A FIELD STUDY OF THE EFFECTS OF EXPOSURE TO EXTREME WINTER CONDITIONS ON THE PERFORMANCE OF THREE MOTOR TESTS

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CHAPTER 1

THE PROBLEM AND THE METHOD OF APPROACH

1. INTRODUCTION

For centuries a small proportion of the population of the world has lived in regions where, for the greater part of the year, the temperature lies below the freezing point, and remains for months at a stretch at an extremely low level.

The nature of the physical environment of these regions during the long winter months is such as to discourage any outdoor activities except the vitally necessary ones relating to the provision of food and fuel.

For a long period of time hunting, trapping, and fuel-gathering were the main cold weather activities, and the only medium of transportation was the sled, drawn by dog team, or by horse. During this period the effects on muscular activity, and especially on finger movement, due to exposure to cold, were observed. Only in occasional instances, however, were these effects of significance to the early settlers.

The development during the present century of mineral and fuel resources in the far North of Canada effected a rapid opening up these regions to industry, with the consequent expansion of mechanical transportation to and from the developed areas. Railway trains and airplanes operated winter and summer, and tractor trains began to move as soon as the lakes and muskegs were frozen solidly enough to bear their weight. Construction and repairs were carried out under weather conditions of all kinds. The need for definite knowledge of the effects of this severe winter cold on the men who performed the greater part of their work outdoors was increasing.

The difficult conditions encountered by the Allies in the second World War in maintaining operational fronts in Arctic waters and territories caused this growing need to become of immediate and pressing importance, and the result has been the beginning of an intensive scientific study of the effects upon man of the severe environmental conditions obtaining in Arctic or sub-Arctic regions.

11. THE PROBLEM

Statement of the problem. It was the purpose of this study (1) to make an objective evaluation of the effects of exposure to severe winter conditions on the performance of simple motor tasks; (2) to assess the modifications of the effects of exposure resulting from exercise and isolation and (3) to determine the relationship between these effects and (a) the skin temperature of the hand, and (b) the subjective feeling of cold.

Importance of the study. A considerable amount of research has been carried out relating to the effects upon man of environmental extremes. The greater part of this work, however, has applied to the environmental condition of extreme heat. Moreover, of the meager literature extant pertaining to observations of andexperiments upon the effects of cold on man, the major part describes laboratory experiments carried out in cold-rooms under artificial conditions both of environment and of forms of activity. In very few cases are the effects of low temperature upon motor activity the object of the study, and very rarely are the temperatures recorded in these studies as low as those encountered under winter conditions in Northern Canada.

With the growing importance of Canada's far Northern areas, there has arisen a pressing need for scientific knowledge concerning the effects of prolonged exposure to climatic extremes in the direction of cold, upon the human being.

In order to obtain this knowledge, field experiments simulating as far as is practicable actual operating conditions while at the same time maintaining a high degree of laboratory control, are necessary, as are long-range studies carried out under highly controlled conditions in laboratory cold rooms. Field experiments on a comparatively small scale are being carried on by graduate students at Canadian Universities.

The aim of such research is to study the immediate and long-term effects, physiological and psychological, of exposure to winter conditions in arctic or sub-arctic areas. When these effects are determined, the factors giving rise to them can be isolated through refinements of the preliminary experiments. This knowledge of causes can then be utilized to devise new and improved means for preventing or retarding the onset of the undesirable effects resulting from this extreme environment. Further empirical tests, again, will measure the efficacy of these protective and preventive means.

The present study was undertaken as a small segment of the large area of experimentation outlined above. It was designed to yield information of practical value concerning the effects of cold upon simple motor performance. It was intended also as a check on the results of previous pilot investigations in this particular area of research,[1] and as a guide to further research.

111. THE METHOD OF APPROACH

The problem of the effect of comparatively short periods of exposure to conditions of severe cold upon the performance of simple motor tasks is one which permits of an objective, quantitative approach in the form of a scientific experiment.

Assuming that winter conditions do affect motor performance in such a way as to cause deterioration in speed and efficiency, an experiment was designed to yield objective data in the form of the number of seconds required to perform given tasks.

An analysis of the data obtained by means of the experimental procedure would then reveal whether the hypothesis -- that exposure to severe winter conditions of subjects protected by heavy outer clothing results in a significant loss of speed of motor performance -- was contradicted or confirmed.

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[1] An example of such an investigation is the study of R.N. Frizell: "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).

Refinements in the experimental method were introduced which would, in the event that the hypothesis was confirmed, make possible the further analysis of the data to assess the extent of the deterioration, the function of the time of exposure upon the effect of exposure, and the differential effects of the conditions of exposure.

Further data, in the form of hand skin temperatures obtained during the course of the experiment, and subjective reports recorded during and after the period of exposure, were gathered in the expectation that they would be of importance in the assignment of probable causes for large individual differences in the effects of exposure which might appear from subject to subject in any one trial, or in the same subject on different trials.

The investigation, then, takes the form of a field experiment, comprising simple motor tests which, while realistic, retain the controls necessary to a scientific experiment. These tests are performed under conditions approximating those encountered in outdoor work, and are designed to yield objective, quantitative data which admit of statistical analysis and interpretation.

IV. DEFINITIONS OF TERMS USED

Exposure. As used throughout this thesis, the term "exposure" refers to subjection to outside winter conditions of men protected by Army Arctic outer clothing worn over their normal indoor apparel. The duration of exposure, between the first and last tests on any day, was approximately one and one half hours.

Severe winter conditions. This was interpreted to mean an outdoor temperature of -29°C. (-20°F.) or lower, with or without a wind. For the subjects who remained inactive during the periods of exposure between tests, a temperature of -23°C. (-10°F.) was considered severe when accompanied by a wind of 20 miles per hour or over, especially if the relative humidity was higher than the normal for the season.

Test. This term refers to any one of the three types of test apparatus -- the "blocks", the "bren", or the "bolts" -- utilized in the experiment.

Test-battery. The three tests mentioned above, when carried out consecutively, formed the test-battery, or test group.

Trial. The testing activities carried out during any one day constituted a trial. The outdoor trials included three performances of the test-battery, with a period of activity or inactivity for each subject following each of the first two performances.

Experiment. The full series of six trials -- a preliminary indoor trial, followed by four outdoor trials and a final indoor trial -- constituted the experiment proper.

V. ORGANIZATION OF THE REMAINDER OF THE THESIS

Subsequent chapters of this thesis will embody the following considerations: (a) a survey of literature relevant to the investigation (Chap. II); (b) details of the experiment proper, including a full description of the nature and administration of each test, the order and conditions of their presentation, and a note on the subjects who participated in the experiment, with details of the outer protective clothing worn by them during the course of the experiment, (Chap. III); (c) the presentation, discussion, and interpretation of the data gathered during the course of the investigation, (Chap. IV); and (d) the conclusions drawn as a result of the investigation, together with suggestions for further experimentation, (Chap. V).

CHAPTER II

A SURVEY OF LITERATURE RELATED TO THE INVESTIGATION

I. INTRODUCTION

Specialized knowledge arises out of a definite need for such knowledge. General statements concerning the effects of severe cold upon the performance outdoors of a variety of activities can be had from any resident of Northern Canada or of other equally cold areas. Specific statements as to the nature and extent of such exposure upon a particular form of motor activity, on the other hand, can not be based upon casual observation only, but must be founded upon the concrete results of an intensive scientific study.

The need for specialized knowledge concerning the effects of extreme cold conditions upon man became apparent during the Second World War, when the Allies were forced to maintain operational units in arctic waters and territories. The outcome of this need was an intensified program of research activity directed towards the attainment of a specialized knowledge of the effects of continued exposure to a severely cold environment. Such a knowledge makes possible a more rapid development of preventive and protective measures designed to forestall or retard the adverse effects, both psychological and physiological, of extreme cold.

While the need for specialized knowledge in the field of cold research has intensified the activities of scientific research in this area, the published results of such studies are as yet very limited. This is due, in part, to the fact that such research is carried on under the direction of, or in cooperation with, the Defense Departments of the countries concerned with the research, and the results are, for security reasons, withheld. A further reason for the scarcity of literature on the subject of cold research is the fact that many of the investigations are of a long range order and do not reach the stage of publication until years after they were begun.

In the present survey reports of experiments upon the effects of exposure to cold have been supplemented by literature from the fields of physiology and the psychology of the senses and emotions, especially as these apply to the effects of cold upon the human organism.

II. EXPERIMENTS UPON THE EFFECTS OF EXPOSURE

Inactivity and exposure. An important military operation in cold weather is the immobilization of men for long periods of time in such a way as to prevent them from indulging in even the slightest movement from fear of having their presence detected.

In a cold room experiment[1] concerning the effects of such immobilization, an observation was made of the reactions of soldiers sitting quietly for periods of from two to three hours in environmental temperatures ranging from -1° to $-40^{\circ}C$. Forty-five young men in

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[1] S.M.Horvath, *et al.*, "Some Observations on Men sitting quietly in Extreme Cold," *J. Clin. Invest.*, 25:709-16, 1946. (Abstract)

excellent physical condition were subjects for a total of 430 tests. The subjects were clad in arctic uniforms.

The results of the experiment were as follows: shivering was present in the third hour in most cases; there was a moderate fall in rectal temperatures; mean skin temperatures fell precipitately during the first hour of exposure but were stabilized before the end of the test period; of all skin areas, the hands and feet exhibited the greatest temperature change both in rate and in degree. The experimenters further noted that responses of men exposed to cold environments are subject to considerable variation, and extreme care must be exercised in the interpretation of data obtained, whether on a few, or on a large number of subjects.

The results of this experiment are not directly applicable to the effects of exposure on motor performance, but they do have a relation to the present investigation, where a period of inactivity between tests was one of the conditions of exposure.

Efficiency and exposure. In this investigation, two experiments were performed. In the first, twenty-two men lived in a cold chamber, at -20°F., for periods of from eight to fourteen days. Tests were administered twice daily, before, during, and after the period of exposure to the cold environment. The tests used were: discrimination reaction time to visual stimuli, the Johnson Code test, a gear assembly test, and a dynamometer hand grip test.

In the second experiment, seventy men were exposed to temperatures of from -10° to -14°F. for three hours. These men were tested only with the dynamometer.

The results of this investigation indicated that discrimination reaction time was unaffected by the cold. Dexterity of the fingers and strength of grip were markedly reduced in the cold. Decreased performance on the code test in the cold was attributed to the loss of finger dexterity.[2]

This experiment indicates that motor performance requiring manual dexterity in comparatively intricate manipulations suffers a marked loss in efficiency due to the effects of exposure to cold.

A recent experiment to determine the effect of exposure to sub-arctic winter conditions on the performance of a manual dexterity test, was conducted by R.N.Frizell.[3] The test was a timed one, and involved turning down nuts on three series of bolts, each series of a different size. Short periods of exposure resulted in a marked group deterioration in performance. This deterioration also assumed a differential form, individual subjects being affected differently. The results further indicated that acclimatized subjects suffered less deterioration in performance than did less acclimatized men.

These experiments indicate that exposure to severe cold conditions of subjects well protected by heavy clothing, does affect the performance of motor tasks. The extent of the deterioration differs from individual to individual, and is greater for tasks

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[2] S.M.Horvath, and A.Freedman, "The Influence of Cold upon the Efficiency of Man," J.Aviat. Med., 18:158-64, 1947. (Abstract).

[3] R.N.Frizell, "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), pp. 72-3.

requiring finger dexterity than for activities involving only large muscle groups. Physiological and psychological effects are also brought about by exposure to intense cold. Some of these effects will be discussed in the following section.

III. LITERATURE FROM PHYSIOLOGY AND PSYCHOLOGY

Effects of exposure. Exposure to low temperatures slows the pulse and enhances the volume of the stroke. The volume of blood flow remains the same until the physical conditions become extreme and shivering takes place; both the output and the pulse rate then increase.[4]

At temperatures that require marked bodily adjustments, various kinds of experiential concomitants emerge in the individual. Long before there are outright physical difficulties, discomfort may develop, and work may be interfered with.[5]

Where outdoor tasks involve muscular movements, they and the physiological adjustments both work to maintain body heat against losses encountered in cold surroundings. Contradiction between work and physiological demands may develop in cold temperatures when the muscular activity needed in the task performed is much less than that required to move about and keep warm. Hence the task is constantly

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[4] S.H.Bartley, Fatigue and Impairment in Man, (New York and London, McGraw-Hill Book Company, Inc., 1947), p. 104.

[5] Ibid., p. 100.

interfered with by the urge to greater muscular activity, and this provides a potential source of constant distraction.[6] This is a factor to consider in interpreting the performance of a test such as the "blocks" test used in the present investigation.

Exposure to cold is one of the situations constituting a state of stress, an emergency, in which dire consequences threaten the integrity of the organism. In this, as in other situations (pain, strong emotional excitement, vigorous muscular exercise, asphyxia, states of lowered blood sugar), widespread sympathetic activity leads to changes which anticipate or ameliorate the danger.[7] Some aspects of this sympathetic activity will be discussed in the section on temperature regulation.

Temperature regulation. In order that man may function at his maximum efficiency, physically and mentally, his body temperature must be kept constant; within a very narrow range of variation above or below this temperature his efficiency becomes impaired.

The maintenance of this constancy requires continuous active adjustment to external temperatures. During active exercise, and when external temperature extremes exist, the demands of adjustment become difficult to meet.

In cold surroundings heat production must keep pace with its

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[6] Ibid., p. 99.

[7] Carl Murchison, editor, Foundations of Experimental Psychology, (Clark University Press, 1929), pp. 456-7.

dissipation, and in this respect it is to be noted that air movement and humidity are sizable factors in the impact, physically, of the environment upon the individual.[8]

The constancy of temperature of the human body is not maintained throughout, but, rather, varies several degrees from interior to surface, and is not even uniformly warm at all surface points. This temperature gradient involves a depth of an inch or more, and includes approximately one half of the body tissue. It is the deep body tissue which is maintained at the constant temperature (rarely varying more than 1°C.); the surface tissue may vary 10°C. without impairing motor efficiency, or even arousing the sensation of cold, and in cold surroundings the temperature of the extremities may fall through 20°C., resulting in impaired efficiency of performance, but causing no pain or damage to the part affected.[9]

From this picture of temperature variation in the human body it has been concluded that deep body temperature is the controlled variable in human temperature regulation.[10] The heat regulating center is in the hypothalamus and partakes of the controlled temperature, being sensitive to the temperature of the blood flowing through it.[11]

The controlled temperature of the body bears no fixed relation

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[8] Bartley, op cit., p. 101.

[9] This temperature drop and its effects were observed during the course of the present investigation.

[10] Bartley, op cit., p. 102.

[11] Ibid., p. 103.

to the temperature of the skin receptors. The heat regulating center in the hypothalamus, and the skin receptors both function in the maintenance of deep body temperature, however, the former being sensitive to the controlled temperature, and the latter not only to the level of temperature at the surface of the body, but also to the rate of change of this temperature, and, possibly, to the skin-internal gradient in temperature.[12]

The skin receptors, then, indicate the direction and extent of changes in thermal demand from the environment.

Following such a change in thermal demand upon the organism from its surroundings, there is an alteration of the level of the controlled temperature. A heightened demand almost always results in a slight rise in deep body temperature. This manifestation in the human organism has been termed a load error or droop.[13]

The load error, (or rise in the deep body temperature resulting from increased thermal demand upon the organism) is made minimal by the employment of the thermoregulatory center in the brain in conjunction with the action of the peripheral receptors.[14] This combination of central and peripheral temperature sensitivity enables the organism to maintain a maximal over-all adjustment and efficiency relative to

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[12] Ibid., p. 103.

[13] Loc. cit.

[14] Ibid., p. 104.

the environmental conditions which it encounters.

The somatic changes that prevent the fall in deep body temperature in a cold environment by increasing heat production are muscle tensing, shivering, and medullari-adrenal secretion.[15] Increased medullari-adrenal secretion (sympathetically activated) is the cause of the increased production of heat and the consequent rise in deep body temperature immediately following a heightened thermal demand upon the organism. During inactivity, this action does not materially alter heat production even under conditions of distinct deficit. Marked heat deficit, however, gives rise to shivering, and heat production is greatly increased during any form of muscular activity.[16]

Working in conjunction with the function of heat production are the somatic changes which act to conserve body heat. These sympathetic activities are vasoconstriction and piloerection.

Heat loss is adjusted by shifts in peripheral blood circulation only in the range of skin temperatures lying between 28° and 30° or 31°C. Below 28°C. no regulation of heat loss occurs through additional vasoconstriction,[17] although there may be other physiological changes which act to prevent the body surface from losing heat. The existence of such changes has not, however, been established.[18]

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[15] Ibid., p. 102.

[16] Ibid., pp. 106-7.

[17] Ibid., p. 108.

[18] Ibid., p. 122.

Where exercise does not occur, heat conservation is more marked than added heat production.[19]

The discussion of temperature regulation in the human organism has a definite bearing upon the interpretation of the results of the experiments upon the effects of cold upon motor efficiency. In the present investigation the differences in deterioration of performance following the exposure conditions of activity and inactivity might well be due largely to differences in heat production during these two periods, with the accompanying deficiency of blood flow to the arms and fingers of the subjects who were kept inactive.

The psychological conditions of the exposure period also have an important bearing upon the performance of the subjects. Normally, temperature regulation depends upon physiological stimuli. The intensity of the subjective experiencing of the outer world, however, can be an important factor in heat regulation. It has been demonstrated that in suggestible individuals heat regulation can be controlled by mental influences: if warmth is experienced (subjectively), actual cooling is rendered partly or entirely ineffective in heat regulation; on the other hand, if cold is experienced (subjectively), actual warming is rendered partly or entirely ineffective. Heat regulation, therefore, depends upon, or corresponds to, the type and intensity of the experiencing of the outer world by the individual; it can be

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[19] Ibid., p. 106.

independent of the objective accuracy of this experience, and is not only dependent upon the actual external conditions to which the organism is exposed, being subject to the interpretation of these conditions by the individual.[20]

In the present investigation the exposure conditions of company and isolation presented different psychological conditions for the subjects, who reported a greater sensitivity to cold and more thoughts of feeling cold during isolation than during their periods of exposure in company. Little difference in the effects upon performance of these two conditions were apparent, however. This difference might have been considerable had the subjects been less adapted to severe winter conditions, and completely isolated for the exposure period. For such subjects feelings of cold and worries about their ability to stand the cold for the duration of the exposure period might considerably affect their efficiency in motor performance.

The survey of the literature on the effects of cold upon the human organism has revealed some useful and important information concerning the physiology and psychology of exposure to low ambient temperature conditions. This information is, however, of a general nature and yields no direct or specific answers to questions concerning the nature and extent of the effects of exposure to extreme cold conditions upon the performance of particular motor activities.

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[20] F. Dunbar, Emotions and Bodily Changes, (third edition, New York, Columbia University Press, 1946), p. 174.

It was the aim of the present investigation to present more specific information concerning the effects of exposure to cold upon particular motor performances, and to evaluate the effectiveness of the tests chosen to measure these activities. It is one of a number of pilot investigations in this largely unexplored area of research.

The results of such investigations have important applications in the practical situations which they were designed to approach, and are particularly useful in the design of further investigations.

The evaluation of the effects of the environment upon the human organism is not a simple and straightforward matter. Taking into account the environment itself, objectively considered, is but one part of this problem. The human organism's interpretation of its environment is also an essential factor, and this must not be overlooked or underrated in such an evaluation.[21]

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[21] Ibid., p. 52.

CHAPTER III

THE TESTS AND THEIR ADMINISTRATION

I. INTRODUCTION

The purpose of the present investigation was to obtain a direct measure of the effects of exposure to severe cold upon motor performance under a variety of controlled conditions.

In order that the results of the experiment might have a more direct and meaningful application to actual conditions of work, a test battery was sought which would contain elements approaching a realistic manipulation such as might be encountered in outdoor work, while at the same time permitting a high degree of experimental control.

Such tests, in order to yield a high reliability coefficient, would have to be mechanically simple, involving only simple motor activities requiring a minimum of judgment or of precision in eye-hand coordination, and depending rather on speed of hand and arm movement. Three tests were chosen with these limiting qualifications as guides.

In order to isolate the effects upon speed of performance which were due to exposure from the effects resulting from conditions inherent in the experimental situation (such as series practice and fatigue effects), it was necessary to prepare a master plan of the order of presentation of the tests from beginning to end of the experiment. Further controls involving the clothing of the subjects, placing of the equipment, and activities of the subjects in the intervals between tests on a day's outdoor trial, were introduced, and factors such as the hours of sleep, diet, and physical condition of the subjects, which could not be satisfactorily controlled, were recorded in reports obtained from the subjects after each outdoor trial of the experiment.

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

II. THE TESTS

A. *The "blocks" test.* "Blocks" test was the name adopted during the course of the experiment for the perceptual-motor test properly named The Minnesota Manual Dexterity Test.

Nature of the test. This test of manual dexterity measures the speed with which a person picks up and places cylindrical blocks, all of the same size, in holes in a board. Performance in this simple task depends neither on judgment of differences in size or shape, nor on precise eye-hand coordination, but rather on speed of gross hand and arm movements.[1]

The Minnesota Manual Dexterity Test was chosen as one of the three tests comprising the test battery in order to include in the

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[1] W.V.Bingham, *Aptitudes and Aptitude Testing*, (Third edition, New York and London, Harper & Brothers Publishers, 1937), p. 278.

experiment one laboratory test of recognized validity and reliability.

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]

Figure 1. Blocks test.

Reliability of the test. The test-retest reliability for the blocks test (test period I vs. test period II) was found to be 0.89 for the two indoor trials, and 0.82 for the four outdoor trials.

Administration of the test. The board was placed on a table before the subject with the blocks arranged just beyond the board. The top of the table was 29½ inches above the ground.

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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.

Standard directions,[3] with two changes made necessary by the experimental conditions, were followed in the test administration.

The first of these modifications entailed shortening the test from four repetitions of the placing of the blocks in the board to two. This lowered the reliability of the test but lessened the danger of freezing the hands of the subjects, since they wore only a light glove on the working hand during the test.

The second modification required that the subject replace the blocks and board in position, after filling the board the first time, and proceed at once to fill the board the second time without any aid or instruction from the experimenter, who was thus enabled to time the other member of this pair of subjects in the performance of another test.

The test procedure was learned during indoor trials, and it was unnecessary to give full instructions for the test when it was administered outdoors. The subject began the performance of the test at the second word of the command "Ready?---Go!", and the test was timed from the word "GO!" until the board was completely filled the second time.

The subjects were instructed not to pick up any blocks which might be dropped to the ground during the test, but to proceed with the task. It was felt that the error which would result from taking time to pick up the block would be far larger than that due to

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[3] Bingham, op cit,, p. 279.

omitting that block from the test. If a block was dropped during the first part of the test, it was replaced by the experimenter. Not more than two blocks were dropped during the course of any day's testing.

B. The "bren" test. Bren test was the name applied to a series of movements performed upon a Bren (Mark I) Light Machine Gun.

Nature of the test. In order to include in the test-battery one motor test involving realistic manipulation related to conditions of arctic warfare,the bren test was devised.

To make the test simple and straightforward, requiring a minimum of practice to attain proficiency, and presenting a new and meaningful task to all the subjects, it was necessary to select certain movements from the standard procedures[4] and to combine these so that each movement lead easily to the next, and had relation to the test as a whole.

While each movement in this test was comparatively simple, the test as a whole was more complicated than were the other two tests in the battery, and involved more muscle groups.

Description of the test. The bren test consisted of four basic operations: 1) loading and firing[5]; 2) changing the barrel group;

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[4] All movements were based on the instructions as given in Small Arms Training, Vol. I, Pamphlet No. 4, "Light Machine Gun", 1942, (published by the Department of Defence). This pamphlet deals primarily with the Mark I Bren.

[5] "Firing" here meant simply releasing the trigger and causing the bolt action to move forward. No rounds, dummy or live, were used.

3) reloading and firing; and, 4) unloading.

The details of the movements entailed in these operations are listed immediately below.

1) Loading and firing:

1 Open magazine opening cover.

2 Pick up magazine and place on gun, forward position first.[6]

3 Pull cocking handle back, and push forward.

4 Turn backsight drum to maximum elevation.

5 Release the trigger.

2) Changing the barrel group: (to make this operation a meaningful part of the whole test, the subjects were told to assume that ten magazines had been fired off at the rapid rate of fire, causing the barrel to become overheated.[7])

6 Remove magazine, placing it on the canvas cover and to your right.

7 Close magazine opening cover.

8 Disengage barrel nut catch and rotate barrel nut to its fullest extent.

9 Raise carrying handle, push forward, and remove barrel,

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[6] Since no rounds were used, the magazine platform projected into the breech of the gun, when the magazine was locked into position, and prevented the bolt from moving forward when the trigger was released. To prevent this "stoppage" the subjects were instructed to let the back of the magazine merely rest upon the magazine release catch, without engaging this catch.

[7] Pamphlet #4, <u>op cit</u>., p. 11.

placing on the canvas, to your right.

10 Pick up spare barrel, place on gun, and lock in position.

3) Reloading and firing:

11 Open magazine opening cover.

12 Insert magazine.

13 Cock bolt action.

14 Release trigger.

4) Unloading: (this operation left the gun ready for the next subject).

15 Remove magazine and place by spare barrel, to your right.

16 Close magazine opening cover.

17 Return backsight drum to minimum elevation.

These movements were simple and related to one another. They called for manual dexterity, a minimum of discrimination and reasoning, and the use of both hands. Turning the backsight drum required speed of manipulation in the left hand; loading the gun required discrimination of top from bottom, and front from rear, of the magazine; changing the barrel group required some degree of eye-hand coordination; pulling back the cocking handle required considerable muscular effort, momentarily, twice during the test.

All the operations were carried out with the subject sitting behind the gun with the butt of the gun between his legs. This position enabled the subject to change the barrel group without assistance and without changing his position other than to lean forward; it had the added advantage of presenting a new situation to those subjects already familiar with standard Bren gun procedure.

All but one of the subjects were right-handed. In the testing of the left-handed subject the spare barrel and the magazine were placed on the canvas to his left.

Figure 2. The bren test.

Directions for administering the test. During the performance of this test the subjects were required to wear the leather outer mitt over the fine glove worn for the blocks and bolts tests, with the index finger inserted into the trigger finger provided in these mitts. On the left hand, the woollen inner mitt and the leather outer mitt were both worn throughout the outdoor testing and exposure. In the case of the one left-handed subject, these provisions were reversed, the left hand being used predominantly.

The gun was set up on its bipod upon a canvas cover spread over a firm surface. The magazine and spare barrel were placed within easy reach of the subject.

The test was begun on the instructions "Ready?---Go!", the subject being already in place, seated behind the gun. The test was timed from the word "Go!" to the completion of the last specified movement.

Considerable indoor practice in the procedure of the test was given to each subject before the actual trials of the experiment began. This ensured that the sequential order of the movements were not confused or forgotten during the actual testing.

Reliability of the test. No record of the Bren gun procedure having been used as a controlled test was found. Consequently there were no reliability coefficients available with which to compare the reliabilities obtained during the present investigation.

The test-retest reliability of the bren test in the present experiment were found to be as follows: indoor trials, 0.81; outdoor trials, 0.60.

C. The "Bolts" test. A test involving the turning of bolts into nuts embedded in a wooden base.

Nature of the test. The bolts test was included in the test-battery as it was considered to have practical application to such outdoor activities as might be entailed in heavy construction.

The simplicity of the test, which requires only that five large bolts be turned into five nuts, assured good experimental control.

The test constitutes a crude measure of manual dexterity, and involves the use of the right hand and the muscles of the right forearm predominantly.

Description of the test. The basic design of the test was devised by R.N.Frizell[8], and modified for the present investigation.

The bolts used by Frizell in his heavy series only were included in the present experiment, as these were found to give the highest reliability coefficient.[9]

Following a further suggestion of Frizell,[10] the nuts were mounted in a wooden base and the bolts turned into the nuts. This overcame to some extent the tendency of the nuts to spin freely while being turned down on the bolts; the bolts, being considerably heavier than the nuts, spun less freely into the nuts.

A final modification upon the original test design was the use of a fine glove on the working hand, by the subject, during the actual testing. Frizell's subjects wore heavy outer mitts for the test.

A refinement made upon the original apparatus was the addition of devices designed to control the number of turns through which each bolt could be turned. This number of turns was adjusted to twelve for each bolt, making a total of sixty turns for the test. In the original test sixty-five turns were required in turning the nuts down

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[8] R.N.Frizell, A Field Study of the Effects of Extreme Winter Conditions on a Test of Motor Performance," (unpublished Master's thesis, The University of Manitoba, Winnipeg, 1949), pp. 2-4.

[9] Ibid., p. 54.

[10] Ibid., p. 64.

on the bolts.

The five nuts were sunk into a heavy wooden board in such a manner that the top of each nut was flush with the surface of the board. The nuts were placed in two rows, with three nuts in one row and two in the other. A clear working space of eight inches between the bolt heads was afforded by this arrangement.

In order to increase the accuracy of resetting the bolts, and to decrease the time required for this process, a metal disc, having a diameter greater than that of the bolt, was fastened to the base of each bolt after the bolt had been turned into the nut. This disc effectively limited the distance through which the bolts could be turned out of the nuts by the experimenter in the process of resetting them. A steel pin inserted through the neck of each bolt above the level of the nut controlled the distance through which the bolt could be turned into the nut by the subject.

The board containing the nuts and bolts was mounted on four wooden legs. The top of this board was 34" from the ground, with the top of each bolt 4 3/4" above the surface of the board at the beginning of the test, and 3" above it at the end of the twelve turns.

Reliability of the test. The test-retest reliability of the original test was found by Frizell to be 0.84 for the bare hand (indoors), and 0.95 with the mitt (indoor test-outdoor retest).

In the present investigation, the test-retest reliability was found to be 0.75 indoors (with the glove), and 0.68 outdoors (also with the glove, the test being held immediately upon coming outdoors, and the retest after the first period of exposure).

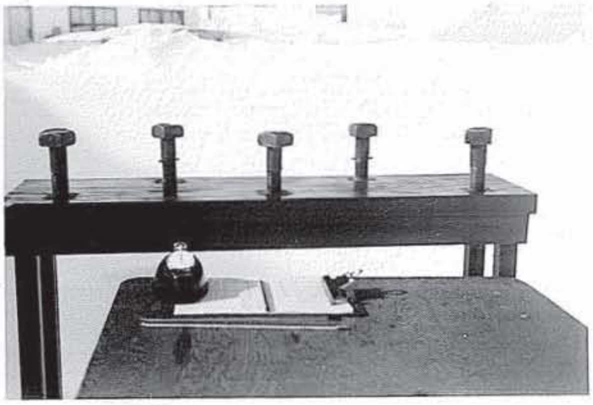

Figure 3. The bolts test

Directions for administering the test. The subjects were instructed to turn the bolts into the nuts as far as the control pin in the neck of the bolt would permit. They were told to work as fast as they could, using only one hand. The test was begun with the subject facing the bolt nearest to him and at the end of the board away from his favored hand. During the test the subject progressively worked his way towards the other end of the board.

The command "Ready?---Go!" was given, and the test was timed from the word "Go!" until the last bolt was turned fully into its nut.

The experimenter reset the bolts by rolling the head of each bolt between the palms of both mitts.

During a practice period before the trials were begun, the subjects were each given an opportunity to try different body positions in order to determine the posture best suited to their particular physique. The parka and light glove were worn during all indoor testing.

The subjects were reminded at each trial to keep the bolt under control of the thumb and fingers throughout the test, and not to cause it to spin freely into the nut.

II. THE PLAN OF THE EXPERIMENT

The experiment under consideration involved ten subjects, a test-battery incorporating three different tests, and four conditions of exposure, in two indoor and four outdoor trials. This number of factors necessitated a careful planning of the experiment in order that the effects of exposure upon the different tests, and thus upon different aspects of motor performance, might be isolable. It was necessary also that the plan provide for the evaluation of the differential affects of the four conditions of exposure, and permit the isolation of effects due to different temperature and wind conditions.

A master plan, drawn up before the actual testing was begun, presented in detail the order of appearance of each subject on each trial, the order of presentation of tests to the individual subject on any one day, and the special conditions of exposure for each pair of subjects during a particular outdoor trial.

This master plan is presented in Table I, page 37. It will be noticed that the special conditions of exposure and the strict order of appearance of the subjects do not apply in the indoor testing. A full description of the separate aspects of the experiment brought together in the master plan will be given in the sections immediately following.

Order of testing of the subjects. The ten subjects who participated in the investigation were all University students.

These subjects were split into five pairs, as two subjects were tested at one time during the experiment. The members of these pairs worked together throughout the experiment.

In each of the five teams a "completely acclimatized" subject was paired with a "fairly well acclimatized" or a "not at all acclimatized" subject. The pairing was made on the basis of the self-ratings of the subjects obtained from an information questionnaire completed by the subjects before the experiment proper was begun.[11]

The order of testing for each pair of subjects on the first outdoor trial was chosen arbitrarily. On the second, and subsequent outdoor trials, the same sequence of pairs was adhered to, but the pair of subjects who came out first for testing on outdoor trial I became the second pair on outdoor trial II, and so on, the fifth pair on any one day becoming the first pair the next day. This rotation of the order of the pairs of subjects on the four outdoor trials is summarized in column 3 of Table I on page 37.

This sequence of testing was designed to counterbalance the effects upon performance speed which might inhere in the order of appearance of the subjects for testing.

Order of presentation of the tests. In each day's trial of

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[11] A sample of this questionnaire appears in Appendix B.

the experiment, every subject performed a total of nine tests, being presented with the battery of the three tests three times during the day. In order to control the serial effects of fatigue and practice, a method of presenting the tests in rotation was adopted.[12]

In this rotation method, two orders of presentation of the group of three tests were alternated throughout the trials:

1 Blocks - bren - bolts;
2 Bolts - bren - blocks.

The reasons for adopting only two out of a possible six orders of presentation of the three tests will be made clear. It was very difficult to arrange for the group of subjects, who were all University students with different time-tables of classes, to meet together for any period of time amounting to three hours or more. At the same time it was desirable to retain the proposed schedule of three presentations of a test-battery of three tests on any one day's trial, to a minimum of ten subjects. In order that this testing program should not take too much of the subjects' time on any day, it was decided to test two subjects at one time. The length of the blocks test made it possible for one subject to be performing it while his partner was being put through the performance of the bolts and bren tests.

A further factor in the limitation of the orders of rotation was the chilling effect, upon the fingers of the hand clad only in the light glove, of the length of the blocks test and the turning of cold

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

metal parts in the bolts test. It was found desirable to interpose the bren test between the blocks and bolts tests and to allow the subject to put his outer leather mitt on over the fine glove for this test. The bren test, with its variety of manipulations and the use of many muscle groups and both hands, warmed the right hands of the subjects to some extent, and rested the particular muscle groups used in the previous blocks or bolts test.

The orders of presentation of the tests for each subject on each trial appear in Table I on page 37. The order of rotation is balanced over each trial (as well as for each performance of the test-battery within each day's trial), for each condition of exposure, and, over the experiment as a whole, for each subject.

Conditions of exposure. The first administration of the test-battery to each pair of subjects on the outdoor trials began as soon as the members of the pair came outside from the dressing room. This first testing, under the condition of no exposure, amounted to a control test for each subject for that day. In order that they would not be kept waiting outside for this first test, the subjects came out at intervals of nine minutes, in the stated order of pairs.

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 in one of four conditions of exposure: 1) activity-in-company; 2) activity-in-isolation; 3) inactivity-in-company; 4) inactivity-in-isolation. The subjects were told by the experimenter, at the end of the performance of the first test-battery of the day, the conditions of exposure which would apply to them for their two periods of exposure on that day.

The condition of activity allowed the subject to walk about, but not to indulge in any strenuous exercise. In the condition of activity-in-company, the members of a pair of subjects went for a walk together, whereas the activity-in-isolation subjects went for a walk alone, away as far as was possible from buildings and main roads. The active subjects were told to return to the site of the experiment within a period of thirty-five minutes in order to have their hand-skin temperature measured before the administration of the next test-battery of the day.

The inactive subjects merely sat, or lay down in the snow, out of the direct sunlight (which was found to provide them with considerable warmth), and sheltered from the wind to some extent by snow drifts. The inactive-in-company subjects remained together, talking to one another during the exposure period, while the inactive-in-isolation subjects remained apart from all others.

The conditions of exposure for each subject, on each day of the outdoor trials, are presented in column two of Table I, on page 37. It will be noticed that, while the conditions are balanced over the period of the experiment as a whole, they are not balanced over each trial. This is due to the fact that with five pairs of subjects and four conditions of exposure, it was necessary to duplicate one of these conditions on each outdoor trial, exposing four subjects under that condition whereas there were only two subjects under each of the other conditions of exposure.

TABLE I

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

Day	Condition	Pair	Subject	Test order: No exp.	Test order: 1st exp.	Test order: 2nd exp.	Subject	Test order: No exp.	Test order: 1st exp.	Test order: 2nd exp.
I	In		1)	A-BC	CB-A	A-BC	2)	CB-A	A-BC	CB-A
II	MX	1		A-BC	CB-A	A-BC		CB-A	A-BC	CB-A
III	NY	2		CB-A	A-BC	CB-A		A-BC	CB-A	A-BC
IV	NX	3		CB-A	A-BC	CB-A		A-BC	CB-A	A-BC
V	MY	4		A-BC	CB-A	A-BC		CB-A	A-BC	CB-A
VI	In			CB-A	A-BC	CB-A		A-BC	CB-A	A-BC
I	In		3)	the same			4)	the same		
II	NY	2								
III	NX	3								
IV	MY	4								
V	MX	5								
VI	In									
I	In		5)	the same			6)	the same		
II	NX	3								
III	MY	4								
IV	NY	5								
V	MX	1								
VI	In									
I	In		7)	the same			8)	the same		
II	MY	4								
III	NX	5								
IV	MX	1								
V	NY	2								
VI	In									
I	In		9)	the same			10)	the same		
II	MY	5								
III	MX	1								
IV	NY	2								
V	NX	3								
VI	In									

CODE: Conditions
In - indoor test
MX - activity-in-isolation
MY - activity-in-company
NX - inactivity-in-isolation
NY - inactivity-in-company

Tests
A - blocks
B - bren
C - bolts

Exp. - exposure

III. FURTHER CONTROLS

A detailed explanation has already been given of the controls applied to the order of presentation of pairs of subjects for testing, 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, however, a number of further controls introduced into the experimental technique of which some mention should be made.

Outer clothing. Army arctic outer clothing was provided for each of the subjects, and for the experimenter. This clothing was worn by the subjects over the normal indoor clothing worn by them in their classes, with the exception that battledress blouses were substituted for suitcoats, sports jackets, and sweaters. The complete description of the outer clothing worn during the outdoor trials appears in Appendix C. For the indoor trials and practice periods, the subjects were required to wear the parka and liner, and the same gloves as were used on each test during the outdoor trials.

Apparatus. The test apparatus was placed outdoors from one-and-a-half to two hours before testing was due to begin to ensure that it would be at environmental temperature for the testing. This was necessary in order that any effects of the cold upon the tests themselves would affect each performance of the test, and each subject, equally. This control was not found to be effective with the bolts test. The apparatus was placed on a hard snow surface which provided a firm footing for the subjects, and a secure support for the tests themselves. This ensured that the height of the tables containing the tests remained constant.

Time and place. The trials were held during the early afternoon on each day of the outdoor trials. The indoor tests were also held during the afternoon. The site of the testing was an empty parking lot near the building in which the combined dressing room and store room was located. On each day of the outdoor tests the sun was shining, and the light conditions were excellent; the apparatus was placed in the shade of the building on each day.

Motivation. The subjects were genuinely interested in the experiment and did their best on the majority of the tests. In very few cases was it necessary to remind a subject that his best efforts were required on the performance of each test.

Questionnaire method. No attempt was made to control the amount of sleep the subjects had during the night preceding the trials, nor the amount of lunch eaten just prior to the trial. These factors were taken account of, however, in a questionnaire completed by each subject after each outdoor trial. This information helped the experimenter to suggest possible causes for deviations in performance which could not readily be explained as due to cold, practice, or defects in the experimental apparatus or plan.

The present chapter has been devoted to a complete description of the experiment itself. The details of the separate tests have been presented fully where these tests were either original, or modifications of previous tests. The experimental procedure, with its subject orders, test orders, conditions of exposure, and numerous controls has been described at some length, accompanied by a more concise presentation in the form of a table.

This detailed presentation contains all the factors within the experiment itself which might affect the results obtained from the investigation, and makes possible a complete analysis of the data gathered. It also permits the reproduction of the experiment itself, should this become necessary.

CHAPTER IV

ANALYSIS AND INTERPRETATION OF THE DATA

I. INTRODUCTION

The present experiment was designed to counterbalance as many series effects, and to control as many variables as was possible. There were, however, some factors which could not be controlled or counterbalanced. One of these factors was the series effect resulting from the three presentations of the test-battery within each trial of the experiment.

Whether these series effects, which could not be avoided, were important in the evaluation of the experimental data was not known; it was suspected, however, that they had a significant effect upon performance during the experiment, and it became necessary to attempt an assessment of them.

The results of this assessment indicated that the series effects might quite seriously affect the interpretation of the experimental results. For this reason, the experimental results are stated in two ways: first, without taking into account the intra-trial series effects; and secondly, with empirical corrections made for these effects.

It is recognized that this second mode of analysis, which is based upon several assumptions, is open to objections which can not be wholly set aside. The picture of the situation without the corrections for the series effects, however, may be even farther from the truth.

The analysis of the experimental data, then, has been presented in the following order, with the results stated in the two ways mentioned:

1 An analysis of the overall effects of the combined conditions of exposure encountered during the experiment upon performance in the three tests.

2 An analysis of the differential effects of the environmental conditions of temperature and wind upon performance, together with a discussion of the effects of exposure to this environment upon the test apparatus.

3 An analysis of the relation of the experimental conditions of exposure to the effects of exposure, comparing the effects of activity and inactivity, isolation and company, and combinations of these four conditions.

4 The relation to exposure effects of skin temperature, subjective reports of cold, and acclimatization.

The complete presentation of the data recorded during the experiment appears in Appendix A. All calculations appearing in the analyses presented in this chapter were made from the ungrouped raw data, using the statistical formulae presented in Appendix D.

II. ANALYSIS OF SERIES EFFECTS

"Series effects" refers to effects upon test performance due to factors such as fatigue, learning, and boredom. These effects are operative during test performance, and in the intervals between tests. Fatigue and learning are presumed to be the chief factors in the series effects.

In the present experiment, series effects operated from test to test within the test-battery, from performance to performance, within each trial, of the test-battery, and from trial to trial. The series effects operating within the test-battery were minimized through the technique of counterbalancing the order of presentation of the tests. This technique was not applicable, however, to inter-trial or intra-trial test performance. A measure of the series effect in these cases was obtainable through an analysis of the data of the indoor control trials carried out as the first and last trials of the experiment -- before and after the outdoor trials. The results of this analysis are presented in Table II, on page 44.

The first half of Part I of this table presents the raw score totals for each of the three tests on trials I and VI, the two indoor trials of the experiment. Each total combines the thirty scores obtained from the ten subjects in the three test-periods of each trial. The second half of this part presents the total time scores for each test-period, each total being the sum of the two totals obtained for the corresponding period in trial I and in trial VI.

Part II of the Table presents the evaluation of the series effects, expressed in percentages. The formulae by which these figures are calculated appear in the Table. It is assumed here that in the indoor trials the differences in total scores from test-period to test-period, and from trial to trial, are due entirely to series effects, all known variables which can be controlled having been controlled.

TABLE II

ANALYSIS OF SERIES EFFECTS

Part I. Raw Score Totals

Test	N	Trial I	Trial VI	N	Test Period I	Test Period II	Test Period III
Blocks	30	3896	3445	20	2567	2412	2362
Bren	30	992	610	20	587	525	490
Bolts	30	1444	1429	20	1028	944	901

Part II. Percentage Effects

Test	Trial I/VI*	Test Period I/II	Test Period II/III	Test Period I/III
Blocks	11.6%	6.0%	2.1%	8.0%
Bren	38.6%	10.6%	6.7%	16.5%
Bolts	1.0%	8.2%	4.6%	12.4%

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* Formulae for computing percentage effects:

1 Trials I/VI:

$$\frac{\text{Total score on trial I - total score on trial II}}{\text{Total score on trial I}} \times 100$$

2 Test period I/II; and, on the same principle, test periods II/III, and I/III:

$$\frac{\text{Score on test-period I - score on test-period II}}{\text{Score on test-period I}} \times 100$$

The first half of part II of the Table gives an assessment of the carry-over of series effects from trial to trial; the second half shows the percentage carry-over of series effects from test-period I to test-period II, from II to III, and from I to III. We shall be particularly concerned with the data in this second half of Table II.

The only data from which we can calculate series effects independently of exposure effects, is the data from the indoor tests; we must assume then, in the analysis of the outdoor data for exposure effects, that here the series effects operate to the same extent as they do in the indoor trials.

The percentage values which are presented in Table II are all positive, indicating that the series effects result in improvement in performance.

Table II indicates a comparatively large carry-over of series effects from trial to trial in the bren test; a moderate carry-over is shown for the blocks test, while inter-trial series for the bolts test are almost non-existent. The intra-trial series effects show more consistency when one test is compared with another. In terms of percentage improvement, the bren again shows the largest series effect, and the blocks test the least. For all tests an improvement in performance from test-period to test-period is indicated, and the extent of this improvement is greatest following the first test-period of the trial.

The large differences in means between the scores of the first and second test-periods of the indoor trials indicate that series effects are considerable. It remains to be demonstrated that these differences cannot be due to chance factors alone. The probabilities of these differences occurring by chance are given below: (P is approximate).

Test	N	M1	M2	SD1	SD2	r12	t	P
Blocks	20	128.4	120.6	15.63	13.86	.89	5.09**	<0.01
Bren	20	29.4	26.3	11.79	10.11	.81	1.95	0.07
Bolts	20	51.4	47.3	11.77	8.56	.75	2.29*	<0.04

The differences in means between the scores of the second and third test-periods of the indoor trials are less reliable. The fact that the differences are all in the same direction, however, increases the probability that there is a significant series effect causing these differences also.

Test	N	M2	M3	SD2	SD3	r23	t	P
Blocks	20	120.6	118.1	13.86	13.40	.88	1.62	0.11
Bren	20	26.3	24.5	10.11	9.22	.85	1.47	0.12
Bolts	20	47.3	45.1	8.56	7.89	.66	1.42	0.12

From the above sets of figures, there is little doubt that the difference in means between the first and third test-period scores are significant.

We may conclude, then, that there is a considerable degree of intra-trial series effects, and these should be taken into account in evaluating the effects of exposure upon performance.

III. THE RELATION OF PERFORMANCE TO EXPOSURE

In this discussion the means of the scores for all the outdoor trials are analyzed as to the extent and direction of change from test-period to test-period. The results express the overall effects, upon performance in each test, of the various conditions of exposure encountered during the experiment.

The means of the combined scores for all subjects on all outdoor trials are presented in Table III, on page 48. In order to evaluate the exposure effects from test-period to test-period for each test, the mean scores for these are presented separately. Each mean represents 39 separate scores.

Table III presents the means of the actual or observed performance scores of the subjects. These scores are effected by exposure and series effects. The analysis of series effects indicated strongly that they operated to improve test scores from test-period to test-period. In order to assess the direction and extent of exposure alone, a table of expected means for each test was drawn up. These means are presented in Table IV, on page 48.

The expected, or theoretical means were calculated in the following manner: beginning with the mean for the first test-period (M_1 in Table III), the expected scores for test-periods II and III (M_2 and M_3) were computed by subtracting from M_1 the improvement in score from test-period I to test-period II, and from test-period I to test-period III, respectively. These improvements, expressed as percentages of M_1, are presented in part II of Table II, on page 44. It will be seen that the expected values for M_2 and M_3 are all smaller than the actual or observed values for these means, indicating that the effect of exposure is

TABLE III

THE MEANS OF THE ACTUAL SCORES

		Test Period					
		I		II		III	
		(no exposure)		(40' exposure)		(80' exposure)	
Test	N	M_1	SD_1	M_2	SD_2	M_3	SD_3
Blocks	39	123.6	11.29	124.0	11.56	124.8	13.25
Bren	39	29.8	8.43	29.7	6.98	27.7	7.19
Bolts	39	72.3	18.85	69.9	19.24	71.9	18.16

TABLE IV

THE MEANS OF THE EXPECTED SCORES

		Test Period					
		I		II		III	
Test	N	M_1	SD_1	M_2	SD_2	M_3	SD_3
Blocks	39	123.6	11.29	116.2	11.56	113.7	13.25
Bren	39	29.8	8.43	26.6	6.98	24.9	7.19
Bolts	39	72.3	18.85	66.4	19.24	63.3	18.16

TABLE V

PERCENTAGE DETERIORATION OF PERFORMANCE DUE TO EXPOSURE EFFECTS

	Test Periods		
Test	I/II	II/III	I/III
Blocks	6.3%	2.7%	9.0%
Bren	10.3%	0.0%	9.5%
Bolts	4.9%	7.5%	11.8%

a <u>deterioration</u> in performance of the tests.

We now have our estimate of series effects upon performance (Table II, page 44). Applying these effects to M_1 in Table III, on page 48 -- the means of the observed scores -- we have predicted the scores which should have appeared for the outdoor trials had there been no exposure effects upon performance, (Table IV, page 48). We may now assess the exposure effects by subtracting M_2 and M_3 in Table III from the corresponding means in Table IV, and expressing the differences as a percentage of M_1. This gives us the exposure effects from test-periods I to II, and from I to III. The exposure effects from test-periods II to III are found by calculating the actual effect on performance (the difference between M_2 and M_3 in Table III, expressed as a percentage of M_2), and subtracting this figure from the percentage series effects for this period, as given in Table II. The resulting percentage effects of exposure upon performance in each of the three tests are presented in Table V, page 48.

<u>Analysis of observed data</u>. This analysis indicates a slight deterioration in performance of the blocks test under conditions of exposure, while the bren and bolts tests show improved performance under the same conditions. The reliability of the differences in means of the blocks test scores from test-period to test-period are presented below.

Test	N	M_1	M_3	SD_1	SD_3	r_{13}	t	P
Blocks	39	123.6	124.8	11.29	13.25	.77	0.84	0.40

It will be seen that the largest difference -- that between M_1 and M_3 -- is not significant. In this analysis only the scores which differed in the direction of deterioration have been treated. The observed data means are taken from Table III, page 48.

Analysis of corrected data. When adjusted for series effects, all three tests show a considerable deterioration in mean scores in test-periods II and III; M_2 and M_3, when series effects are taken into account, become corrected means. The corrected mean represents the "true" effects of exposure, since series effects have, theoretically, been eliminated; that is, the difference between an actual mean and the corresponding theoretical mean has been added to the actual mean.

The reliability figures for the corrected means of the three tests appear below. No correction is applied to M_1 since it is the mean of the test scores made by the subjects immediately upon coming outdoors and is, presumably, free from exposure effects.

Test	N	M_1	M_3	SD_1	SD_3	r13	t	P
Blocks	39	123.6	134.7	11.29	13.25	.77	7.76**	<0.01
Bren	39	29.8	32.6	8.43	7.19	.70	2.81**	<0.01
Bolts	39	72.3	80.9	18.85	18.16	.73	3.92**	<0.01

Assuming, then, that we are justified in applying corrections for series effects to the observed means, the difference in means which is due to the effects of "true" exposure is found to be highly reliable for each of the three tests. The problem remains to find tests which are unaffected by series effects to check the assumptions made.

It is highly probable then, that the performance of the subjects, in each of the experimental tests, is significantly affected by exposure to cold. The following analyses will deal more specifically with particular conditions of this exposure and their differential effects upon performance.

IV. ENVIRONMENTAL EFFECTS UPON PERFORMANCE

The environmental conditions of temperature and wind differed to some extent from trial to trial in the outdoor performance of the tests. The differential effects of these conditions upon performance are indicated by the test score means from test-period to test-period for the different trials. These means are presented in Table VI, on page 53, and in Figure 4, page 54. The means for the two indoor trials are included for comparison purposes; in the performance of these tests, series effects only were operative from test-period to test-period. In the outdoor trials, series effects and exposure effects are both operative, and the trend of the means of the test scores in each trial indicate the relative effectiveness of each of these two influences upon performance results.

The means which appear in Table VI are the observed, or actual means of test scores. In Figure 4 both the observed and the corrected means are plotted in order to illustrate the "true" exposure effects.

An examination of Figure 4, page 54, indicates that exposure effects predominate in the two trials when there was a strong wind blowing (trials III and V); only on trial V, when there was a low temperature in combination with the wind, was the exposure effect predominant in all three tests.

A closer examination of the means presented in Table VI will be made, and the reliability of differences in means established, both for the observed means, and where applicable, for the corrected means. The results of this examination are presented in Table VII, page 56.

In treating the observed means for reliable differences, only those cases where an actual deterioration in performance occurred were included, since exposure effects were the primary consideration. The observed means showed a reliable difference, from M_1 to M_3, in the blocks test on trial V. On this same trial the bolts test shows a difference in means which is reliable at the .05 level of confidence.

In the second treatment of the data, using the means corrected for series effects, all but two of the cases showed some deterioration of performance. The corrected means show reliable differences in the means of the blocks test on trials III, IV, and V; the means of the bolts test show a significant difference on trials III and V; and the bren test shows a reliable difference only on trial V.

The main difference in environmental conditions between the trials in which little deterioration of performance occurred (trials II and IV), and those in which significant deterioration took place (trials III and V), is the degree of wind. On trials II and IV there were light, variable winds of 4-6 m.p.h., while on trials III and V, strong winds at from 20-22 m.p.h. were blowing. The temperature was -24°C. on trial II, -20°C. on trial IV, -20°C. on trial III, and

TABLE VI

EFFECTS OF ENVIRONMENTAL CONDITIONS
ON THE PERFORMANCE OF THE TESTS

			Test					
			Blocks		Bren		Bolts	
Trial	Test-period	N	M	SD	M	SD	M	SD
I	1st	10	137.5	12.89	35.9	12.11	49.5	11.06
	2nd	10	128.2	8.67	32.8	9.65	47.5	9.32
	3rd	10	123.9	11.33	30.5	7.56	47.4	6.87
II	1st	10	129.9	12.21	35.6	10.79	85.7	15.11
	2nd	10	125.5	11.73	34.8	8.83	72.6	22.34
	3rd	10	123.9	13.44	29.5	8.78	72.0	17.09
III	1st	9	124.4	12.43	30.4	6.22	82.9	18.79
	2nd	9	125.5	13.21	29.1	6.19	83.5	19.78
	3rd	9	126.2	17.13	27.3	7.78	85.8	17.81
IV	1st	10	124.1	13.20	27.5	7.23	60.4	10.87
	2nd	10	121.9	11.78	24.3	5.89	55.8	9.94
	3rd	10	122.7	13.56	25.1	5.33	60.5	13.53
V	1st	10	115.9	9.21	25.8	8.02	61.4	18.08
	2nd	10	124.2	13.31	30.7	8.23	69.2	18.34
	3rd	10	126.5	13.42	29.0	7.34	70.6	21.31
VI	1st	10	119.2	12.11	22.8	5.78	53.3	14.07
	2nd	10	113.0	12.86	19.7	3.82	46.9	9.10
	3rd	10	112.3	11.79	18.5	4.91	42.7	8.76

Environmental Conditions

Condition	Trial I	Trial II	Trial III	Trial IV	Trial V	Trial VI
Temperature	+ 21°C.	-24°C.	-20°C.	-20°C.	-26.5°C.	+ 21°C.
Wind	(indoor)	4 mph.	20 mph.	6 mph.	22 mph.	(indoor)
Relative humidity	"	82%	86%	86%	91%	"

Note: all means are "actual" or "observed" means.

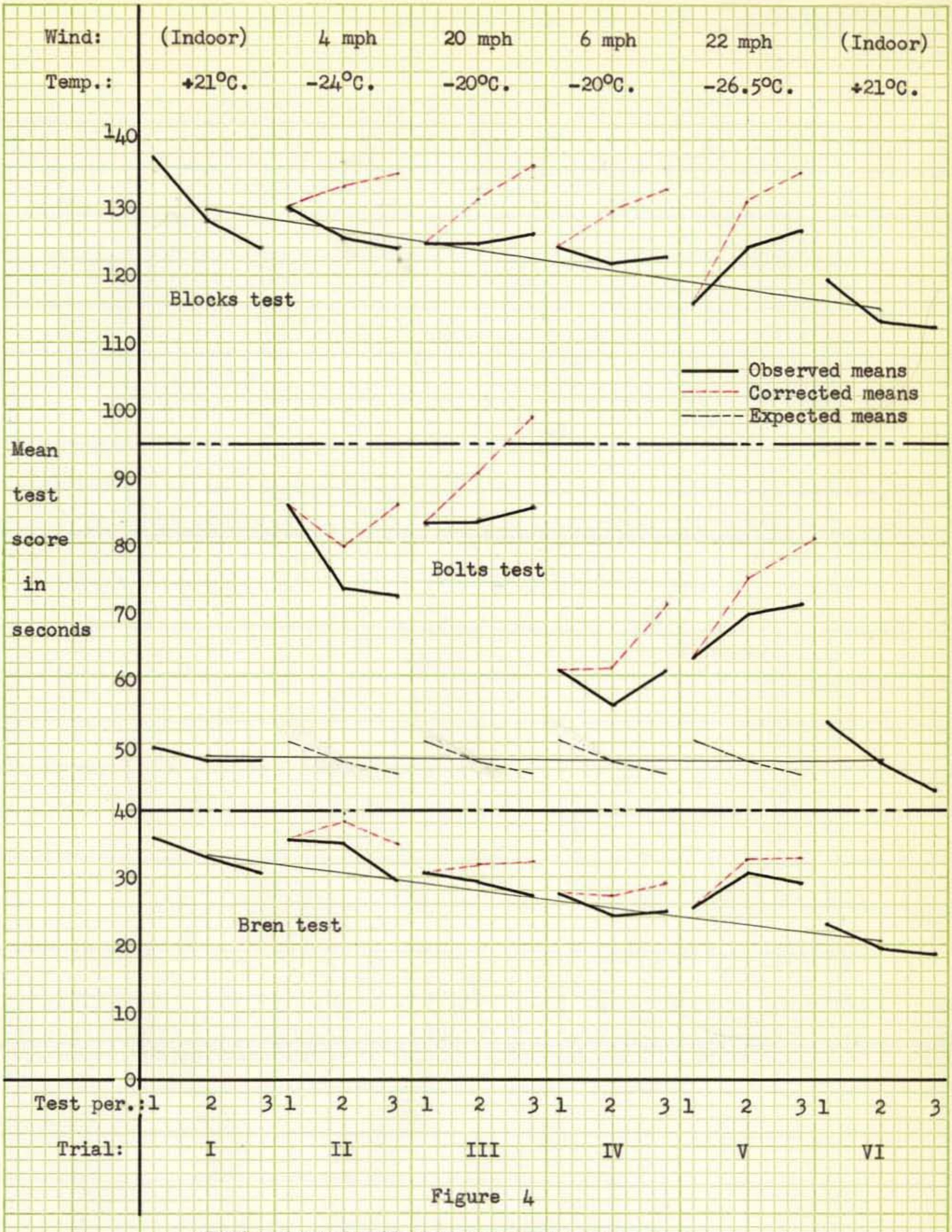

Figure 4

Environmental Effects upon Test Performance

-26.5°C. on trial V. Since the averages for the temperature readings on the two pairs of trials are nearly the same, the cause of the large effects from exposure on trials III and V may be attributed chiefly to wind conditions on those days.

The differential effects of the conditions of trials IV and V appear as the last analysis in Table VII, page 56. These trials were chosen because they represent the extremes, in wind and temperature conditions, encountered during the experiment. Observed means only enter into these calculations. D_1 is the difference between M_1 and M_3 on trial IV; D_2 is the difference between M_1 and M_3 on trial V. The differential effects of these two days, while considerable, do not prove to be significant, except for the blocks test.

From the analysis carried out in this section, it may be concluded that environmental conditions do affect performance on the three tests; the more extreme the conditions, the greater is the deterioration in performance. This deterioration is great enough to counteract series effects in many cases. The extent of the deterioration effect differs from test to test, being greatest upon the blocks test, and least upon the bren test.

Effects of exposure upon the test apparatus. In the blocks and bren tests the difference between "expected" score means and actual score means, in the outdoor trials, is in no case greater than can be accounted for by considering the series and exposure effects which act to modify performance from trial to trial and from test-period to test-period. This is indicated by the assumed learning curve for these tests.

TABLE VII

RELIABILITY OF DIFFERENCES IN MEANS
DUE TO EXPOSURE EFFECTS

Trial	Test	N	M_1	M_3	SD_1	SD_3	r_{13}	t	P
(Treatment 1: calculations made with observed means)									
III	Blocks	9	124.4	126.2	12.43	17.13	.73	0.458	0.40
	Bolts	9	82.9	85.8	18.79	17.81	.91	1.05	0.20
V	Blocks	10	115.9	126.5	9.21	13.34	.64	4.19**	< 0.01
	Bren	10	25.8	29.0	7.34	8.02	.54	1.30	0.15
	Bolts	10	61.4	70.6	18.08	21.31	.84	2.37*	< 0.05
(Treatment 2: M_3 corrected for series effects)									
II	Blocks	10	129.9	134.4	12.21	13.44	.80	1.65	0.12
III	Blocks	9	124.4	136.1	12.43	17.13	.73	2.97*	< 0.02
	Bren	9	30.4	32.3	6.22	7.78	.62	0.905	0.18
	Bolts	9	82.9	99.6	18.79	17.81	.91	6.03**	< 0.01
IV	Blocks	10	124.1	132.5	13.20	13.56	.89	3.95**	< 0.01
	Bolts.	10	60.4	70.6	10.87	13.53	.21	1.96	0.09
	Bren	10	27.5	29.7	7.23	5.53	.86	1.76	0.11
V	Blocks	10	115.9	135.8	9.21	13.34	.64	7.87**	< 0.01
	Bren	10	25.8	33.3	7.34	8.02	.54	3.05*	< 0.02
	Bolts	10	61.4	80.8	18.08	21.31	.84	5.01**	< 0.01
(Treatment 1:)			D_1	D_2					
IV vs. V	Blocks	10	+1.4	-10.6	8.01	10.91	-.38	2.31*	< 0.05
	Bren	10	+2.4	- 3.2	4.14	8.04	.21	2.05	0.08
	Bolts	10	-0.1	- 9.2	15.02	8.02	-.41	1.39	0.15

Note: P is approximate.

In the bolt test, however, the discrepancy between expected and actual performance means in trials II and III is so great that some factor or factors, other than effects upon the performance of the subjects, must be looked for to account for the difference. Figure 4, page 54 illustrates this anomaly in the performance of the bolts test. The expected scores have been indicated for the bolts test only in this figure.

A clue to the cause of the markedly increased performance times in the outdoor trials of the bolts test over the indoor times, was found in the reports of the subjects on trials II and III. All of the subjects stated that the bolts turned into the nuts with difficulty on these days. On trial II the bolts loosened up somewhat after the first test-period, and on trials IV and V the bolts were not appreciably more difficult to turn than on the indoor trials. On trial III no loosening up of the bolts during the tests was reported.

(This discussion is continued on the next page).

These reports from the subjects on the performance of the bolts test led to an analysis of the exposure effects upon the tests themselves. This analysis was directed primarily upon the effects of exposure upon the bolts test apparatus. Slightly increased stiffness in operation of certain parts of the bren gun, such as the bolt action, was also reported by the subjects, so an analysis, less extensive in scope than that for the bolts test, was made upon the exposure effects upon this test. No exposure effects were reported, or expected, upon the blocks test, but an analysis was made upon it in order to give a rough check on the results of the analyses made upon the other two tests.

The analysis of exposure effects upon the test apparatus was carried out as follows: it was assumed, first of all, that the learning curve for each test had a constant slope; this assumption was made to simplify calculation, and Figure 4, on page 54, indicated that, in the case of the blocks and bren tests, this assumption would not lead to serious errors. On this assumption, and from the symmetrical distribution of the indoor and outdoor trials with respect to inter-trial series effects, it was reasoned that the mean of the indoor trial scores and the mean of the expected outdoor trial scores, for each test, would coincide. Further, since the test scores in the first test-period of each outdoor trial were, apparently, little affected by exposure of the subjects for the few minutes required to perform them, the mean of the first test-period scores of the two indoor trials should differ little from the mean of the corresponding scores for the four outdoor trials.

On the basis of this reasoning an estimate of the exposure effects upon the bren and blocks tests was made by subtracting the mean first-test-period score for the four outdoor trials from the mean of the first-test-period scores of the two indoor trials, and expressing the difference as a percentage of the latter mean score. The resulting exposure effects appear in Table VIII, page 60, as the average effect over the four outdoor trials. The blocks test shows an improvement in performance on the outdoor first test-period trials, and the bren shows no exposure effects. It was expected that some exposure effects would appear for the bren test since actual mechanical effects were apparent. These effects may have been so small, however, as to be lost in the process of calculation, which assumed that the learning curve had a constant slope, and that the mean intra-trial series effects, as calculated from the two indoor tests, applied directly to the outdoor trials. Due to the large relative errors inherent in the calculations, for the blocks and bren tests, no attempt was made to assess the exposure effects for each of the outdoor trials on these two tests.

The bolts test showed negligible inter-trial series effects. That is, the learning curve appeared to be a straight line parallel to the x-axis. On this assumption it was possible to assess the exposure effects upon the apparatus for each outdoor trial. This effect, expressed as a percentage of the indoor first test-period mean, was considerable, far outweighing possible errors due to assumptions made in computing it. These figures appear in Table VIII. No average or over-all figure was given as this would be largely affected by the exposure effects of trials II and III.

While some exposure effects upon the apparatus were anticipated, no satisfactory explanation could be found for the large effects which were apparent on trials II and III, or for the lessening of these effects on trials IV and V. Frizell, whose experiment using the identical nuts and bolts has been mentioned (page 29), reported no such effect. It is interesting to note that in Frizell's experiment, the extent of deterioration in subject performance after fifteen minutes exposure is comparable with the exposure effects (both expressed as percentages) upon the test apparatus itself as measured in trials IV and V in the present experiment. Although the bolts were outdoors only a short time in Frizell's experiment, it is possible that part of the deterioration in performance of the subjects in his experiment was due to effects upon the bolts test apparatus. Even on the indoor trials the forearm muscles become tired and it is difficult to perform as quickly on the last bolts as on the first two or three. It is conceivable that even a very slight exposure effect upon the bolts themselves would considerably increase the time required to turn all five bolts into the nuts. In a test procedure where an indoor performance is followed by a single out door performance, it would not be possible to check exposure effects upon the test apparatus, and this effect might be overlooked.

TABLE VIII

EFFECT OF EXPOSURE UPON TEST APPARATUS

Trial	Bolts	Bren	Blocks
II	-61.7%	---	---
III	-61.3%	---	---
IV	-17.5%	---	---
V	-20.2%	---	---
Overall	---	0	+3.7%

V. PERFORMANCE IN RELATION TO CONDITIONS OF EXPOSURE

The effects of the environmental conditions of exposure have been discussed. The differential effects upon performance of the tests due to the experimental conditions of exposure forms the next step in the analysis of the experimental data.

The specific experimental conditions of exposure for the subjects during the periods between testing in the outdoor trials were those of activity-in-company, activity-in-isolation, inactivity-in company, and inactivity-in-isolation. From the test scores of the subjects under these specific conditions of exposure, the effects upon performance of the more general conditions of activity, inactivity, company, and isolation were derived.

The means of the observed test scores for all subjects under the general and specific condtions of exposure are presented in Table IX, on page 62. The means of the general conditions were derived by combining the individual scores in two of the specific conditions; that is, the general condition of "activity", for instance, includes the specific experimental conditions of "activity-in-company", and "activity-in-isolation". The individual scores entering into the calculation of the mean test scores for each condition were distributed over the four outdoor trials. The distribution is not altogether balanced, however, as there were five pairs of subjects, and one of the four specific conditions of exposure had to be assigned to two pairs of subjects on each trial. The result of this distribution of conditions is that

TABLE IX

EFFECTS OF CONDITIONS OF EXPOSURE
ON PERFORMANCE OF THE TESTS

General Conditions	Test-period	N	Test: Blocks M	Blocks SD	Bren M	Bren SD	Bolts M	Bolts SD
Active	1st	20	123.7	14.21	29.6	9.51	72.4	19.38
	2nd	20	122.7	11.29	27.8	6.73	70.1	18.41
	3rd	20	120.6	12.32	26.9	6.54	71.2	21.32
Inactive	1st	19	123.4	11.32	30.1	8.75	72.3	21.37
	2nd	19	125.5	12.29	31.3	9.63	69.8	23.08
	3rd	19	129.3	14.68	28.6	8.69	72.7	18.52
Company	1st	19	123.1	14.37	31.2	10.62	69.4	20.43
	2nd	19	123.0	14.78	28.9	8.75	68.6	20.87
	3rd	19	124.2	17.75	28.7	7.75	70.6	16.89
Isolation	1st	20	124.0	11.13	28.5	7.09	75.1	20.86
	2nd	20	125.0	11.19	30.1	8.63	71.3	20.73
	3rd	20	125.4	13.54	26.8	7.68	73.1	22.69
Specific Conditions								
Active-in-company	1st	10	123.7	16.73	31.9	10.89	68.9	16.94
	2nd	10	121.1	11.75	26.8	5.51	69.9	19.12
	3rd	10	119.6	12.19	27.5	6.49	69.7	17.72
Inactive-in-company	1st	9	122.4	12.41	30.5	10.31	70.0	22.68
	2nd	9	125.1	15.16	31.2	9.76	67.1	22.93
	3rd	9	129.3	16.77	30.0	8.29	71.5	16.08
Active-in-isolation	1st	10	123.7	10.64	27.3	6.84	75.8	21.31
	2nd	10	124.2	11.87	28.7	8.03	70.3	17.53
	3rd	10	121.5	13.15	26.3	6.38	72.4	24.64
Inactive-in-isolation	1st	10	124.3	11.30	29.6	8.53	74.4	20.37
	2nd	10	125.8	10.10	31.4	9.50	72.2	23.83
	3rd	10	129.2	13.52	27.3	8.78	73.8	20.84

Note: all means are "observed" means.

CHAPTER V

SUMMARY AND CONCLUSION

I. DISCUSSION OF RESULTS

The Tests. Several observations were made during the course of the experiment regarding the tests chosen, and these will be noted in the discussion of each test, which follows immediately.

The blocks test. Of the three tests chosen for the experiment, the blocks test was the least realistic in relation to actual tasks which might be encountered in outdoor work in cold winter weather. This factor, however, had no noticeable adverse effect upon the motivation of the subjects, who put forth their best efforts upon it.

Being free from moving parts, the test was not mechanically affected by the cold weather. Furthermore, the wooden blocks did not conduct warmth from the fingers of the subjects through their light working glove. These factors, together with the simplicity of the movements involved, contributed to make this test the most reliable in the battery.

The blocks test was the most sensitive of the three tests in measuring differences in the performance of the subjects due to the different conditions of the experiment. These conditions included the environmental conditions of temperature, wind, and relative humidity encountered during the four outdoor trials, and the physiological and psychological conditions of the two degrees of activity and isolation

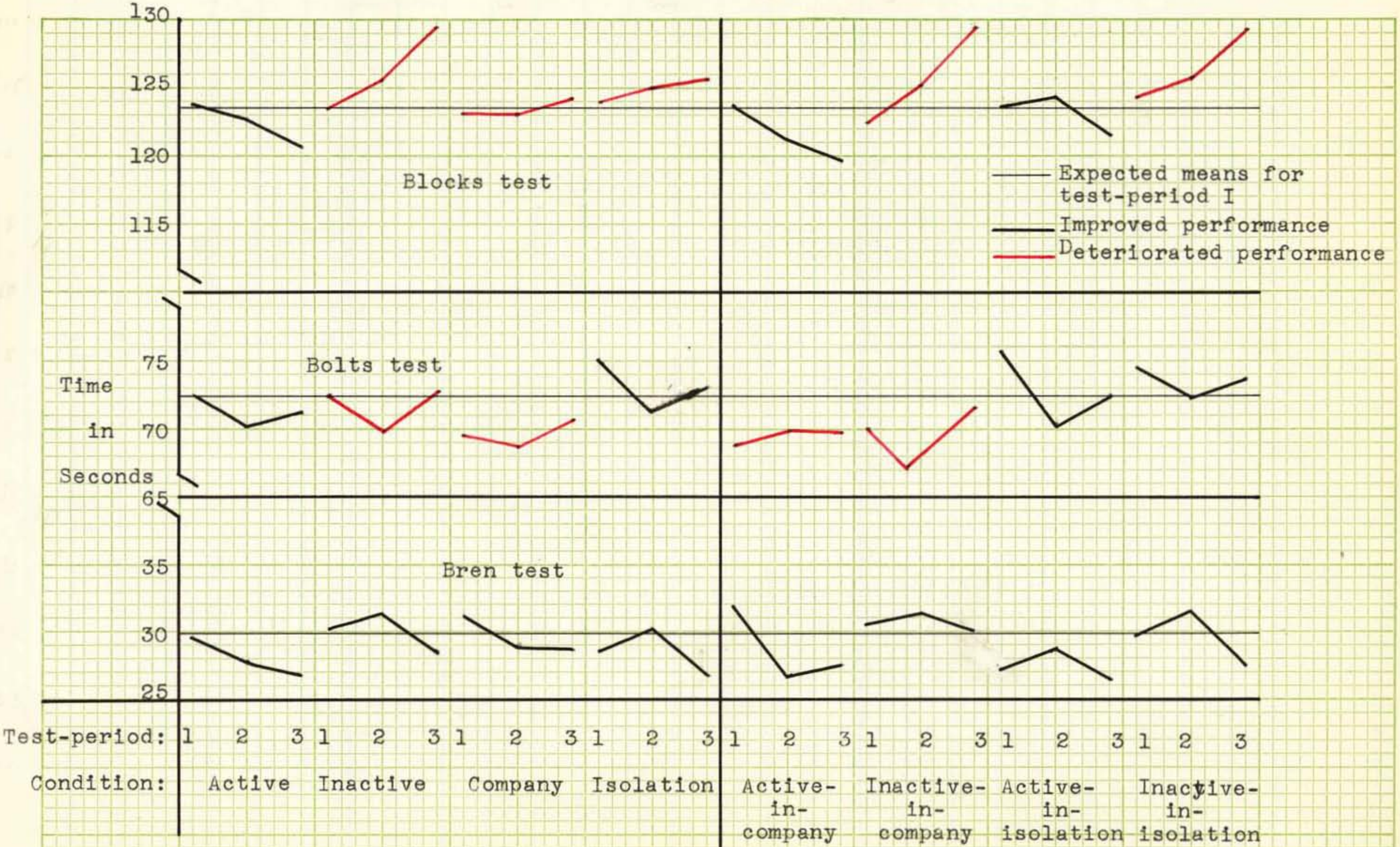

Figure 5.

The Effects of the Conditions of Exposure upon Test Performance.

the effects of the environmental conditions of exposure are not quite counterbalanced. The environmental conditions of trials II and V, for example, each affect 6 of the 20 scores in the general experimental condition of "activity", while the environmental conditions of trials III and IV affect only four, each, of these scores.

Figure 5, on page 63, illustrates the trend of the performance scores, from test-period to test-period, for each of the general and specific conditions of exposure. The observed means only have been presented. The black lines indicate that exposure effects have not been as great as series effects, and the observed performance has shown an improvement from test-period I to test-period III. When the exposure effects have resulted in a deterioration of observed performance scores, the performance graph for the condition of exposure is shown in red.

Figure 5 indicates that the conditions of activity and inactivity affect performance to a considerable extent, and in apparently different directions--activity causing improved performance, and inactivity, deteriorated performance. Actually, activity does not improve performance but acts more effectively than does inactivity to uphold it against the deteriorating effects of exposure. The conditions of company and isolation affect performance only slightly, and are not consistent in the direction of this effect, greater deterioration occurring under the condition of company as often as it does for the condition of isolation.

The significance of the differences in deterioration due to pairs of conditions of exposure appear in Table X, page 65. Here the differ-

TABLE X

SIGNIFICANCE OF THE DIFFERENTIAL EFFECTS OF THE EXPERIMENTAL CONDITIONS OF EXPOSURE

Condition	Test	N	D_1	D_2	SD_1	SD_2	D	t	P
Activity vs. inactivity	Blocks	20	3.1	-5.9	8.98	10.01	9.0	2.91	0.01
	Bren	20	2.7	1.5	6.74	6.48	1.2	0.46	0.65
	Bolts	20	1.2	-0.4	13.61	13.03	1.6	0.30	0.75
Company vs. isolation	Blocks	20	-1.1	-1.4	9.58	9.48	0.3	0.08	0.95
	Bren	20	2.5	1.7	6.71	6.84	0.8	0.31	0.75
	Bolts	20	-1.2	2.0	13.33	13.05	-3.2	0.70	0.50
Activity-in-company vs. Inactivity-in-isolation	Blocks	10	4.1	-4.9	8.09	9.20	9.0	2.21	0.05
	Bren	10	4.4	3.3	7.37	7.43	1.1	0.85	0.50
	Bolts	10	-0.8	0.6	14.62	13.96	-1.4	0.30	0.80

Note: P is approximate.

$D_1 = \frac{\sum(X_1 - X_3)}{N}$, where X_1 and X_3 represent the raw scores in the first and third test-periods, respectively, under the conditions of activity, company, and activity-in-company.

$D_2 = \frac{\sum(X_1 - X_3)}{N}$, where X_1 and X_3 are the raw scores in the first and third test-periods, respectively, under the conditions of inactivity, isolation, and inactivity-in-isolation.

$D = D_1 - D_2$. Where D is negative, performance,under the condition of exposure which generally shows effects in the direction of greater deterioration, has shown a relative improvement.

ence in effect upon the performance of the subjects of (1) Activity and inactivity, and (2) isolation and company were tested for significance.

Since the socres in the specific conditions of exposure enter into the calculation of the relative effects of the general conditions, no new information would be forthcoming through pairing the specific conditions and comparing their relative effects upon performance. Only in the case of the specific conditions of activity-in-company and inactivity-in-isolation, where considerable differences in effects upon performance were expected, has the reliability of this difference been computed.

The difference in effects upon performance, due to the conditions of activity and inactivity, is significant only in the case of the blocks test. The differences which appear for the bren and bolts test are in the expected direction -- towards greater deterioration in the condition of inactivity -- but the extent of these differences is by no means reliable. The conditions of company and isolation show no differences in effect of any significance whatever, in any of the tests. The specific conditions of activity-in-company and inactivity-in-isolation show differences in effect which are reliable at the .05 level in the case of the blocks test, but which have no significance in the case of the other two tests.

It must be concluded, then, that the exposure conditions of activity and inactivity, in the present experiment, were not sufficiently different to cause significant differences in the performance of any but the most sensitive tests. The conditions of company and inactivity, apparently, were not different conditions at all.

VI. PERFORMANCE IN RELATION TO HAND-SKIN TEMPERATURE AND THE SUBJECTIVE FEELING OF COLD

Hand-skin temperature. At the end of each exposure period, just prior to the second and third test-periods on each of the outdoor trials, the skin temperature of the right hand of each subject was measured. A thermometer was slipped into the subject's mitt, and he was instructed to keep its bulb against the skin of his fingertips until the reading remained at a constant level. In the case of the left-handed subject, the temperature of the fingers of the left hand was measured, as it was the temperature of the hand used predominantly in the performance of the tests which was required throughout.

From the resulting hand-skin temperature data, two groups of cases were selected -- the "warm handed" and the "cold handed" cases. The warm handed group included all those cases where the hand-skin temperature of a subject at the end of the second exposure period was not less than 30°C. Thirteen cases appeared in this group, of which twelve were active during their period of exposure. Sixteen cases appeared in the cold handed group, which included all cases in which the skin temperature of the hand was no higher, at the end of the second exposure period, than 14°C. Of the sixteen cases in this group, twelve were inactive during their exposure periods. The class limits for each group were selected in such a manner as to include most of the thirty-nine cases available, and yet form two distinct groups.

The performance of the two groups in each test is compared in the figures which appear below. The formula for the reliability of the differences between means in small independent samples[1] is used in these calculations, and in subsequent calculations in this section. N_1 and M_1 represent respectively, the number of cases, and the mean of the differences between first and third test-period scores for these cases, for the warm handed group. N_2 and M_2 represent the corresponding statistics for the cold handed group. The standard deviation ("s") and the standard error of the difference between means ("s_D") are based on all the observations of performance differences of the two groups, combined. D is the difference of the two means M_1 and M_2.

Test	N_1	N_2	M_1	M_2	s	s_D	D	t	df	P
Blocks	13	16	5.2	-7.4	8.61	3.18	12.6	3.96**	27	<0.01
Bren	13	16	3.0	-0.1	6.22	2.32	3.1	1.35	27	0.20
Bolts	13	16	1.6	-1.2	14.16	5.25	2.8	0.53	27	0.60

In all three tests performance improved in the case of the warm handed group and deteriorated in the cold handed group. The difference in performance of the two groups is significant in the case of the blocks test only, however. A direct relationship between hand-skin temperature and performance is indicated from this analysis. This conclusion is substantiated by the reliability of the difference in means for the blocks test, the direction of the differences in means

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[1] This formula appears in Appendix D.

in the bren and bolts tests, and the consideration of the nature of the tests themselves. The performance of the blocks test requires the use of the fingertips predominantly; the bolts test also requires finger strength and dexterity, but depends more upon the muscles of the forearm for its performance. The bren test alternates the use of each hand, requires the wearing of heavy mitts on both hands, and is not dependent upon finger dexterity to any appreciable extent; the bren test is also considerably more subject to intra-trial series effects than are the other tests.

Performance in relation to reported feelings of cold. From the subjective reports of their feelings of cold obtained from the subjects prior to the second and third test-periods of each trial, and from the questionnaire completed by them after each trial, the thirty-nine cases were divided into two classes, the warm and the cold. The "warm" group comprised the cases where the subject remained warm throughout the trial, and reported "no discomfort", or "comfortable"; there were nineteen of these cases, of which sixteen were active and three inactive. The "cold" group included the cases where the subjects reported that they were cold, ("mild discomfort"), or very cold, at the end of the second exposure period; sixteen of these cases were inactive during the exposure periods of the trials. All cases were included in the two groups, as the subjective rating scale was crude, and the subjects reported only whether they were warm, or cold; the ratings of degrees of cold appeared in the questionnaire, but only three subjects indicated that they were very cold, the rest reporting mild discomfort.

The performance of the two groups is compared below. Again M_1 and M_2 represent the means of the differences between first and third test-period scores, M_1 being the mean for the warm group. Fifteen of the cases which appeared in the "cold handed" group are included in the present "cold" group, and the "warm" group includes eleven cases which appeared in the previous "warm handed" group, indicating a direct relationship between hand-skin temperature and overall feelings of cold.

Test	N_1	N_2	M_1	M_2	s	s_D	D	t	df	P
Blocks	19	20	3.7	-6.0	9.73	3.11	9.7	3.13**	37	<0.01
Bren	19	20	3.0	1.0	6.98	2.23	2.0	0.89	37	0.40
Bolts	19	20	3.1	-1.6	14.02	4.48	4.7	1.05	37	0.25

The performance of the warm group improved on the blocks and bolts tests, while that of the cold group showed deterioration. The same relative effect is apparent in the bren test where the cold group, while it did not show actual deterioration, improved less than did the warm group.

Again the indications all point towards a direct relationship between test performance and subjective feelings of cold. As in the previous analysis, however, the blocks test, which is the most sensitive test in the battery, alone shows a significant difference in the performance of the two groups.

Acclimatization differences and performance. All but one of the subjects for the present experiment had lived several years in Manitoba, and were, consequently, well adapted to the severe winter conditions of that province. However, on the basis of the self-ratings of the subjects concerning the degree of their acclimatization to severe winter weather, they were divided into two groups, each of five subjects.

In the following comparison of the performance of the two groups, N_1 represents the number of cases, and M_1 the mean of the test score differences from first to third test-period, for the "completely acclimatized" group; N_2 and M_2 are the corresponding figures for the "fairly well acclimatized" group.

Test	N_1	N_2	M_1	M_2	s	s_D	D	t	df	P
Blocks	20	19	-1.1	-1.1	10.58	3.35	0	0.00	37	1.00
Bren	20	19	0.6	3.3	7.04	2.34	-2.7	1.15	37	0.25
Bolts	20	19	0.6	1.0	13.33	4.21	-0.4	0.095	37	0.95

This analysis indicates that there was no real difference in the degree of acclimatization of the subjects. The difference in performance which appears for the bren test is not significant, and is in the direction of relatively improved performance in the case of the less acclimatized group.

A further analysis in terms of participation in outdoor sports was made, to see if this had any effect upon outdoor performance of the tests. The subjects were divided into two groups on the basis of hours per week devoted to outdoor sports. One group included the two subjects who spent six hours or more a week in this way. The three subjects who spent no time outdoors at sports formed the comparison group.

In the following analysis, N_1 and M_1 refer to the athletic group, and indicate, respectively, the number of cases of score differences involved and the mean of these differences. Again the differences in scores are as between the first and third test-period scores.

Test	N_1	N_2	M_1	M_2	s	s_D	D	t	df	P
Blocks	8	12	3.3	-0.3	10.82	5.72	3.6	0.63	18	0.55
Bren	8	12	-0.4	3.1	6.98	3.70	-3.5	0.95	18	0.35
Bolts	8	12	-2.4	-0.2	13.39	7.08	-2.2	0.31	18	0.75

Again no difference in performance of any significance appears. The blocks test performance of the athletic group improved, while it deteriorated in the case of the non-athletic group. The bren and bolts tests, on the other hand, show less deterioration in the performance of the non-athletic group than appears for the athletic. It can only be concluded that there is no appreciable difference in the degree of acclimatization of the subjects who participated in the experiment.

In the present chapter an analysis has been made of the effects of exposure upon the performance of three motor tests. The preliminary analysis of the general or overall effects of all the experimental and environmental conditions of exposure revealed no significant effects upon the performance of any of the tests. It was demonstrated, however, that there were series effects operating to improve performance from test-period to test-period, and that these effects were significant. When these intra-trial series effects were taken into account in the evaluation of exposure effects, the latter were found to cause performance differences in the direction of deterioration which were highly reliable.

Further analysis of the experimental data demonstrated that exposure effects were significant, even without taking into account series effects, under certain specific conditions of exposure, and for one or another of the three tests. Physiological conditions of hand-skin temperature, and the psychological, or subjective feeling of cold, were each found to have significantly different effects upon performance in the blocks test. It was concluded from these analyses that the effects of exposure to severe winter conditions had definite and significant effects upon motor performance.

CHAPTER V

SUMMARY AND CONCLUSION

I. DISCUSSION OF RESULTS

The Tests. Several observations were made during the course of the experiment regarding the tests chosen, and these will be noted in the discussion of each test, which follows immediately.

The blocks test. Of the three tests chosen for the experiment, the blocks test was the least realistic in relation to actual tasks which might be encountered in outdoor work in cold winter weather. This factor, however, had no noticeable adverse effect upon the motivation of the subjects, who put forth their best efforts upon it.

Being free from moving parts, the test was not mechanically affected by the cold weather. Furthermore, the wooden blocks did not conduct warmth from the fingers of the subjects through their light working glove. These factors, together with the simplicity of the movements involved, contributed to make this test the most reliable in the battery.

The blocks test was the most sensitive of the three tests in measuring differences in the performance of the subjects due to the different conditions of the experiment. These conditions included the environmental conditions of temperature, wind, and relative humidity encountered during the four outdoor trials, and the physiological and psychological conditions of the two degrees of activity and isolation imposed upon the subjects during their two periods of exposure between test-battery administrations in each trial.

The sensitivity of this test was attributed to the fact that it depends largely upon finger dexterity for speed of performance. It was observed that the fingers and toes of the subjects were the first parts of the body to be sensitive to the effects of cold. Furthermore, the test required sustained attention to the task of placing cylinders of wood in round holes in a board, and offered little warmth-giving exercise. It was thought that the demands of the chilled organism for more violent exertion might interfere with the task at hand.

The blocks test was, on the whole, the most satisfactory test in the battery.

The bren test. The bren test, while the most realistic of the battery, proved to be the least sensitive to performance differences of the subjects brought about by different conditions of exposure. Involving as it did a number of muscle groups, and depending for its performance upon large-muscle groups rather than small-muscle groups, it was less susceptible to performance deviations in the direction of deterioration from subjects none of whom became markedly cold during the course of the experiment.

The variety of movements in the bren test, involving the use of both hands, permitted a large series effects to affect test performance. These effects were attributed largely to learning, including the central process of memory.

The complex mechanism of the test apparatus made it susceptible to exposure effects from the cold environment. This effect acted to considerably increase the effort required to cock the bolt action. As this action occurred only twice during the test, it did not affect the performance of the subjects appreciably. It was learned, after the outdoor trials were completed, that a low test oil has been made available for guns in use in temperatures below -20°C.

A further mechanical difficulty caused some hardship in the operation of changing the barrel group. This difficulty occurred during the fifth trial, when blowing snow became lodged in the barrel locking threads and had to be removed from time to time.

It is entirely possible that under more extreme environmental conditions the bren test will prove an effective measure of the performance of subjects in whom the conditions of exposure have affected not only the fingers, but caused severe discomfort to the organism as a whole. These conditions did not obtain in the course of the present investigation.

The bolts test. The bolts test proved to be the least reliable of the three tests included in the experiment. It also caused the most discomfort to the subjects, as the heavy metal bolts conducted warmth from the fingers of the subjects, through the light glove worn for the test. The effects of exposure upon the apparatus itself was considerable, and inconsistent. The test was sensitive only to performance differences in the subjects resulting from extreme environmental conditions of exposure.

The conditions of exposure. The environmental conditions of exposure could not be controlled. The outdoor trials were carried out on the coldest days of the month of February. The coldest weather of the winter occurred in January, but the army clothing and equipment was not available in time to take advantage of this. It became apparent that the temperature conditions encountered during the outdoor trials were not sufficiently extreme to cause significant deterioration in performance of all the tests.

It is suggested that further experimentation be carried out under more extreme environmental conditions of temperature and wind, holding the experiments, whenever possible, in the early morning or late evening. The present experiment was carried out during the early afternoons, which is the time at which the daily temperature reaches its highest point.

Experimental conditions. The experimental conditions of activity and inactivity were significantly different in their effects upon the blocks test in the present experiment. The indications are that, under more extreme conditions of temperature and wind, the effects of these conditions upon the bren and bolts tests would also be significant. It is felt that the failure of the conditions of company and isolation to affect performance differently may be due to the fact that these conditions were not sufficiently different for the subjects in the experiment, as it was impossible to isolate any subject to any considerable degree. It is suggested that further experimentation be carried out upon the relative effects of these two conditions with controls that will ensure that they are different.

II. SUMMARY OF THE EXPERIMENT

1. An experiment was conducted to determine the effect of exposure to severe winter conditions on motor performance.

2. The experiment consisted of three timed motor tests, performed under a variety of environmental and experimental conditions, by a group of ten subjects, protected by heavy arctic clothing.

3. The three tests used in the experiment were the blocks test, the bren test, and the bolts test. These formed the test-battery.

i. The blocks test (Minnesota Manual Dexterity Test) consisted of a board with 58 round holes in it, in which to place, one by one and using only one hand, 58 round blocks of wood. The test required about two minutes to perform.

ii. The bren test consisted of a number of manipulations to be performed upon the Bren Light Machine gun. This test required only about twenty-five seconds to perform.

iii. The bolts test required the turning of five large bolts into nuts fastened into a board, using one hand only. One minute was required for this test.

4. The environmental conditions were the temperature, wind, and relative humidity. These could not be controlled, but the trials were held on days when these conditions were most severe.

5. The experimental conditions were those of activity or inactivity, company or isolation, imposed upon the subjects during the periods between the performances of the test battery during an outdoor trial.

6. The ten subjects were male University students, between the

ages of nineteen and thirty-one, and all in sound health.

7. The subjects were supplied with standard army arctic outer clothing for the outdoor trials of the experiment.

8. The experimental plan called for six trials. Each trial included three presentations of the test-battery of three tests. The first and last trials were control trials, conducted indoors with the subjects fully dressed, in order to permit an assessment of series effects. The four remaining trials were the field trials, the data from which, when analyzed, led to the conclusions which follow.

9. The experiment was carefully controlled throughout, in order that analyses of the effects of specific environmental and experimental conditions of exposure upon performance might be made. It was not possible to control inter-trial and intra-trial series effects upon performance; a measure of these effects was made possible, however, through an analysis of the time scores of the two indoor trials of the experiment.

III. CONCLUSIONS

1. Significantly large series effects were found to be operating to improve performance from test-period to test-period within the indoor trials. These effects were considered to apply to the outdoor trials of the experiment.

2. When the data for all the subjects, under all conditions of the four outdoor trials, were pooled, the general or overall effects of exposure upon performance were not found to be significant

for any of the three tests. When corrections were made for series effects, however, the "true" exposure effects were found to be highly significant for all three tests.

3. Both series effects and exposure effects were found to have their greatest effect upon performance between the first and second test-periods of each trial.

4. The environmental conditions of -26.5°C., a 22 mph. wind, and a relative humidity of 91% were sufficiently severe to cause significant deterioration in the performance of the blocks and bolts tests. These significant differences were obtained despite series effects which operated to improve performance during the trials.

5. The experimental conditions of activity and inactivity were found to be significantly different, as measured by performance of the subjects on the blocks test.

6. The experimental conditions of company and isolation were, on the basis of their effects upon test performance, found to be closely similar conditions.

7. Hand-skin temperature was found to be positively related to performance on all three of the tests. Significant differences in performance as between a warm-handed and a cold-handed group were found in the case of performance on the blocks test. A further positive relation was found to obtain between the experimental exposure conditions of activity and inactivity, and hand-skin temperature.

8. Subjective reports of general feelings of warmth or cold were found to be positively related to performance. The difference in performance of the blocks test by a warm and a cold group was found to be significant. Again it was found that activity tended to

maintain warmth in the subject, while a feeling of cold and discomfort resulted from a state of inactivity. Hand-skin temperature was also found to be positively related to the subjective feeling of warmth or coldness.

9. The blocks test was found to be a highly reliable test, and the most sensitive test of the battery, indicating changes in the performance of the subjects due to different environmental and experimental conditions of exposure, hand-skin temperature, and feelings of cold or warmth.

10. The bolts test proved to be less reliable and less sensitive than the blocks test. Mechanical difficulties were experienced in the outdoor trials, in the form of stiffness of the moving parts, which made it difficult to evaluate performance results as measured on the test.

11. The bren test was found to be the least reliable and the least sensitive test of the battery. This test was relatively complex, calling for the memorizing of a sequence of movements. It also required the use of large-muscle groups which were, apparently, little affected by the exposure conditions of the experiment.

12. The army outer clothing worn by the subjects during the experiment was found to be highly effective in maintaining warmth, even in the condition of inactivity.

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APPENDIX A

RAW SCORE DATA FOR TRIAL I (INDOOR)

Subject	Test-period I			Test-period II			Test-period III		
	Blocks*	Bren	Bolts	Blocks	Bren	Bolts	Blocks	Bren	Bolts
1	132	27	50	121	33	60	119	26	49
2	125	25	42	122	21	36	115	23	39
3	137	36	60	132	34	56	124	39	47
4	164	48	64	140	37	47	134	34	39
5	138	24	47	118	22	37	110	25	39
6	137	51	48	125	44	55	119	36	54
7	145	31	66	139	34	57	134	32	55
8	142	27	38	135	24	43	140	27	52
9	118	35	44	119	30	41	111	21	46
10	137	55	36	131	49	43	133	42	54

* The test order in each test-period was rotated. To simplify the presentation of the test scores, this order of rotation has not been followed in the raw data tables.

The figures presented in the body of the tables represent seconds.

Data Concerning the Subjects of the Experiment.

Subject Number	Age	Height	Weight	Racial Origin	Acclimatization	Outdoor Sports*
1	30	68"	125#	Irish	Completely	0
2	25	70½"	155#	Irish	Fairly well	1
3	22	74"	185#	Scottish	Completely	3
4	31	67"	152#	Norwegian	Fairly well	3
5	20	75"	179#	Scot/Can.	Completely	10
6	25	71½"	155#	English	Fairly well	6
7	21	73"	158#	Welsh	Fairly well	3
8	19	71"	145#	Hebrew	Completely	0
9	21	69"	170#	Ukrainian	Completely	1
10	21	69"	145#	Irish	Fairly well	0

*The figures in this column represent the number of hours per week devoted to outdoor sports.

APPENDIX A (Continued)

RAW SCORE DATA FOR TRIAL II

Subject	Test-period I			Test-period II			Test-period III		
	Blocks	Bren	Bolts	Blocks	Bren	Bolts	Blocks	Bren	Bolts
1	126	30	97	125	28	77	116	25	99
2	121	29	89	110	38	56	105	20	54
3	125	44	78	133	39	70	128	38	67
4	135	47	105	139	43	56	145	35	80
5	127	21	62	121	33	48	116	19	57
6	123	35	105	120	50	108	122	41	94
7	136	33	82	123	27	56	133	24	54
8	155	44	90	140	31	87	135	29	83
9	113	23	69	109	22	63	108	24	64
10	138	50	80	135	37	105	131	40	68

Environmental Conditions: Temperature: -24°C.
Wind: 4 mph.
Relative humidity: 82%

Further Data

Subject	(Objective) Hand-skin Temperature*		(Subjective) Feelings of Cold	Experimental Condition of exposure
1	34°C.	30°C.	none	activity-in-isolation
2	34	18	none	ditto
3	27	18	none	inactivity-in-company
4	29	14	very cold	ditto
5	21	20	mild discomfort	inactivity-in-isolation
6	20	3	mild discomfort	ditto
7	29	30	none	activity-in-company
8	34	21	none	ditto
9	33	34	none	ditto
10	32	32	none	ditto

* The first temperature reading was taken after the first exposure period, and the second reading after the second exposure period.

APPENDIX A (Continued)

RAW SCORE DATA FOR TRIAL III

Subject	Test-period I			Test-period II			Test-period III		
	Blocks	Bren	Bolts	Blocks	Bren	Bolts	Blocks	Bren	Bolts
1	121	27	103	111	30	120	130	31	95
2	---	--	--	---	--	---	---	--	--
3	127	32	73	135	39	78	142	42	87
4	133	37	100	131	32	92	141	30	103
5	107	21	58	121	20	63	107	16	63
6	116	31	66	115	30	70	105	29	76
7	127	28	70	122	30	72	134	18	77
8	140	36	92	136	27	97	140	26	90
9	112	25	76	108	21	66	104	23	66
10	137	37	108	142	33	94	133	30	110

Environmental Conditions: Temperature: -20°C.
Wind: 20 mph.
Relative Humidity: 86%

Further Data

Subject	(Objective) Hand-skin Temperature		(Subjective) Feelings of Cold	Experimental Condition of Exposure
1	17°C.	13°C.	Mild discomfort	Inactivity-in-company
2	--	--	---	---
3	28	16	Comfortable	Inactivity-in-isolation
4	27	14	Very cold	ditto
5	34	34	Comfortable	Activity-in-company
6	24	8	Comfortable	ditto
7	19	17	Mild discomfort	Inactivity-in-isolation
8	19	13	Mild discomfort	ditto
9	34	34	Mild discomfort	Activity-in-isolation
10	34	34	Comfortable	ditto

APPENDIX A (Continued)

RAW SCORE DATA FOR TRIAL IV

Subject	Test-period I			Test-period II			Test-period III		
	Blocks	Bren	Bolts	Blocks	Bren	Bolts	Blocks	Bren	Bolts
1	124	23	77	130	18	44	141	26	44
2	113	22	56	115	23	49	108	21	54
3	115	39	66	117	23	59	123	29	65
4	135	35	50	130	32	55	127	27	72
5	108	20	42	105	18	42	104	15	43
6	120	26	71	110	24	63	115	27	81
7	129	32	59	130	26	58	125	31	55
8	139	22	67	125	24	58	130	23	56
9	113	22	54	106	20	55	113	21	59
10	145	34	62	141	35	75	141	31	76

Environmental Conditions: Temperature: -20°C.
Wind: 6 mph.
Relative Humidity: 86%

Further Data

Subject	(Objective) Hand-skin Temperature		(Subjective) Feelings of Cold	Experimental Condition of Exposure
1	17°C.	11°C.	Mild discomfort	Inactivity-in-isolation
2	16	10	Mild discomfort	ditto
3	33	22	Comfortable	Activity-in-company
4	34	30	Comfortable	ditto
5	30	27	Comfortable	Inactivity-in-company
6	17	3	Mild discomfort	ditto
7	30	28	Comfortable	Activity-in-isolation
8	31	34	Comfortable	ditto
9	28	13	Mild discomfort	Inactivity-in-company
10	33	30	Mild discomfort	ditto

APPENDIX A (Continued)

RAW SCORE DATA FOR TRIAL V

Subject	Test-period I			Test-period II			Test-period III		
	Blocks	Bren	Bolts	Blocks	Bren	Bolts	Blocks	Bren	Bolts
1	114	25	87	116	30	91	116	32	107
2	108	18	41	105	26	50	111	25	45
3	119	28	68	134	39	78	128	40	73
4	128	34	93	140	37	98	142	25	96
5	118	17	48	123	17	47	110	19	43
6	108	19	53	115	24	71	122	27	67
7	119	32	58	139	42	62	148	39	65
8	116	23	57	132	30	61	140	33	78
9	101	22	45	110	26	54	115	22	57
10	128	40	64	138	36	80	133	28	75

Environmental Conditions: Temperature: -26.5°C.
Wind: 22mph.
Relative Humidity: 91%

Further Data

Subject	(Objective) Hand-skin Temperature		(Subjective) Feelings of Cold	Experimental Condition of Exposure
1	25°C.	12°C.	Mild discomfort	Activity-in-company
2	33	31	Comfortable	ditto
3	21	17	Comfortable	Activity-in-isolation
4	33	13	Mild discomfort	ditto
5	33	33	Comfortable	Activity-in-isolation
6	8	6	Mild discomfort	ditto
7	8	11	Mild discomfort	Inactivity-in-company
8	13	12	Very cold	ditto
9	16	11	Mild discomfort	Inactivity-in-isolation
10	28	24	Comfortable	ditto

APPENDIX A (Continued)

RAW SCORE DATA FOR TRIAL VI (INDOOR)

Subject	Test-period I			Test-period II			Test-period III		
	Blocks	Bren	Bolts	Blocks	Bren	Bolts	Blocks	Bren	Bolts
1	108	23	50	111	16	57	109	19	56
2	111	18	49	103	19	41	95	18	39
3	116	24	60	107	24	56	112	29	51
4	132	30	85	135	21	51	128	20	54
5	116	15	35	110	14	34	120	12	34
6	109	23	47	99	21	37	95	15	37
7	123	27	53	112	19	47	108	20	42
8	130	20	49	119	25	47	122	16	35
9	107	17	44	102	16	42	109	15	35
10	140	31	61	132	22	58	125	21	44

FURTHER GENERAL INFORMATION

I. Duration of Outdoor Trials

	Trial II	Trial III	Trial IV	Trial V
Time at beginning of Trial	13.40	13.30	12.27	12.13
Time at end of Test-period I	14.25	14.13	13.04	13.00
Time at end of Test-period II	15.10	14.53	13.42	13.41
Time at end of Trial	15.55	15.35	14.28	14.26
Length of Trial	2 hr.15'	2 hr.05'	2 hr. 01'	2 hr.13'

II. INTER-TEST CORRELATIONS

Tests	Correlation
Blocks-bolts	0.41
Blocks-bren	0.52.
Bren-bolts	0.44

APPENDIX B

SUBJECT DATA QUESTIONNAIRE

Please supply the following information as completely and as accurately as possible. If you think of any further facts pertinent to your acclimatization to a severely cold environment, please append them to this questionnaire.

Name ______________________. Racial origin _______________.

Age _______. Height __________. Weight ______________.

How many winters have you spent in Manitoba (or in a climate of comparable severity)? _______.

How many hours a week do you devote to outdoor sports or activities? _______.

Which (if any) areas of your body are particularly sensitive to cold? ____

Do you consider yourself acclimatized to severe winter conditions?

(not at all) (fairly well) (completely)

Describe the nature of the most severe discomfort you have ever experienced due to the effects of extreme cold conditions _____

____.

Further remarks ____

____

<u>Note</u>: at the conclusion of each outdoor trial of the experiment you will be asked to make a report on your thoughts and feelings of cold. To this end it will be necessary that you consciously note these thoughts and feelings during the outdoor trials, especially during the periods between the presentations of the tests, and that you complete the report,by filling out the questionnaire provided, as soon as possible after the trials.

APPENDIX B (Continued)

SUBJECTIVE REPORT QUESTIONNAIRE

Subjects are requested to complete a report as soon as is practicable after each trial. Please supply all the information requested.

Name ________________. Date of trial ______________.

Rate the state of your health and vitality on the day of this trial.

(below normal) (average) (better than usual)

How many hours sleep did you have during the night preceding this trial? _______. How many hours sleep do you normally have? ______.

Did you have a substantial lunch on the day of this trial? (Rate this on the basis of your usual lunch in winter time).

(less than) (as much as) (more than)

Did you feel tired at the beginning of this trial? ______. At the end? ________.

How soon after you came outdoors did you begin to feel cold? ______.

Did you become progressively colder? ________.

What parts of your body were affected by the cold, and in what order?
____.

During any of the tests, did you find it difficult to evoke quick accurate responses from the muscles of your hands or arms due to the effects of cold, rather than to clothing or fatigue? ______. Name the test, the part of the body involved, and describe the nature of the difficulty.____.

Do you think that with additional motivation you could have considerably bettered your time score on any test? _____. Which test(s), and during which test-period(s) ________________________________.

Rate your feelings of discomfort due to the effects of cold during this trial against the most severe discomfort you have ever experienced as the result of being outdoors over a long period in severe cold.

(no discomfort) (mild discomfort) (as cold as I have ever been) (colder than I have ever been)

APPENDIX B (Continued)

SUBJECTIVE REPORT QUESTIONNAIRE (Continued)

Please make a short, introspective report of your thoughts and feelings due to the cold, particularly those occurring during your inactive and isolated periods of exposure. (Did your thoughts influence -- that is, heighten your sensitivity to -- your feelings of cold? Did the feeling of cold direct the course of your thoughts? Do you think either the thought or feeling of cold had any effect upon the other? Mention any instances of shivering, their duration, and effects).

APPENDIX "C"

DESCRIPTION OF ARMY ARCTIC CLOTHING PROVIDED FOR THE EXPERIMENT

	Description	Army catalogue number
1)	Battledress, blouse	
2)	Parka trousers (windproof)	A - 26170
3)	Boots, shearling lined, tank crew, (1949 patt.)	A - 2680
4)	Parka, (fur-trimmed), with liner	A - 25870
5)	Cap, comforter	C - 1050
6)	Mitts, woollen	A - 21650
7)	Mitts, winter shell	A - 21635

OTHER EQUIPMENT

8)	Gun, machine, Bren .303, Mk.I (complete as per EIS 3052 CAFM 23-1004)	BE - 8176
9)	Cover, waterproof	IJ - 3300

APPENDIX D

STATISTICAL FORMULAE

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

2. The Standard Deviation or SD.

   a) $SD = \sqrt{\frac{\Sigma X^2}{N} - \left(\frac{\Sigma X}{N}\right)^2}$ (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) $SD \text{ or } s = \sqrt{\frac{\Sigma(X_1 - M_1)^2 + \Sigma(X_2 - M_2)^2}{(N_1 - 1) + (N_2 - 1)}}$

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

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

   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) σ_D, 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), p. 32.

[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 D (C0ntinued)

b) $$s_D = \sqrt{\frac{\Sigma(X_1-M_1)^2 + \Sigma(X_2-M_2)^2}{(N_1-1) + (N_2-1)}}\sqrt{\frac{N_1+N_2}{N_1N_2}}$$

(for small independent samples)[8]

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

(for correlated means)[9]

5 The Critical Ratio.[10]

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

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 $N \overline{\overline{<}} 10$)[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.