the high correlations which actually exist, when practice effects are equated. Such may be the reason for the low correlations shown above and, if this could be taken into consideration, individuals may be found to be differentially affected by exposure to cold.

Correlations were calculated between condition 1 (test period 1) and condition 3 (test period 1) and between condition 2 (test period 1) and condition 4 (test period 1). Individuals subjected to condition 1 and 3 all performed the test bettery in the warm room, whereas individuals subjected to condition 2 and 4 performed in the cold room. Since

practice effects between conditions 1 and 3 would be equally as great as between conditions 1 and 2, then if we find high correlations here, it would indicate that practice effects are of little consequence and the low correlation between conditions 1 and 2 are due to the conditions of the room and the conditions of testing. The results of these correlations are as follows:

	Blocks	Bolts A	Bolts B
Condition 2 (trial 1) vs condition 4 (trial 1) r =	.47	.46	.63
Condition 1 (trial 1) vs condition 3 (trial 1) r =	.50	.65	.45

The low correlations indicate that practice effects are the cause for the discrepancies found in test performance when trial 1 in the warm and trial 1 in the cold room are compared.

IV. THE RELATION OF HAND - SKIN TEMPERATURES TO IMPAIRMENT SCORES:

At the end of each exposure period, just prior to the second and third test - periods, the skin temperature of the right hand of each subject was measured. Each subject was given a thermometer and was instructed to keep its bulb against the palm of his hand until the reading remained at a constant level. There are a number of shortcomings in this measurement, but these did not seem too important in view of the gross differences with which we are to be concerned. On the basis of no better knowledge, the temperatures at the beginning of an exposure period and at the end of the exposure period were averaged - the assumption being that the member had endured the mean temperature over the whole period.

In assessing the relationship of skin temperature to changes in efficiency only the three conditions where the individuals were exposed

to cold have been taken into consideration. Thus two sets of forty-eight measures of skin temperature for each of the three motor tests utilized in the experiment were obtained. The first set is the average of the skin temperatures before starting the tests and the temperature after thirty-five minutes of exposure. The second set is the average of the initial skin temperature and the temperature before the second exposure period.

There are a number of ways be which the relationship between skin temperature and deterioration or maintenance of efficiency might have been assessed - Two main approaches have been utilized:

(1) the use of skin temperatures that have been averaged, employing quintiles,

(2) the utilization of skin temperatures at a given point.

a) 1st Method of analysis

The subjects were grouped as nearly as possible into five equal groups, the warmest being at one end of the scale, the coldest at the other. Deterioration scores were calculated and the scores which were associated with each of the measure of skin temperature were then averaged for each quintile. The results are shown below in table IX. Impairment scores refer to the difference in score between test-period 1 and test-period 2 or 3. Where the score is positive it represents an improvement, where negative an impairment.

TABLE IX

BLOCKS TEST

Periods 1 and 2

	Quintiles 1.	2.	3.	4.	5.
	8	10	10	9	11
Range of temp. (n 35)	35-32	31-28	27-25	24-23	22-17
Mean Imp. Score	-2.5	-3.0	-7.4	-4.77	-4.36

Periods 1 and 3

	10	11	11	9	7
Range of temp. (n 70')	36-32	31-25	24-23	22-21	20-15
Mean Imp. score	-3.4	-4.54	-2.63	-12.33	-17.55

BOLTS - SUB-TEST A

Periods 1 and 2

	Quintiles 1.	2.	3.	4.	5.
	8	10	10	9	11
Range of temp (35')	35-32-	31-28	27-25	24-23	22-17
Mean Imp. Score	-1.12	-6.2	-22.9	-2255	-18.27

BOLTS SUB-TEST A

Periods 1 and 3

	1.	2.	3.	4.	5.
	10	11	11	9	7
Range of temp (n 70')	36-32	31-25	24-23	22-21	20-15
Mean Imp score	-1.8	-15.63	-24	-27.66	-4656

BOLTS SUB-TEST B

Periods 1 and 2

	1.	2.	3.	4.	5.
n	8	10	10	9	11
Range of temp. (70^{n})	35-32	31-28	27-25	24-23	22-17
Mean Imp. Score	-3.37	-2.9	-8.8	-12.44	-9.18

Periods 1 and 3

	1.	2.	3.	4.	5.
n	10	11	11	9	7
Range of temp. (70^{n})	36-32	21-25	24-23	22-21	20-15
Mean Imp. Score	-2.3	-4.9	-9.36	-13.77	-15

In Table IX the progression of impairment scores accompanying lowered skin temperatures, indicates a general relationship between fall of temperature and impairment of performance, but these mean scores hide many exceptions to the general trend. Impaired performance does not always result from a fall of skin temperature.

For the 'blocks' test, the 1st and 2nd quintiles shown an improved performance in the skin temperature ranges from 28-35° C when periods 1 and 2 are considered. As the skin temperature falls, it is accompanied by deteriorated performance. Considering periods 1 and 3 after seventy minutes of exposure performance improves in the first quintile and thereafter diminishes as the skin temperature is reduced. Bolts sub-tests A and B start out with a mean deteriorated performance at the warm end of the scale. This was possibly due to the fact that the cold bolts caused a rapid cooling down of the fingers, thus giving negative scores. In addition, the discomfort caused from

touching the cold metal of the nuts, may have slowed down the performance. It may also be observed from this table that with a given period of exposure, the lower the temperature, the greater was the impairment. Also after seventy minutes of exposure, deterioration is more marked than it is after thirty-five minutes exposure and in all cases, the longer the duration of exposure, the lower the skin temperatures fell.

The use of quintiles does not permit a direct comparison of score ranges in assessing the effects of duration. The assumption made in treating the scores was that there was a continuous uniform rate of fall. However, in some cases the hand cooled down rapidly and was at a "low" temperature for a considerable length of time, whereas in other cases, hand cooling was much slower and as a result, the hand did not endure the low temperature as long as it did when cooling was rapid. Another approach to the problem of duration is shown below.

b/ 2nd Method of Analysis

It was believed that the length of time that the body was exposed was of considerable importance in affecting the time scores on the motor tests. The second method of analysis used in this section presents essentially the same data as was used in the former section, but is in a different form. Figures 2, 3, and 4, p. 43a show the skin temperatures after thirty five minutes of exposure, which are plotted on the ordinate, and the temperature after seventy minutes on the abscissa. Plotted against these two axes are the

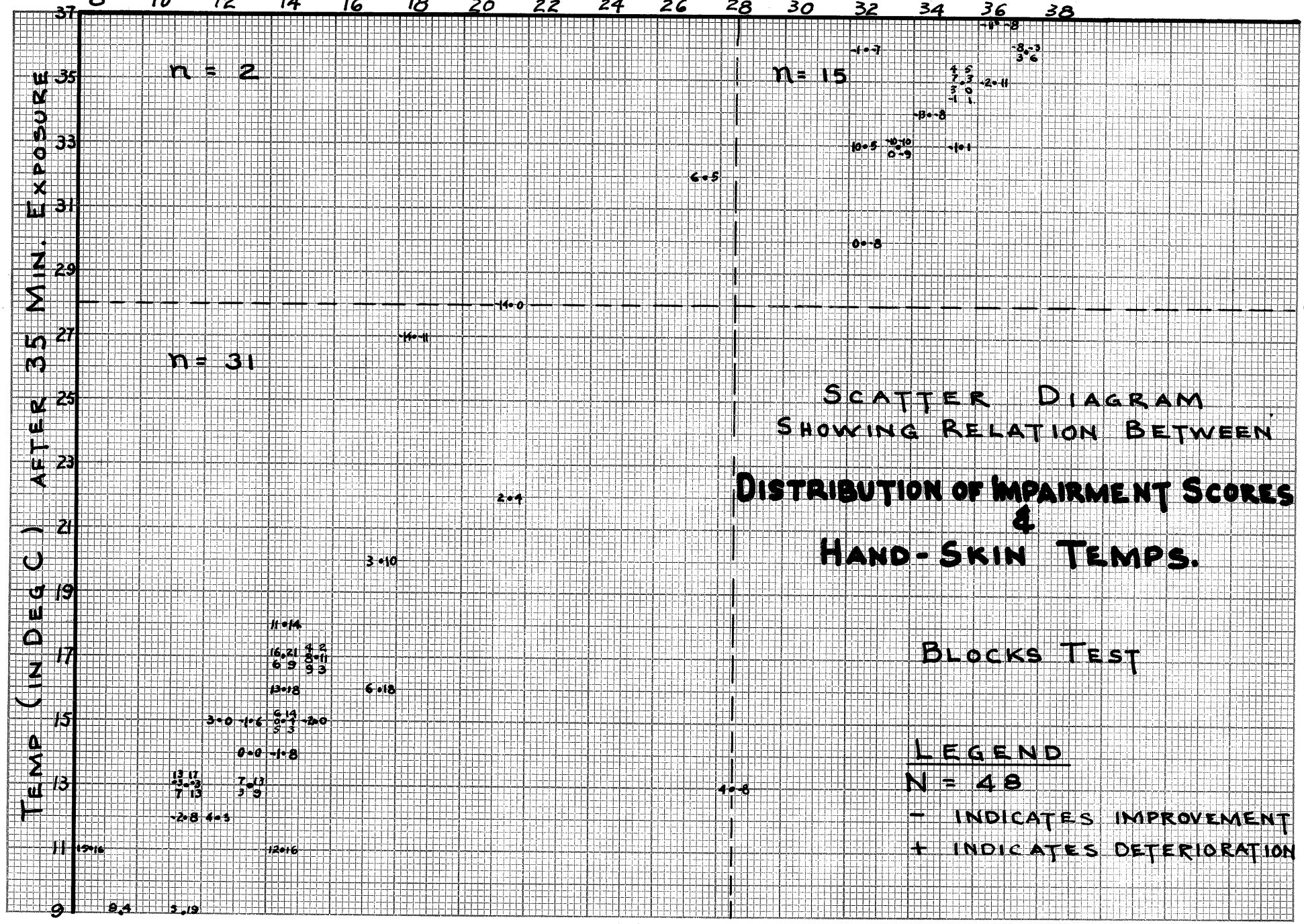
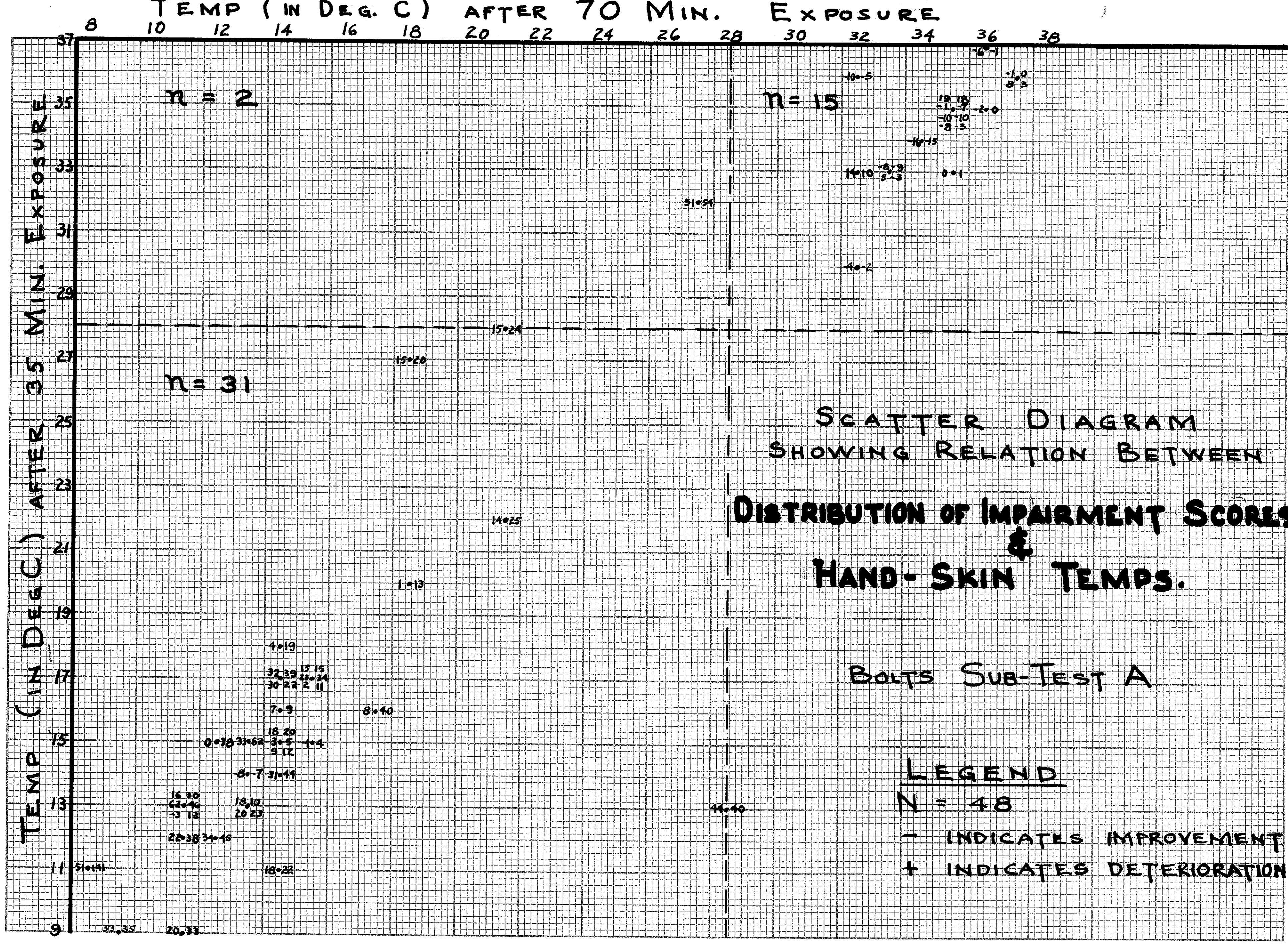

TEMP (IN DEG C) AFTER 70 MIN. EXPOSURE
8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38
37 35 33 31 29 27 25 23 21 19 17 15 13 11 9
TEMP (IN DEG C) AFTER 35 MIN. EXPOSURE
n = 2
n = 15
n = 31
SCATTER DIAGRAM
SHOWING RELATION BETWEEN
DISTRIBUTION OF IMPAIRMENT SCORES
&
HAND-SKIN TEMPS.
BLOCKS TEST
LEGEND
N = 48
- INDICATES IMPROVEMENT
+ INDICATES DETERIORATION

Fig 2

43a



TEMP (IN DEG. C) AFTER 70 MIN. EXPOSURE
TEMP (IN DEG. C) AFTER 35 MIN. EXPOSURE
n = 2
n = 15
n = 31
SCATTER DIAGRAM
SHOWING RELATION BETWEEN
DISTRIBUTION OF IMPAIRMENT SCORES
&
HAND-SKIN TEMPS.
BOLTS SUB-TEST A
LEGEND
N = 48
− INDICATES IMPROVEMENT
+ INDICATES DETERIORATION

Fig 3

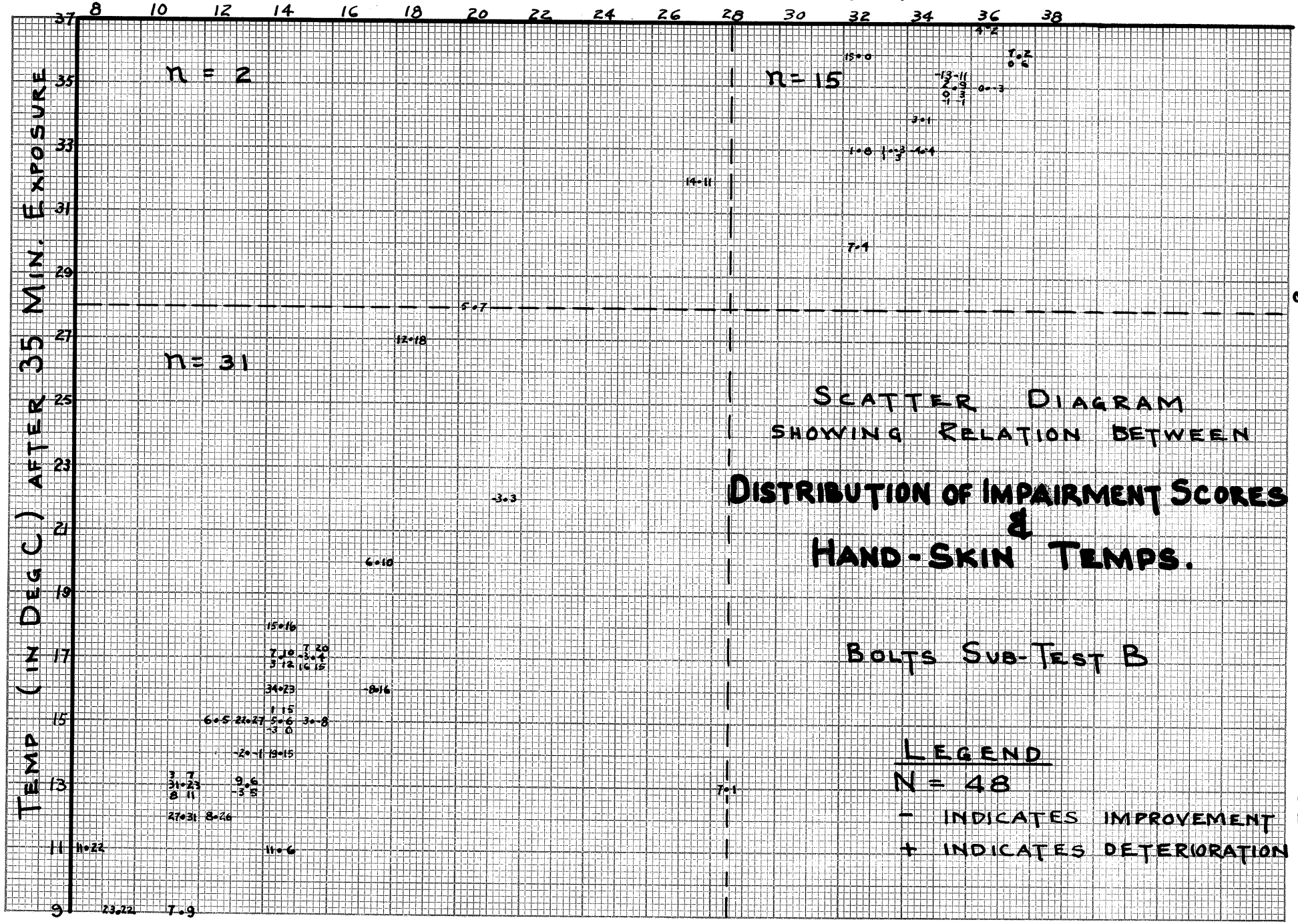

TEMP (IN DEG C) AFTER 70 MIN. EXPOSURE
8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38
TEMP (IN DEG C) AFTER 35 MIN. EXPOSURE
37 35 33 31 29 27 25 23 21 19 17 15 13 11 9
n = 2
n = 31
n = 15
SCATTER DIAGRAM
SHOWING RELATION BETWEEN
DISTRIBUTION OF IMPAIRMENT SCORES
&
HAND-SKIN TEMPS.
BOLTS SUB-TEST B
LEGEND
N = 48
- INDICATES IMPROVEMENT
+ INDICATES DETERIORATION

Fig 4

43C

The data on the scatter diagrams was grouped into classes of equal step intervals so that the effect of duration at a given temperature range could be studied as well as the relationship between lowered skin temperature and impairment. The performance scores falling within each of these intervals for both the thirty five minutes and seventy minutes exposure periods were summated. The results were as indicated below.

TABLE X

	Blocks		Bolts Sub-Test A		Bolts Sub-Test B	
Length of exposure	35'	70'	35'	70'	35'	70'
Temperature Range						
38° - 34° C	-1.9	0	-2.7	-2	1.7	3
33° - 29°	.83	-2.6	9.7	8.5	3.3	3.1
28° - 24°	- .14	-5.5	15	22	8.5	12.5
23° - 19°	2.5	7.5	7.5	19	1.5	6.5
18° - 14°	5.2	8.2	13.9	23.4	7.6	12.4
13° - 9°	6.1	12.6	28.2	39.7	10.9	14.9

\- Indicates improved scores

\+ Indicates deteriorated score

The results indicate that duration of exposure to cold is a factor of considerable importance in affecting the deterioration in performance scores. There is some variability in

the mean performance scores in the upper ranges of the table which includes the warm skin. There is no appreciable difference between the thirty-five minute and the seventy minute exposure periods down to the second temperature range which is to 29° C. Here, practice effects are showing up. However, in the lower skin temperature ranges from 28° to 24° C, deterioration is more marked for the two bolts sub-tests after seventy minutes of exposure than it is after thirty-five minutes. From the skin temperature ranges twenty-three to nine, the deterioration is consistently greater after seventy minutes of exposure than it is after thirty-five minutes for the blocks test and both of the bolts sub-tests.

Additional evidence concerning the importance of duration of temperature arises from a comparison of the mean skin temperatures of the group at the end of thirty-five minutes and at the end of seventy minutes exposure, and a correlation of the skin temperatures at each of these points. The results are as follows:

Mean skin temperature after thirty-five minutes exposure.... 21.80 C

Mean skin temperature after seventy minutes exposure..... 20.96 C

Difference..... .84 C

r..... .89

The average skin temperatures differ by only .84 C and the coefficient of correlation is high. This analysis indicates clearly that, on the whole, each individual has stablized his hand-skin temperature by the thirty-five minute mark. It would appear, then, that duration of cold is a factor of importance in affecting performance,

since skin temperatures are stabilized but deterioration continues.

The scatter diagrams were divided into three categories with the intention of studying deterioration and the effect of duration from the viewpoint of a critical point, falling below 28° C in neither period, falling below 28° C in the last period, but not in the first, and falling below 28° C in both periods. The individuals that maintained their skin temperature at 28°C or higher in both periods were those under the condition of cold-body, warm hand, the temperatures being maintained by local application of heat. Those whose skin temperatures were cold in both periods were the subjects experiencing the conditions of cold body-cold hand, and warm body-cold hand. The results are summarized in Table XI , on page 47 .

It was anticipated that the results would further substantiate the hypothesis formulated - namely, that impairment scores are directly related to the length of time that an individual is exposed to cold. Figures from Table XI, in general, confirm this hypothesis. In the case of the blocks test, the subjects that maintained their skin temperature at 28°C or higher during the two periods had a mean improved score both for the thirty-five minute and the seventy minute exposure periods. Although there were 5 subjects after thirty-five minutes exposure and nine after seventy minutes exposure that had a deteriorated performance in spite of the fact that their skin temperatures were high, their performance was only very slightly impaired, hav ing been maintained close to the mean score. This also applies to bolts sub-test A, which shows a mean improved score

SUMMARY OF FIGURES - 2, 3, &4

		35 minute exposure			70 minute exposure		
		Not Imp.	Imp.	Mean Imp. Score	Not Imp.	Imp.	Mean Imp. Score
Falling below 28° C in neither period	BLOCKS	15	10	5 -1.3	6	9	-1.4
	BOLTS A	15	11	4 -1.3	11	4	-1.5
	BOLTS B	15	6	9 +1.5	6	9	+1.1
Falling below 28° C in the last period but not in the first	BLOCKS	2	1	1 -4.0	1	1	+2.5
	BOLTS A	2	-	2 +33.0	-	2	+39.0
	BOLTS B	2	-	2 +9.5	-	2	+9.0
Falling below 28° C in both periods	BLOCKS	31	8	23 +4.8	6	25	+9.2
	BOLTS A	31	4	27 +19.0	1	30	+29.6
	BOLTS B	31	6	25 +8.6	3	28	+12.4

\+ indicates impaired score

\- indicates improved score

after thirty-five minutes and after seventy minutes exposure. Bolts sub-test B was always performed after bolts sub-test A. This means that by the time the first sub-test had been completed, the subjects' skin temperature had fallen a little, and this factor might possibly be the reason that the mean performance score for this test was impaired by 1.5 seconds after thirty-five minutes exposure and 1.1 seconds after seventy minutes exposure, despite the fact their temperature had not fallen below 28° C.

For the two subjects whose temperature fell below 28°C in the last period, the mean score after thirty-five minutes exposure on the blocks test was improved, whereas it was impaired after seventy minutes exposure. For the two bolts sub-tests it was impaired, the score for bolts sub-test A being more affected from cold after seventy minutes exposure than after thirty-five minutes. However, for bolts sub-test B, the difference in mean score differs by .5 seconds, being slightly higher after 35 minutes exposure. It might be pointed out that the data for the subjects whose temperature fell below 28° C in the last period is not too reliable, for there are only two subjects that fall within this category. It might have been preferable to include these two subjects in one of the two major groups, but since they fell in a different category, they are kept separate.

For the thirty-one subjects whose skin temperatures fell below 28° C in both periods, the deterioration scores are, for the three tests, greater after seventy minutes of exposure than after thirty-five minutes.

The frequencies with which individuals fall in the categories of maintaining their skin temperatures above 28° C, and those whose skin temperatures fall below 28° C in both periods is tested for significance. This gives an indication of whether or not the means are affected by one or two extreme cases. Only the seventy minute exposure period is taken into consideration, and the Chi square method is utilized in this comparison. The results are as follows:

a/ Blocks (1st Category) vs Blocks (3rd Category)

	Not Imp.	Imp.	
Warm	3.91 6	11.09 9	15
Cold	8.09 6	22.91 25	31
	12	34	46

$$\frac{12 \times 15}{46} = 3.91$$

$$X^2 = \frac{(2.09)^2}{3.91} + \frac{(2.09)^2}{11.09} + \frac{(2.09)^2}{8.09} + \frac{(2.09)^2}{22.91} = 2.23$$

Probability of a deviation greater than 2.23 is between .10 and .20.

b) Bolts sub-test A (1st category) vs Bolts sub-test A (3rd category)

	Not Imp.	Imp.	
	3.91	11.09	
Warm	11	4	15
	8.09	22.91	
Cold	1	30	31
	12	34	

$\frac{12 \times 15}{46} = 3.91$

$X^2 = 25.79$

P = highly significant

c) Bolts sub-test B (1st category) vs Bolts sub-test B (3rd category)

	Not Imp.	Imp	
	2.93	12.07	
Warm	6	9	15
	6.07	24.93	
Cold	3	28	31
	9	37	

$\frac{9 \times 15}{46} = 2.93$

$X^2 = 5.93$

P = between .01 and .02

Probabilities are significant for the two bolts sub-tests. They are not, however, significant for the blocks test, despite the fact that only three individuals have shifted over from a performance

score that was not impaired to one that was impaired ie in a comparison of bolts sub-test B with the blocks test. However, it will be noticed that the pattern for the blocks test is much the same as it is for bolts sub-test B.

CHAPTER V

SUMMARY AND CONCLUSION

I. SUMMARY OF THE EXPERIMENT

1. An experiment was conducted to determine the effect of different conditions of exposure to cold on motor performance - primarily with the intention of determining whether or not motor efficiency might be maintained by applying heat to a local part.

2. The experiment consisted of three timed motor tests, performed under four conditions of exposure, by a group of sixteen subjects.

3. The tests used in the experiment were the blocks test, bolts sub-test A, and bolts sub-test B. These constituted the test battery.

4. The sixteen subjects were male University students, between the ages of eighteen and twenty-seven, and all in good health.

5. Warm and cold hand were regarded as two anchorage points in deciding what conditions of exposure were to be used. These may have two different combinations - namely warm and cold body. Therefore, the four conditions of exposure utilized were warm hand - warm body, cold hand - cold body, cold hand - warm body and warm hand - cold body.

6. The experimental plan called for four trials - one

trial under each condition of exposure. Each trial included three presentations of the test-battery. The first presentation was given as soon as the subject entered the room; the second after thirty-five minutes of exposure and the third after a further exposure of thirty-five minutes.

7. The experiment was carefully controlled throughout, in order that an analysis of the effects of the various conditions of exposure upon performance might be made. A master plan, drawn up before the actual testing was begun, was so designed that the order of rotation was balanced for each condition of exposure. In an attempt to eliminate cooling of the hand at random, the subjects with warm body - cold hand, and cold body - warm hand, performed both of the bolts sub-tests before the blocks. However, for the other two conditions of exposure, the tests were presented in rotation.

II. DISCUSSION OF RESULTS

The Tests. In the first four chapters, the manner in which this investigation was carried out has been described, and the results have been presented under several separate headings. In this section, observations that were made during the course of the experiment regarding the tests chosen, will be noted in the discussion of each test.

The Blocks Test. The blocks test, although not as sensitive

in measuring differences in the performances of the subjects due to exposure to cold, as were bolts sub-test A and B, neverthless were quite satisfactory. Depending largely upon finger dexterity for speed of performance, motor impairment due to cold exposure was quite obvious.

Having no moving parts, the blocks test was not mechanically affected by the cold. In addition, the wooden blocks did not conduct warmth from the fingers of the subjects. These factors, together with the simplicity of the movements involved, contributed to make this test the most reliable in the battery.

Bolts sub-test A. Bolts sub-test A also proved to be a highly reliable test. The coating of the bolts with glycerine tended to eliminate free spinning of the nuts, and since the test was used indoors, it was not affected by exposure to the winter elements. The heavy metal nuts did, however, conduct warmth from the fingers of the subjects. This sub-test proved to be very sensitive, as impairment in motor performance was quite marked when the subjects were exposed to cold.

Bolts sub-test B. This sub-test had a test-retest reliability of .74, which was lower than that for both the blocks test and for bolts sub-test A. It proved sensitive however, in measuring the motor impairment due to exposure to cold. As in bolts sub-test A, the cold metal nuts conducted warmth from the fingers.

In the event that both of these tests be used in a future investigation, it might be suggested that this test be separated from

bolts sub-test A to better enable the control of series effects.

The conditions of exposure. The enviromental conditions of exposure were well controlled, since the investigation was conducted indoors. The temperature in the warm room was nearly constant - between 33 and 34 C. The temperature in the cold room varied from -1°C to -8°C. The heating pads provided a constant amount of heat. Although our investigation revealed that application of heat to a local member helps to maintain close to operational efficiency, nevertheless the problem exists of how much heat is required to prevent extensive deterioration in performance. It would be desirable to repeat this experiment, using different amounts of heat in an attempt to determine the amount most conducive to maintenance of operational efficiency.

111. CONCLUSIONS.

1. The blocks test and bolts sub-test A proved highly reliable tests. Bolts sub-test B had the lowest test-retest reliability.

2. When the data for all the subjects, under all conditions of exposure were analyzed, the effects of exposure upon performance were found to be statistically significant for the two exposure conditions of cold body-cold hand and warm body - cold hand. For the condition of cold body -warm hand, the data showed little change in performance.

3. Application of heat to a local part, when the remainder of the body was exposed to cold, did prevent deterioration in motor performance as it enabled the subjects to maintain

near maximal effieiency.

4. In a comparison of the first test-periods, results of tests conducted in the warm room were found to be different from when they were conducted in the cold room. It was concluded that the experimental design obscured, if present, any individual differences in the response to cold.

5. The lower the skin temperature the greater the impairment.

6. Duration of exposure to cold is a factor of considerable importance in affecting the deterioration in performance scores. Deterioration was in all cases greater after seventy minutes of exposure than after thirty-five minutes.

7. The longer the duration of exposure, the lower the skin temperatures fell, until thirty-five minutes had elapsed, at which time they appeared to have been stabilized.

8. Results suggest that the effects of cold enviroment as used in this investigation within the seventy minute range of exposure are explicable due to the change in temperature of the local part.

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APPENDIX A

RAW SCORE DATA FOR BLOCKS

Subject	Condition I			Condition II		
	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
1	112	110	104	106	103	103
2	115	101	95	99	105	113
3	86	85	83	98	111	116
4	108	107	109	123	132	126
5	114	110	110	115	130	175
6	95	86	91	98	98	102
7	130	128	119	126	132	135
8	101	93	92	98	102	100
9	116	109	112	113	116	123
10	125	117	112	114	117	123
11	106	111	106	128	127	134
12	99	92	100	117	115	117
13	95	95	99	102	113	116
14	112	113	115	108	124	129
15	89	90	88	117	125	121
16	105	94	93	105	117	121

Subject T_B	Condition III			Condition IV		
	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
	95	102	108	95	93	106
	99	98	102	95	98	95
	90	89	98	88	91	94
	108	116	119	120	119	121
	119	125	137	115	125	120
	118	104	107	100	100	92
	115	122	128	140	146	145
	89	102	106	126	113	118
	114	116	118	118	118	109
	114	112	122	115	114	116
	103	108	122	103	107	108
	102	102	102	110	99	102
	112	98-	112	105	95	95
	117	121	109	110	117	113
	94	98	97	107	99	104
	103	108	106	120	119	113

RAW SCORA DATA FOR BOLTS SUB/TEST A

Subject	Condition I			Condition II		
	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
1	92	85	85	97	94	110
2	66	65	68	82	100	102
3	82	83	85	71	101	93
4	99	100	104	84	107	118
5	92	81	80	145	196	286
6	87	81	77	91	98	100
7	93	91	107	90	122	129
8	104	105	98	123	138	138
9	67	61	64	77	78	90
10	97	96	81	101	119	111
11	70	74	76	64	97	126
12	82	78	80	84	83	88
13	69	71	75	93	97	112
14	79	79	78	100	126	129
15	76	77	74	55	88	90
16	99	94	93	98	116	120

	Condition III			Condition IV		
	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
	92	112	125	92	84	89
	75	135	113	87	86	80
	73	104	117	85	93	88
	83	85	94	99	97	99
	112	120	152	96	110	106
	76	91	96	80	76	78
	132	148	162	75	126	129
	110	172	156	119	103	104
	62	76	87	96	101	93
	100	122	138	98	98	99
	82	102	115	102	92	92
	79	71	72	80	74	79
	76	91	100	78	70	69
	76	120	116	85	104	103
	65	99	110	66	65	66
	85	88	90	90	100	85

APPENDIX A (continued)

RAW SCORE DATA FOR BOLTS SUB-TEST B

Subject	Condition I			Condition II		
	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
1	44	52	45	46	54	57
2	43	57	40	47	52	53
3	38	39	41	34	68	57
4	46	46	45	48	55	68
5	43	49	47	65	76	87
6	49	40	45	41	42	56
7	50	50	45	41	44	53
8	43	46	54	53	69	68
9	35	41	35	40	46	50
10	50	42	42	50	59	56
11	40	35	39	33	55	60
12	37	40	34	46	43	46
13	33	35	39	37	52	53
14	36	36	41	47	54	57
15	36	36	34	28	51	50
16	61	58	54	49	60	55

Subject	Condition III			Condition IV		
	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
	54	51	59	64	51	53
	46	52	51	54	53	53
	37	56	52	39	46	41
	46	43	50	49	49	46
	60	52	76	52	53	60
	34	46	52	38	45	42
	51	54	58	41	55	52
	51	82	74	54	57	55
	44	41	47	55	56	52
	38	65	69	56	52	52
	45	52	54	41	41	44
	38	36	37	36	40	38
	42	47	49	37	38	40
	43	50	44	45	47	54
	35	43	61	31	31	37
	59	62	51	55	70	55

APPENDIX A (continued)

HAND SKIN TEMPERATURES OF THE SUBJECTS
BEFORE STARTING AND AFTER COMPLETION OF THE TEST-BATTERY

Subject I									Subject II							
Condit.	T_B^1	T_A^1	T_B^2	T_A^2	T_B^3	T_A^3	T_B^4	T_A^4	T_B^1	T_A^1	T_B^2	T_A^2	T_B^3	T_A^3	T_B^4	T_A^4
No. exp.	26	26	32	21	27	28	28	20	35	35	29	24	35	35	29	24
35' exp.	31	32	13	11	13	29	35	21	32	32	15	16	15	21	35	25
70' exp.	33	33	11	13	13	27	35	22	33	33	14	13	12	20	35	25
Subject III									Subject IV							
	35	35	31	32	31	33	35	33	35	35	36	36	36	35	35	22
	36	35	16	14	14	22	36	25	35	32	17	14	17	33	35	22
	36	35	14	13	14	21	37	28	32	30	15	13	15	33	36	21
Subject V									Subject VI							
	20	29	22	13	27	29	22	23	33	34	31	27	31	31	33	29
	23	24	11	9	16	25	33	15	32	33	15	16	27	28	30	22
	24	26	8	14	17	22	32	18	33	33	14	16	18	23	32	26
Subject VII									Subject VIII							
	23	24	25	22	28	30	28	33	29	32	33	22	33	32	31	31
	32	28	17	12	13	20	32	19	34	33	17	16	13	25	34	23
	28	26	14	11	11	17	27	16	33	32	15	15	11	22	34	21

APPENDIX A (continued)

Subject IX									Subject X							
Condit.	T_B	T_A	T_B	T_A	T_B	T_A	T_B	T_A	T_B	T_A	T_B	T_A	T_B	T_A	T_B	T_A
No exp.	34	35	30	23	36	36	28	21	25	25	26	17	27	28	26	19
35'exp.	35	35	20	18	22	32	33	22	29	30	13	13	12	22	33	24
70' exp.	35	35	17	16	21	30	33	23	31	31	13	13	11	22	35	21
Subject XI									Subject XII							
	36	36	36	36	33	33	24	16	31	32	34	34	33	33	34	25
	33	33	15	15	9	28	35	23	31	32	15	14	14	29	37	25
	35	35	13	8	11	28	35	22	32	32	15	12	13	30	36	25
Subject XIII									Subject XIV							
	35	35	36	27	35	36	36	23	36	36	33	30	36	36	35	36
	35	36	18	17	28	33	33	23	37	37	17	19	13	21	35	23
	34	36	14	14	21	28	33	24	37	36	14	18	28	29	35	24
Subject XV									Subject XVI							
	33	32	26	30	34	35	34	24	32	33	28	23	32	32	32	37
	32	32	9	7	12	22	36	24	32	32	11	16	15	23	36	25
	32	33	9	7	12	21	37	24	32	32	14	11	14	25	32	23

N.B. T_B : Temp. before

T_A : Temp. after

APPENDIX B

STATISTICAL FORMULAE

1. The Arithmetic Mean.[1] $M = \frac{\Sigma X}{N}$

2. The Standard Deviation or SD.

   a/ $SD = \sqrt{\frac{\Sigma X^2}{N} - \frac{\Sigma X^2}{N}}$ (where N is large)[2]

   b) $s = \sqrt{\frac{\Sigma X^2}{N-1} - \frac{(\Sigma X)^2}{N(N+1)}}$ (where $N < 50$)[3]

   c) SD or $s = \sqrt{\frac{\Sigma(X_1 - M_1)^2 + \Sigma(X_2 - M_2)^2}{(N_1 - 1) + (N_2 - 1)}}$

   (when two small independent samples are pooled) [4]

3. The Standard Error (SE) of the Mean (σM).

   a). $SE_{mean} = \frac{SD}{\sqrt{N}}$ (where N is large)[5]

   b). $SE_{mean} = \frac{SD}{\sqrt{(N-1)}}$ (where $N<50$)[6]

4. The Standard Error of the Difference between Means.

   a) σD, OR $\sigma M_1 - M_2 = \sqrt{\sigma^2 M_1 + \sigma^2 M_2}$

   (for uncorrelated means, where N is large)[7]

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1 H.E.Garrett, Statistics in Psychology and Education, (third edition, New York, Longmans, Green and Co., 1947)

2 Ibid., p. 62.

3 Ibid., p.189.

4 Ibid., p.206.

5 Ibid., p.184

6 Ibid., p.189

7 Ibid., p.198.

APPENDIX B (Continued)

b) $$s_D = \sqrt{\frac{\Sigma(X_1-M_1)^2 + \Sigma(X_2-M_2)^2}{(N_1-1) + (N_2-1)}} \sqrt{\frac{N_1+N_2}{N_1 N_2}}$$

(for small independent samples)[8]

c) $$D = \sqrt{\sigma^2_{M_1} + \sigma^2_{M_2} - 2r_{12}\sigma_{M_1}\sigma_{M_2}}$$

(for correlated means)[9]

5. The Critical Ratio.[10]

$$CR = \frac{D}{\sigma_D} \quad \text{(where } D = M_1 - M_2\text{)}$$

6. The Coefficient of Correlation.

a) $$r = \frac{N\Sigma XY - (\Sigma X)(\Sigma Y)}{\sqrt{[N\Sigma X^2 - (\Sigma X)^2][N\Sigma Y^2 - (\Sigma Y)^2]}}$$

(where N is large)[11]

b) $$\rho = 1 - \frac{6\Sigma D^2}{N(N^2 - 1)}$$ (where D = rank-difference in X and Y)

(where $N \geq 10$)[12]

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8 Ibid., p. 206.

9 Ibid., p. 209.

10 Ibid., p. 199.

11 Ibid., p. 292.

12 Ibid., p. 345.