THE EFFECTS OF PROLONGED IMMOBILIZATION OF THE BODY UPON INTELLECTUAL PROCESSES

A Thesis

Presented to

the Faculty of Graduate Studies and Research

University of Manitoba

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

by

Lorraine Rose Wilgosh

April 1963

ABSTRACT

In view of the almost total lack of data on the role of motor activity in behaviour, an experiment was carried out to determine the effects of a week long period of immobilization upon intellectual functioning.

A group of 22 experimental subjects were immobilized for periods of seven days. When their performance on a battery of 12 intellectual tests was compared with that of matched control subjects, a significant impairment of recall, verbal fluency, and perceptual ability (cancellation) was observed. The decreased scores on dexterity, space relations, and numerical reasoning bordered on statistical significance. The remaining abilities were not significantly impaired. However, on all tests the experimental subjects performed worse than the matched controls.

The findings of this thesis have several implications e.g. to orthopedic treatment, space travel, and infant cradling practices.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION AND HISTORICAL BACKGROUND

I. STATEMENT OF THE PROBLEM

A review of the experimental literature has revealed that there is an almost total lack of studies on the effects of restriction of motor activity upon various behavioural processes. Such experiments would be relevant to a number of situations e.g. orthopedic treatment, space travel, and infant cradling practices.

The only relevant study in this area was recently completed at the University of Manitoba. In this experiment, a group of 40 male subjects were completely immobilized for periods of up to 24 hours. No other restrictions were imposed upon the subjects. A battery of intellectual and perceptual tests was administered before and immediately after immobilization. Two control groups, of 40 subjects each, were also given the same tests at the same time intervals. An analysis of the data revealed that several perceptual processes were impaired. However, no intellectual deficits were observed. It was suggested that these negative results might be due to the periodic aches and pains which all of the experimental subjects experienced. This physical condition may have kept the brain in a reasonably alert state, counteracting some of the effects of reduced kinesthetic stimulation upon intellectual performance. It is known that noxious stimulation is particularly effective as an alerter of the reticular activating system.

In order to eliminate the factor of pain, the present experiment has employed a longer but less severe form of immobilization. By means of intermittent "relief" periods it has been possible to extend the duration to one week, without, at the same time introducing pain. This experiment also differs from the early one in that daily measures of intellectual performance are employed.

II. INTRODUCTION

A knowledge of the effects of movement restraint upon the intellectual and physical functioning of human beings is essential in order that these effects may be better understood and, where necessary, controlled or prevented.

There are a great number of situations involving restriction of motor activity. Certain Indian tribes still employ cradling practices from early infancy to the age of one or two years. It is important to determine whether these practices may produce intellectual deficits. A knowledge of the effects of restricted movement is also of importance in the hospital setting where patients may be immobilized for long periods of time in casts or in iron lungs. The present trends in national defense and space travel are further evidence of the increasing need for an understanding of the dynamics involved when an individual is subjected to restriction of movement (as in a submarine, tank, or space craft) so that prevention of undesirable, if not disastrous results may be achieved. The relevant variables can be determined only by controlled experimentation.

In addition to its practical significance, such research is of theoretical importance. Neurophysiological data suggests that exposure to varying sensory stimulation is essential for normal functioning of the waking brain (Jasper, 1941; Walter, 1953). French (1960) states that kinesthetic sensibility is one of the most powerful contributors to reticular excitation and brain alertness. On the basis of this physiological evidence it would appear that any noticeable interference with kinesthetic activity may affect behavioral functioning. Thus there are both practical and theoretical reasons for carrying out this study.

The thesis proper begins with an historical resumé of the relevant literature on the effects of immobilization. The second chapter includes a description of the apparatus, subjects, tests, and procedure. The thesis concludes with a statement of the results obtained, an interpretation of these results, and a general discussion.

III. HISTORICAL BACKGROUND

Although this thesis is concerned with the effects of immobilization of the body upon intellectual processes, the review of the literature will be broadened to include the physiological as well as the behavioral effects of restricted movement, (in animals as well as in human beings). This is done for two reasons. First, no comprehensive review of this topic is available in the literature. Second, an understanding of the physiological changes may help to throw further light on behavioral functioning.

Animal Studies

Numerous animal experiments, utilizing various species, have been carried out to study the effects of restraint. Most of these studies have been concerned with physiological effects. These physiological studies will be considered first. A discussion of the limited behavioral data on animal restraint will follow.

Restraint has found wide application in animal experimentation as a "stress producer". Two methods are generally employed in restricting animal movement. The first makes use of a wire restraining jacket which firmly encloses the body but does not restrict breathing. The limbs may be left free or taped. The second method, used with larger animals, involves taping the limbs to supports and placing the head in a vice, without interfering with breathing.

One line of investigation employing these procedures is concerned with whether restraint can produce such physiological symptoms as ulcers. Menguy (1960) found that 20 hours of restraint stress resulted consistently in hemorrhagic erosions of the gastric mucosa of the rat. Brodie et al. (1960) also produced the same effects in small laboratory animals after 24 hours of restraint. However, they found this interval too short to produce ulceration in rabbits or monkeys. Upon measuring changes in gastric secretion during restraint, it was concluded that the important factor in producing ulceration is increased acid concentration (Brodie et al., 1962). Such procedures as hypophysectomy and adrenalectomy have failed to prevent ulcer formation during restraint, whereas vagectomy provides considerable protection (Menguy, 1960).

A second line of investigation employing restraint as a stress variable has been concerned with examination of the factors involved in hypothermia. In general, restraint combined with cold temperatures has been found to cause a significant decrease in the body temperature of animals, as opposed to cold alone (Bartlett *et al.*, 1953). Furthermore, animals higher on the phylogenetic scale are found to be less susceptible to restraint-produced hypothermia (Bartlett, Helmendach, and Inman, 1954; Bartlett *et al.*; 1956). Restriction of movement *per se* does not appear to be the cause of hypothermia; indeed, animals tend to struggle a great deal under this dual stress (Bartlett, Bohr, Foster, Miller, and Helmendach, 1954; Bartlett, 1959). The phenomenon is believed to be emotional in nature (Bartlett *et al.*, 1953; Bartlett, Bohr, Helmendach, Foster, and Miller, 1954). Bartlett (1956) found support for this hypothesis in the fact that when animals are adapted to the restraint-cold situation they show significantly decreased susceptibility to hypothermia. Measurements taken during the stress interval reveal significant physiological changes e.g. leucopenia in rats (Bartlett and Register, 1953; Register and Bartlett, 1955; Lavenda *et al.*, 1956). Furthermore, the effects of *heat* and restraint upon small laboratory animals are even greater than those of cold and restraint. Death occurs rapidly as a result of increased body temperatures (Frankel, 1959; Megel *et al.*, 1961).

Finally, investigations have been carried out regarding the effects of restraint upon the "blood picture" of Rhesus monkeys. Marked hyperglycemia and granulocytosis were found (Poirier *et al.*, 1955). Furthermore, bilateral lesions of the temporal lobe involving emotional centres e.g. hippocampus, and amygdala, resulted in a marked reduction of the hyperglycemic effects of restraint (Poirier *et al.*, 1956). It was concluded that these blood changes were a result of the animal's emotional response to immobilization.

The behavioral effects of restraint in animals will now be considered.

An unusual phenomenon in which immobilization appears to be a factor is that of "animal hypnosis" or "death feigning" which has been of cursory interest since the work of Kircher in 1646. Mowrer (1932) as well as Gilman and Marcuse (1949) have published excellent reviews of the literature regarding the phenomenon. It appears that animals can be put into a trance-like state by diverse methods, all of which involve some degree of movement restraint. A major role is ascribed to fear in producing the effect (Gilman et al., 1950). Unfortunately, the major concern of all of these studies has been merely in producing the effect by various procedures. Very little has been done in an attempt to determine the causative factors.

Another area of behavioral investigation has been concerned with activity changes after physically-enforced inaction. When the movement of rats was restricted for 6 hours during the period of greatest activity in their daily cycle, significant diminution of activity was found immediately following restraint (Siegel and Alexander, 1948). On the other hand, Levy (1944) found that restriction of movement led to the development of tics, stereotyped movements, and hyperactivity. This difference in results is likely due to the fact that Levy's observations were made primarily in situations where the animal's movement frustration is never alleviated e.g. in zoo cages.

Very little has been done regarding the influence of restraint upon animal perception. Previously, Riesen (1961) had observed various perceptual deficits in mammals reared under conditions of visual deprivation. Recently he has demonstrated similar deficits in kittens and primates that were merely restrained in holders. Although they were reared in a normal visual environment "they were not permitted to move freely during such visual exposure".

This review of the literature on animal restraint concludes with two studies on the effects of early environment upon the problem-solving ability of mature rats (Hymovitch, 1952; Forgays and Forgays, 1952). In order to determine the significance of muscular exercise and visual experience in problem-solving, the performance of a group of animals reared in a "free environment" was compared with that of two "restricted" groups. The first restricted group was reared in activity wheels which permitted increased physical experience while restricting visual experience. The second group lived in stove pipe cages which restricted total experience. At maturity, the "free environment" group was superior to the "restricted" groups in problem-solving ability. There was no difference in the performance of the two "restricted" groups. Since these latter groups did not differ in problem-solving ability, Hymovitch (1952) eliminated the restricted muscular exercise of the "stove pipe" group as a factor in their poor performance as compared to the "free environment" group. The availability of visual experience was considered to be the important variable in performance. However, the stove pipe cages were sufficiently large to permit a fair degree of movement. Consequently before muscular exercise can be eliminated as a factor in problem-solving ability, it is essential to compare the performance of a fourth group of animals whose movements are severely restricted in early life. This remains to be done.

Human Studies-Physiological

The available literature on the effects of immobilization upon human beings can, for purposes of discussion, be subdivided into physiological and behavioral studies. The former will be dealt with first.

Most of the early literature regarding physiological changes due to restricted movement is comprised of subjective reports based on observations of the harmful effects of complete and prolonged bed rest as opposed to early ambulation, in recovery from numerous types of illness (Powers, 1944; Norman, 1945; Krusen, 1947; Asher, 1947; Whedon, 1951; MacKinnon, 1955; Benton and Kriete, 1956; Peszczynski, 1957). Observations are primarily in terms of the increased speed of recovery with early ambulation. Among the many evil effects attributed to prolonged bed rest are pulmonary embolism, hypostatic pneumonia, and decubitus ulcers (Deitrick, 1948).

The experimental studies resulting from observations of the harmful effects of bed rest were controlled attempts to determine the physiological effects of restricted movement unconfounded by the factors of illness and disease. Procedures generally involved three phases: pre-experimental standardization periods during which healthy young men were trained to a certain criterion of physical fitness; varying intervals of complete bed rest, with or without physically-imposed restraint; and post-experimental retraining periods.

One of the earliest studies regarding the physiological effects of prolonged bed rest was carried out by Cuthbertson (1929). Having observed slight changes in mineral metabolism during orthopedic treatment, he attempted to obtain quantitative measurements of these changes. Following a pre-test interval during which nitrogenous equilibrium was established, mineral metabolism was measured during eleven days of complete bed rest. The findings included definite losses of nitrogen, phosphorous, sulphur, and in lesser degree, calcium. These effects were attributed to non-use of the muscles and bones.

A second study concerned with measurement of mineral changes during bed rest was carried out by Deitrick et al. (1948). They immobilized men for six or seven weeks in bi-valved plaster casts extending from the umbilicus to the toes. During immobilization they found nitrogen losses of 29.8 to 83.6 grams, calcium losses of 9.0 to 23.9 grams, and smaller losses of phosphorus, sodium and potassium. In addition, deterioration was found in the mechanisms essential for adequate circulation of the blood in an erect position as evidenced by the increased tendency to faint on "tilt-table" tests. Recovery of the various functions required from three to four weeks. Whedon et al. (1949) found a significant decrease in the magnitude of these effects when an oscillating bed replaced the fixed bed of the earlier study (Deitrick et al., 1948).

Similar methodology was employed by Taylor et al. (1945; 1949) in order to measure cardiovascular functions during immobilization. After three weeks of bed rest there was an average loss in blood volume of 9.3 per cent, due almost entirely to contraction of plasma volume. A 17 per cent decrease in heart volume, and an 8 per cent decrease in the transverse diameter of the heart were also observed. In addition, bed rest caused a marked deterioration in the cardiovascular response as measured by pulse rate and blood pressure changes produced by tilting to 68 degrees on a "tilt-table". Recovery of function was found to be roughly proportional to the extent of deterioration.

Finally, White et al. (1951) investigated the effects of bed rest and age upon plasma fat particles, finding a significantly greater increase in chylomicrons with bed rest than with age.

The above studies report gross physiological effects from prolonged bed rest even without imposing severe physical methods of restraint. It is unfortunate however, that in no case were any behavioral measurements taken during the experimental period.

Human Studies-Behavioral

Data regarding the behavioral effects of immobilization of human beings comes from many diverse sources.

Some observations made in the Arctic are relevant (Page, 1959). Page reports on an hypnotic state which may occur after a seal-hunting Eskimo has been semi-encased in his kayak for hours, under conditions of a clear sky and a motionless sea. This trance may be due, in part, to the fact that the Eskimo remains almost completely immobile during this time. However, it is impossible in this situation to separate the influence of restricted movement from that of other relevant variables e.g. reduced visual and auditory stimulation.

A second source of information on the behavioral effects of immobilization is provided by studies of the centuries old customs of swaddling and cradling infants. These methods are still employed in certain cultures at the present time.

The research of Dennis in this area was a direct result of Watson's presentation in 1917 of a theory of native emotions. Watson claimed that the "rage" reaction was specific to a restraint stimulus i.e. that of holding an infant's head, arms, or legs. Dennis (1940) postulated that Watson's rage reaction was the result of *intense* stimulation, not of restricted movement *per se*. Dennis' primary source of evidence on infant restraint was the cradling practices of Hopi Indians (Dennis and Dennis, 1940; Dennis and Dennis, 1940). He found that, contrary to Watson's predictions, infants were extremely placid and well-behaved while on the cradle board.

In addition to observations of infant reactions to restraint, Dennis explored the general area of motor development. He found an almost total lack of retardation in the motor development of cradled infants e.g. a comparison of groups of Hopi employing the cradle board with those not doing so yielded an average difference of only one or two days in onset of walking. The main drawback in Dennis' work was the difficulty of controlling conditions adequately. Dennis was forced to rely primarily on verbal accounts from the infants' mothers. Unfortunately, no observations were made regarding intellectual functioning.

Greenacre (1944) reviewed the literature on various swaddling and cradling customs. Of particular relevance is his review of a study by Danziger and Frankl regarding the swaddling of Albanian infants. The findings included general retardation in the motor development of restrained infants as compared to non-restrained controls. These investigators, however, claimed that there was no evidence of lasting intellectual impairment. It is very likely that this statement is merely a subjective judgement on their part, because no factual evidence is reported in support of the statement.

A definite contradiction to the above statement regarding intellectual functioning following restraint is available from another source. Hill and Robinson (1929) present an account of a child whose hands and feet were tied to his bed for the major part of his life to age six, in order to prevent his continually scratching and irritating his skin. Mental retardation was noted in the child at the age of two years but was not associated with the movement restraint. The retardation was of much greater severity at age six. Hill and Robinson strongly suggest that the long period of severe restraint may have caused the mental retardation. Although the other members of the family appeared to be of normal intelligence, there is, however, a record of mental illness in the child's ancestry, and the possibility exists, therefore, that the child's retardation was hereditary. The difficulty with clinical cases of this type obviously lies in being unable to separate the effects of restraint from the influence of various other relevant factors.

Some observations made in the hospital setting have relevance to the behavioural effects of immobilization. There have been many reports on the development of psychotic-like symptoms i.e. disorientation, confusion, hallucinations, and delusions, in polio patients who are confined in tank-like respirators, (Mendelson and Foley, 1956; Mendelson, Solomon, and Lindemann, 1958; Leiderman et al., 1958). However, it is necessary to stress the possible influence of other variables in addition to restriction of movement in producing these effects e.g. restricted visual stimulation, and the use of patients rather than healthy subjects.

Further information from the hospital setting is provided by Erickson (1949). He observed that for many mental patients restraint appears to be associated with comfort and security. For other patients, restraint appears to be valuable in averting episodes of violent and unmanageable behaviour by providing a force against which the patient can struggle. Erickson postulates that this struggling provides a sense of personal achievement for the patient. In keeping with this psychoanalytic interpretation of the effects of restraint is Burlingham's (1953) attempt to link muscular movement to general discharge of libidinal energy.

Further evidence for the importance of kinesthetic activity in behavioral functioning comes from the so-called "sensory deprivation" studies (Freedman and Greenblatt, 1959) in which subjects are isolated under conditions of reduced visual and auditory stimulation. Freedman and Greenblatt (1959), in a survey of this literature, state that hallucinations are most frequent in those isolation experiments in which motility is restricted.

For example, Courtney, Davis, and Solomon (1961) found more visual distortion in subjects making small finger movements during perceptual deprivation than in those required to make larger body movements. Fiske (1961) states that severe restriction of kinesthetic stimulation alone "may disrupt normal functioning as much as a similar degree of restriction in the visual or auditory sphere". However, caution must be exerted in interpreting these results as being due to reduced kinesthetic stimulation because this variable cannot be separated in this situation from the other relevant variables i.e. the reduced visual and auditory cues.

Very few attempts have been made to study the behavioral effects where decreased motility is the only experimental variable. Goldman (1953) found a longer duration of the autokinetic effect in subjects who were immobilized in a specially designed chair for ten minutes prior to stimulus presentation, as compared to controls who were required to perform specified movements during that interval. However, the immobilization period was very short and no further behavioral measurements were taken. Another study involved having subjects lie in bed for eight hours without making excessive movements (Freedman and Greenblatt, 1959). No changes were found on eight perceptual tests. Perhaps this was due to the fact that kinesthesis was not sufficiently restricted. Recently, Freedman and Pfaff (1960) have reported that body movements are important in determining the accuracy of dichotic time differences in auditory discriminations. Furthermore, bodily movements have been shown to play a crucial role in compensating for errors induced by optically-produced disarrangements of the visual field (Held, 1961).

Only two of these earlier studies on reduced motility have some bearing upon intellectual processes. Beigel (1952) observed differences in thought processes when subjects were required to interpret material or make decisions in a prone as compared to a standing position. The reclining position produced thoughts of a variable, indefinite nature, whereas the standing position was found to be more conducive to decision making and to the expression of emotional involvement. In the second study, Krus _et al_. (1953) presented pictures of objects suggesting movement, to their subjects. Significantly more "movement" responses were obtained from subjects required to stand erect and motionless as compared to those subjects required to press against a "push board" for 20 seconds prior to stimulus presentation.

From a review of the above studies two facts become obvious. First, immobilization, even without physically-imposed restraint, produces gross physiological and behavioral changes. Second, there is a dearth of quantitative evidence on the effects upon intellectual processes of controlled restraint procedures, where other variables are eliminated in so far as possible.

To date, only one study has been carried out in an attempt to provide objective information regarding intellectual and perceptual processes under conditions of reduced kinesthetic stimulation. This study was recently completed at the University of Manitoba (Zubek *et al.*, 1963). In this experiment, a group of 40 male students were completely immobilized for periods of up to 24 hours. There was no interruption of this condition for such needs as feeding, the subject being fed by an experimenter who was present at all times. No other restrictions were imposed upon the subject. He could listen to the radio or communicate with the experimenter whenever he wished. Various pictures were placed above him and were changed from time to time. The lights were put out when he wished to sleep.

Before and immediately after immobilization, a battery of 15 tests was administered. When the 40 experimental subjects were compared with 40 ambulatory and 40 recumbent control subjects a significant impairment was found on four of the eight perceptual-motor tests i.e. dexterity, reversible figures, color discrimination, and kinesthetic acuity. However, no impairment was found on seven intellectual tests measuring such abilities as numerical reasoning, verbal reasoning and space relations. There are two possible explanations as to why no intellectual impairment was found. First, no testing was done <u>during</u> the immobilization period. Therefore, it is quite possible that any temporary effects may have dissipated while the subject was being unstrapped and prepared for testing. Second, all subjects experienced some degree of physical pain which may have served to keep the brain in a reasonably alert state, counteracting some of the effects of reduced kinesthetic stimulation upon intellectual performance. Definite evidence as to the importance of the pain factor is found in the fact that only eight out of 40 subjects were able to endure 24 hours of immobilization.

The present study employed similar procedures of movement restriction. However, by employing less severe conditions of restraint, and by introducing relief periods, it was possible to extend the immobilization period to seven days. This seven day interval is superior to the 24 hour period of the first experiment in several ways. First, the longer period permits daily appraisal of intellectual functioning, thus allowing for the study of any long term or cumulative effects. Second, it eliminates the factor of pain. Furthermore, this week-long period of immobilization also permits a comparison of results with those obtained in the seven day experiments on visual and auditory deprivation (Zubek *et al.*, 1960; 1962).

CHAPTER II

EXPERIMENTAL METHOD

I. THE PROBLEM

The preceeding chapter outlined the research which has been done on the effects of immobilization, stressing the almost total lack of quantitative data on intellectual functioning under this condition. The purpose of this study is to determine the effects of a seven day period of immobilization upon performance on a battery of 12 intellectual tests.

II. APPARATUS

Immobilization Box

A schematic view of the immobilization box is shown in Figure 1. The box measures 7 ft. in length, 28 inches in width, and 18 inches in height. It is lined with a thick layer of foam rubber cut in the shape of a human figure. Adjustable straps are placed in the box, two for immobilizing each limb, and two, the body. In addition to the straps, S's arms are placed in cardboard cylinders, with an opening at the elbow allowing slight movement when necessary to alleviate any stiffness at the elbow. At one end of the box is located

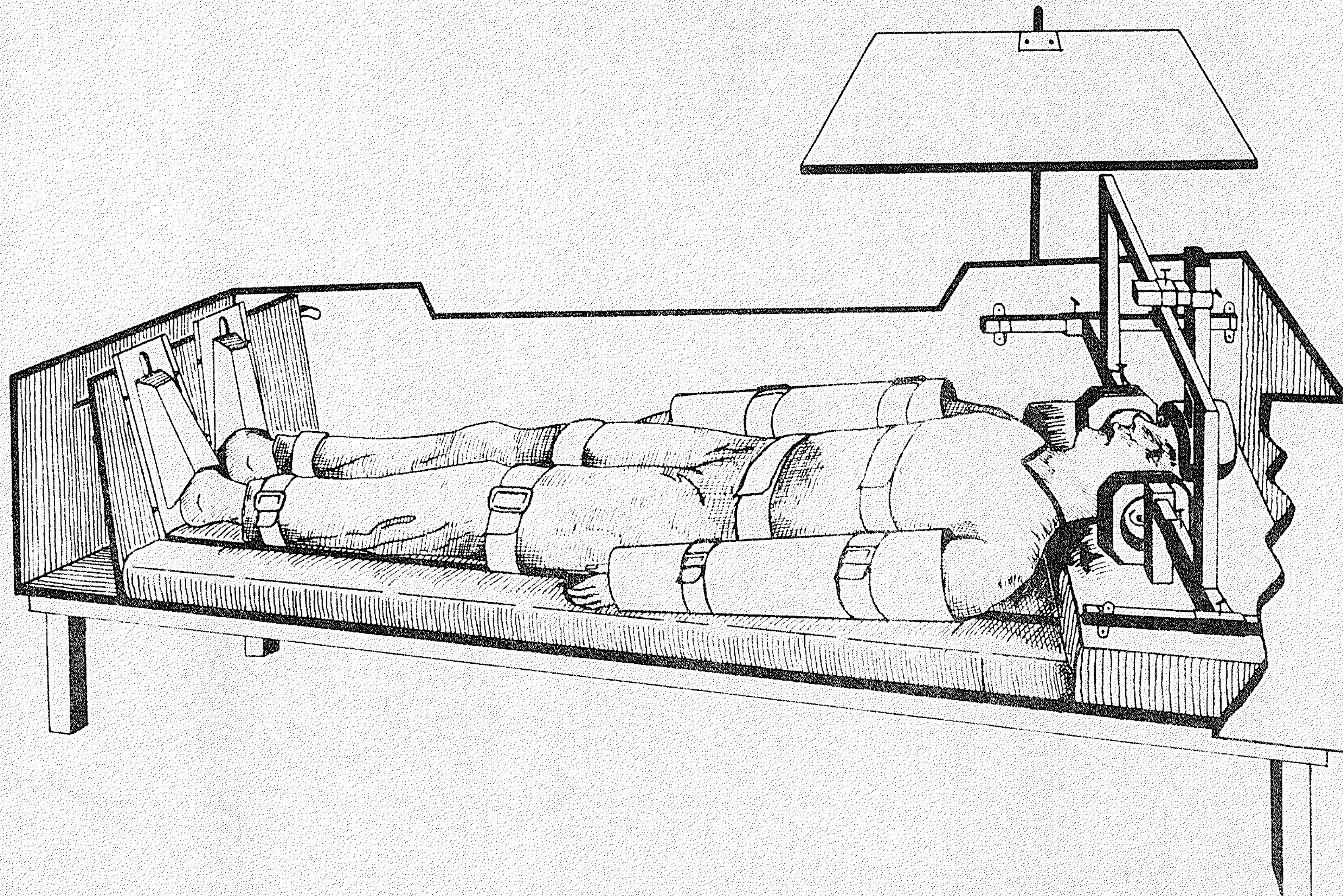

FIGURE 1. IMMOBILIZATION BOX

an adjustable, padded head-holding device, which fits snuggly against the forehead and sides of the head. No padding is placed over the ear section so as not to interfere with S's hearing. At the other end of the box, two V-shaped restraining devices serve to immobilize the feet.

A cardboard frame to which pictures can be attached is placed some distance above the head-holder.

The room in which the box is placed is adjacent to the main laboratory. It is 15' x 10' x 9' in dimension, khaki in color, and illuminated by a 40 watt bulb.

All tests are carried out in the main laboratory under constant illumination.

Tests

A battery of 12 tests, ten of an intellectual nature, and two of a perceptual-motor nature, was constructed. There were seven equivalent forms of each battery, one for use in each of the seven testing sessions. The first battery was administered prior to immobilization, and subsequent batteries on the following six days. Tests were randomized within each battery.

The tests, with time limits where applicable, are listed below:

(1) Numerical Reasoning (4 min.) involved the solution of various numerical sequences (e.g. 2, 4, 6, 8, __, __).

(2) Number Facility (4 min.) involved performance of addition, subtraction, multiplication, and division in various orders.

(3) Verbal Reasoning (3 min.) was appraised by such problems as the following:

"______ is to borrow as rich is to ________". S was required to select from two lists of words the ones which would logically go in the blank spaces.

(4) Verbal Fluency (3 min.) S was required to write down all the words he could think of beginning with a certain letter.

(5) Space Relations (8 min.) was measured by two tests. The first test, of two-dimensional space visualization, consists of examining a certain design and then selecting the exact patterns which will fit together to make it. The second test, of three-dimensional space, consists of patterns which can be folded into figures. For each pattern, five figures are shown and S must decide which of these figures can be made from the pattern shown.

(6) Recall. S was presented with a list of 20 nonsense

syllables which he studied for three min., reading the list over as many times as possible. Then an attempt was made to reproduce these syllables.

(7) Recognition. After the attempt at reproduction, S was shown a list of 50 nonsense syllables, containing the 20 previously learned. From the list he attempted to select the 20 syllables first learned.

(8) Abstract Reasoning (4 min.) was tested by items of the type found in the abstract reasoning test of the Differential Aptitude Battery. Each problem consists of four designs or figures which make a series; S is required to determine the principle governing the series and to select from the answer figures the one which would be next or fifth in the sequence.

(9) Digit Span (Forward and Backward). The test was adapted from the Wechsler-Bellevue test of intelligence, and was administered according to its standardized procedure.

(10) Rote Learning was tested by presenting aurally a list of nine three-letter words (e.g. red, ask, tub) which S was required to learn to a criterion of two successive errorless trials. The inter-word interval was one sec.,

and the inter-trial interval, five sec.

(11) Perceptual Ability (1 min.) S was presented with a page of randomized numbers ranging from 0 to 9, and was required to cancel as many of a particular number as possible within the time limit.

(12) Dexterity (three 1 min. tests) consisting of: placing one dot in each triangle (1/8 in. high); making two check-marks in each square (3/8 in. x 3/8 in.); and tracing a line through a maze without touching the sides.

Total administration time for the daily battery of tests was approximately 45 min.

III. SUBJECTS

Ss were paid male volunteers almost exclusively from the Faculty of Arts and Science at the University of Manitoba. The sample consisted of 22 experimental Ss, the mean age of the group being 20.7 years. There were no failures. The first 22 Ss successfully endured the week of immobilization. The ambulatory control group consisted of 40 Ss, from the same category as the experimentals. The mean age of controls was 23.1 years.

IV. PROCEDURE

The following instructions were read to the experimental Ss prior to immobilization:

"This is an experiment on the effect upon intellectual processes, of lying still. There is no danger involved. Many people have been immobilized in iron lungs and in casts for long periods of time, with no injurious after-effects. We want you to lie quietly for 7 days. For this you will be paid $100.00. During the night you <u>will not</u> be strapped down, but during the day you will be immobilized from head to toe. If the condition should become unbearable, however, ask the experimenter to remove the straps so that you can move about and flex your muscles. Keep these 'relief periods' brief and relatively infrequent. Their duration and frequency will be recorded. The fewer 'relief periods' you take, the greater will be the likelihood that you will receive a bonus of $25.00. You will leave the box once a day for about an hour, to take a battery of tests. You can use this period for a <u>very brief</u> visit to the washroom. At other times a urinal will be provided. Also, you can sit up while eating. At the completion of the experiment you are not to talk about your experiences to anyone."

After the administration of the initial test battery, Ss were strapped into the immobilization box. The procedure was as follows: S was told to lie on the foam rubber with his head in the padded head-holder and his feet in the restraining holders. The legs and trunk were immobilized by means of belts fastened to the base of the box. The arms were placed in rigid but comfortable cylinders which were then fastened down by means of belts. About 1 in. of movement was allowed at each belt, and $\frac{1}{4}$ in. head movement in any direction.

The only restriction imposed upon S was that of gross bodily movement. No visual or auditory restrictions were imposed, the aim being to maintain in all other respects as normal an environment as possible.

The following conditions prevailed: S was immobilized daily at 9. a.m. During the day the lights were on in the laboratory. Above S's head pictures were placed to avoid the constant visual stimulation of a bare ceiling. S was able to listen to the radio when he so desired, and was in no way socially isolated from the experimenters. At midnight S was freed from the straps and permitted to sleep until 9 a.m. in any preferred position in the box. However, he was not allowed to sit up or stand up during the night.

The longest prescribed "free" period during the day was the testing session. S was unstrapped one-half hr. prior to daily tests to permit moderate flexion of muscles, so that muscular stiffness would not be a factor in test performance. S was allowed to leave the box only for the tests, which took place in the main laboratory at approximately 24-hr. intervals. After the tests he was permitted to go to the washroom for about five min. The only other prescribed "free" periods during the day were for meals.

The ambulatory control Ss were given the same seven intellectual batteries as were the experimental Ss. These were administered at 24-hr. intervals, after which time S was allowed to leave the laboratory and to carry on his normal daily activities. All tests were administered under the same standard conditions employed with the experimental Ss.

CHAPTER III

EXPERIMENTAL FINDINGS AND DISCUSSION OF RESULTS

I. RESULTS

The pre-immobilization scores of the 22 experimental Ss, on the battery of 12 intellectual tests, were matched with the initial scores of 22 out of 40 control Ss. From this larger sample it was possible to select 22 Ss whose "pre" scores were identical or almost identical to those of the experimentals. In a few cases, however, a close match was not possible and consequently the data from those subjects was not used. This explains why the size of the sample in Table I is not always the same for the different tests. The mean performance of the two groups of Ss during the week of immobilization, or of the control period, was then evaluated by 2-tailed t tests for correlated measures.

Figures 2 to 13 show the mean scores for both experimental and control groups prior to and at daily intervals during the week. It can be seen that on all of the tests the performance of the experimental Ss was poorer than that of the controls.

Table I shows that on three of the tests there were significant differences in performance between exper-

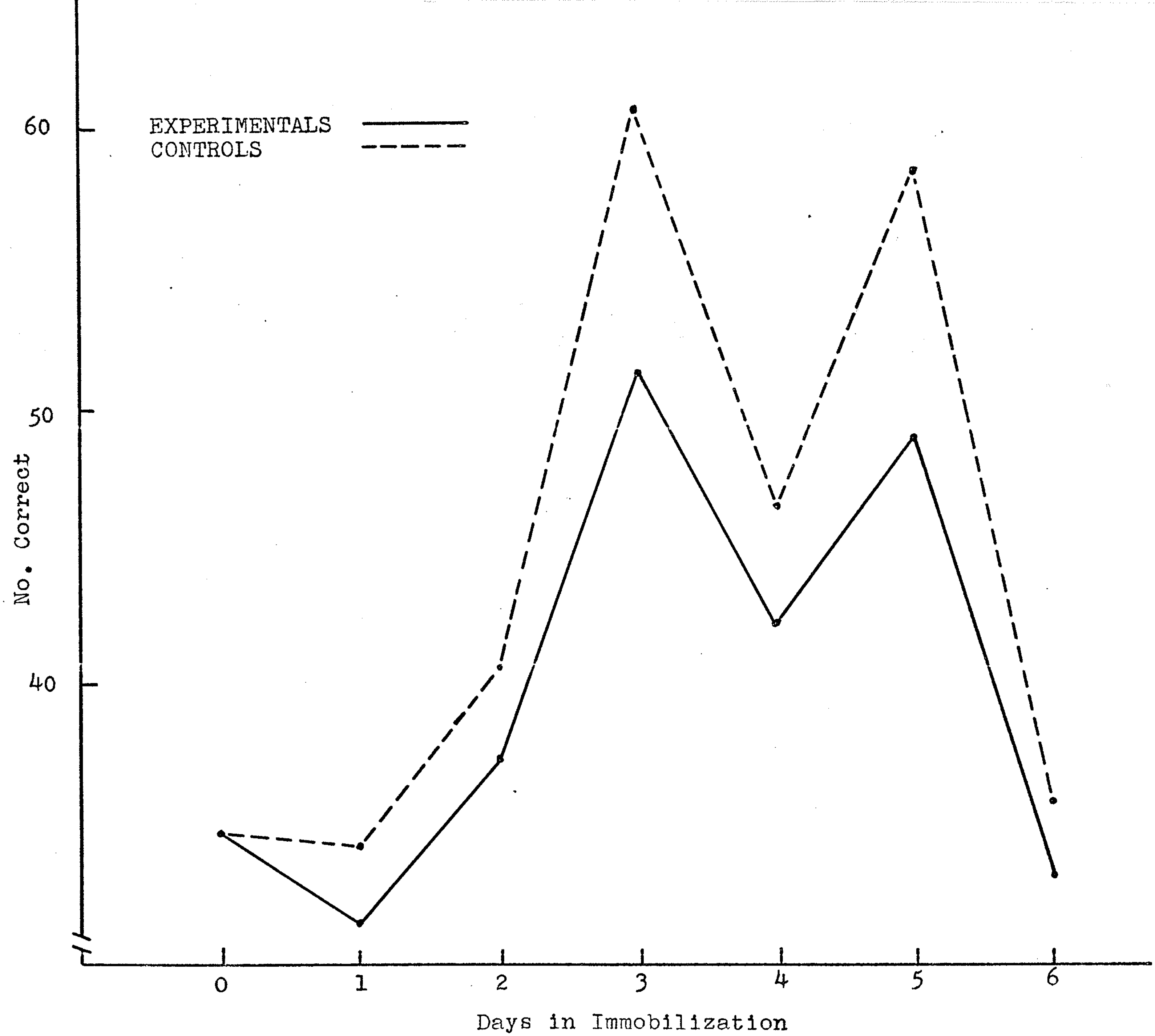

FIGURE 2. MEAN SCORES: PERCEPTUAL ABILITY

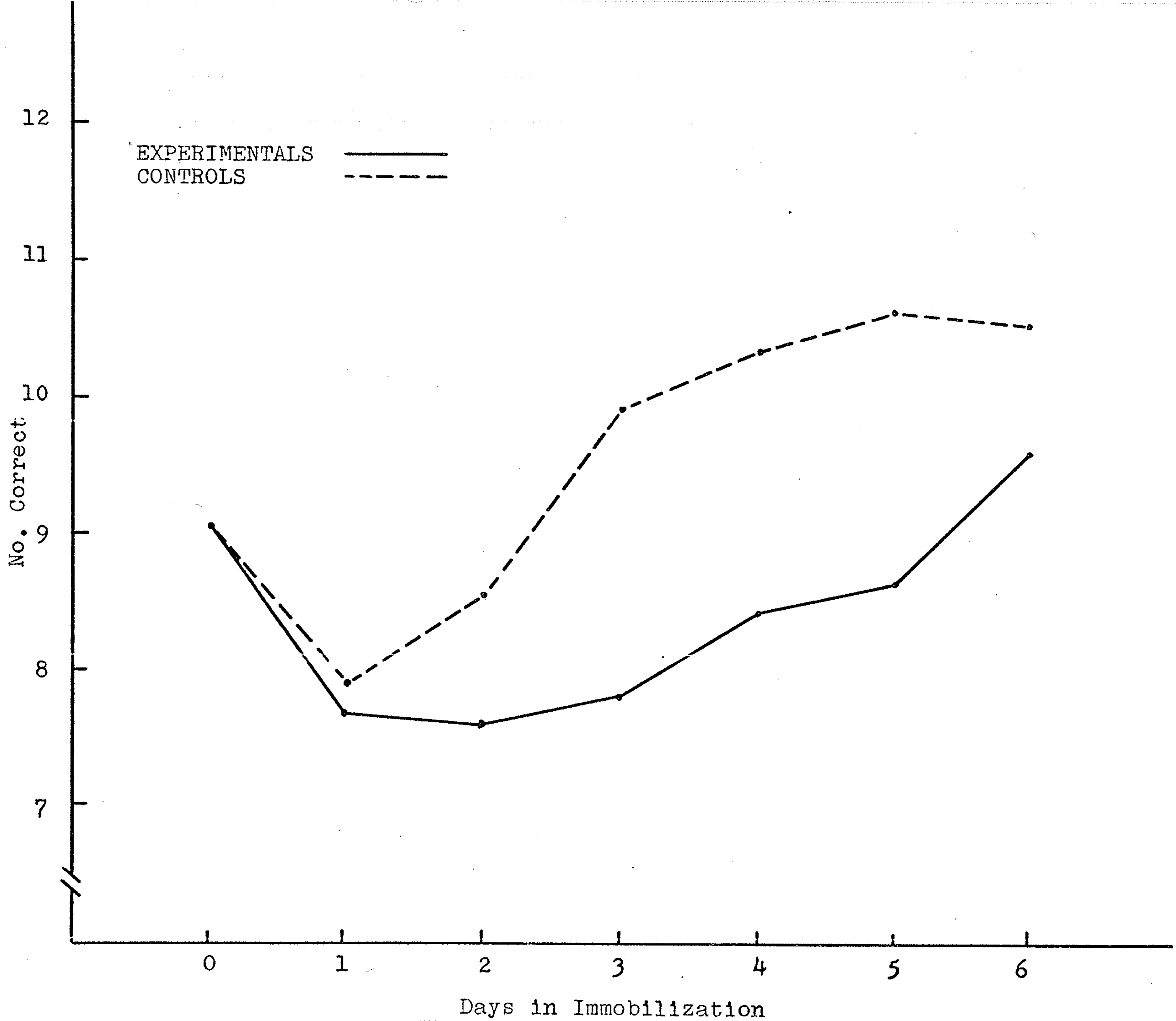

FIGURE 3. MEAN SCORES: RECALL

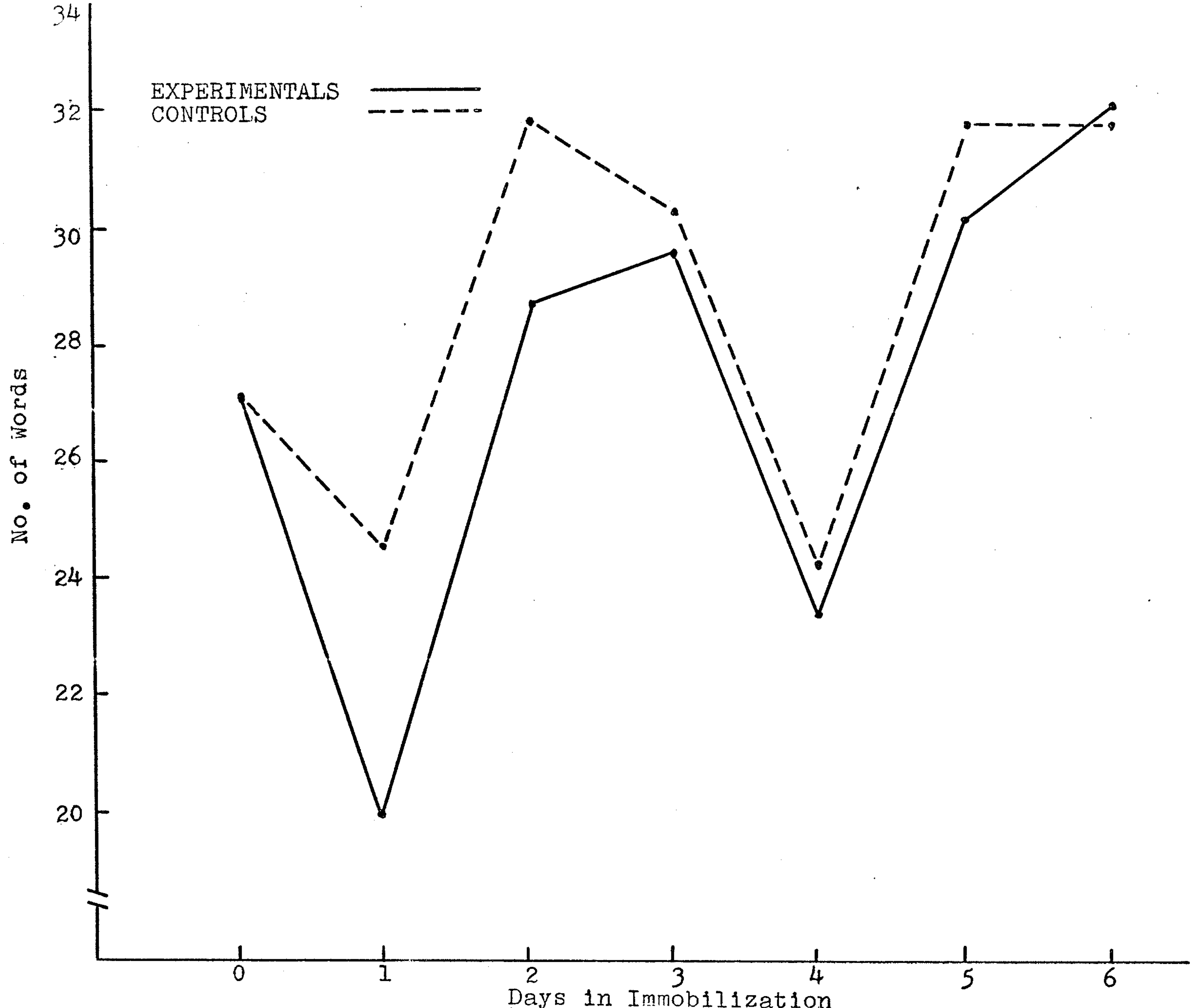

FIGURE 4. MEAN SCORES: VERBAL FLUENCY

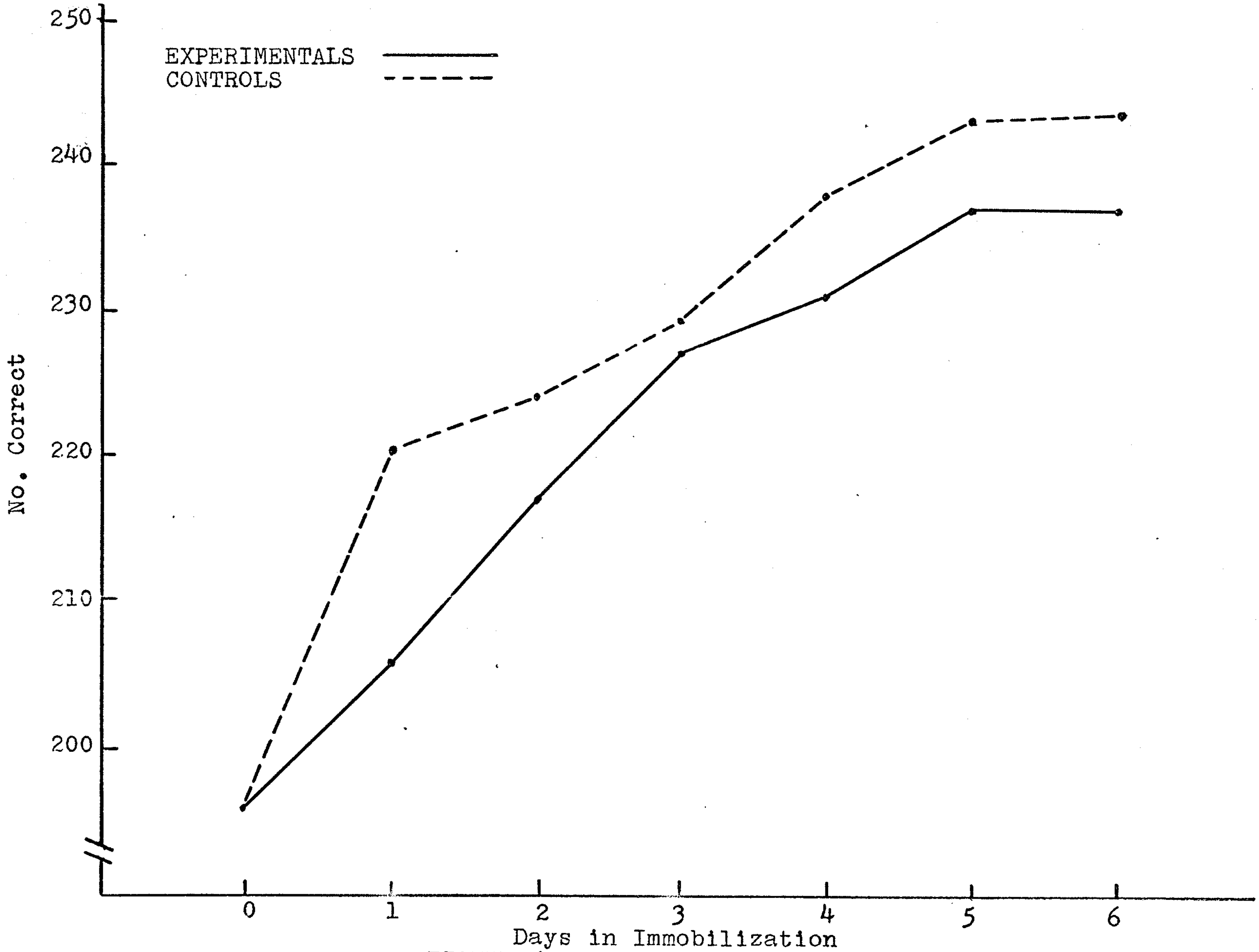

FIGURE 5. MEAN SCORES: DEXTERITY

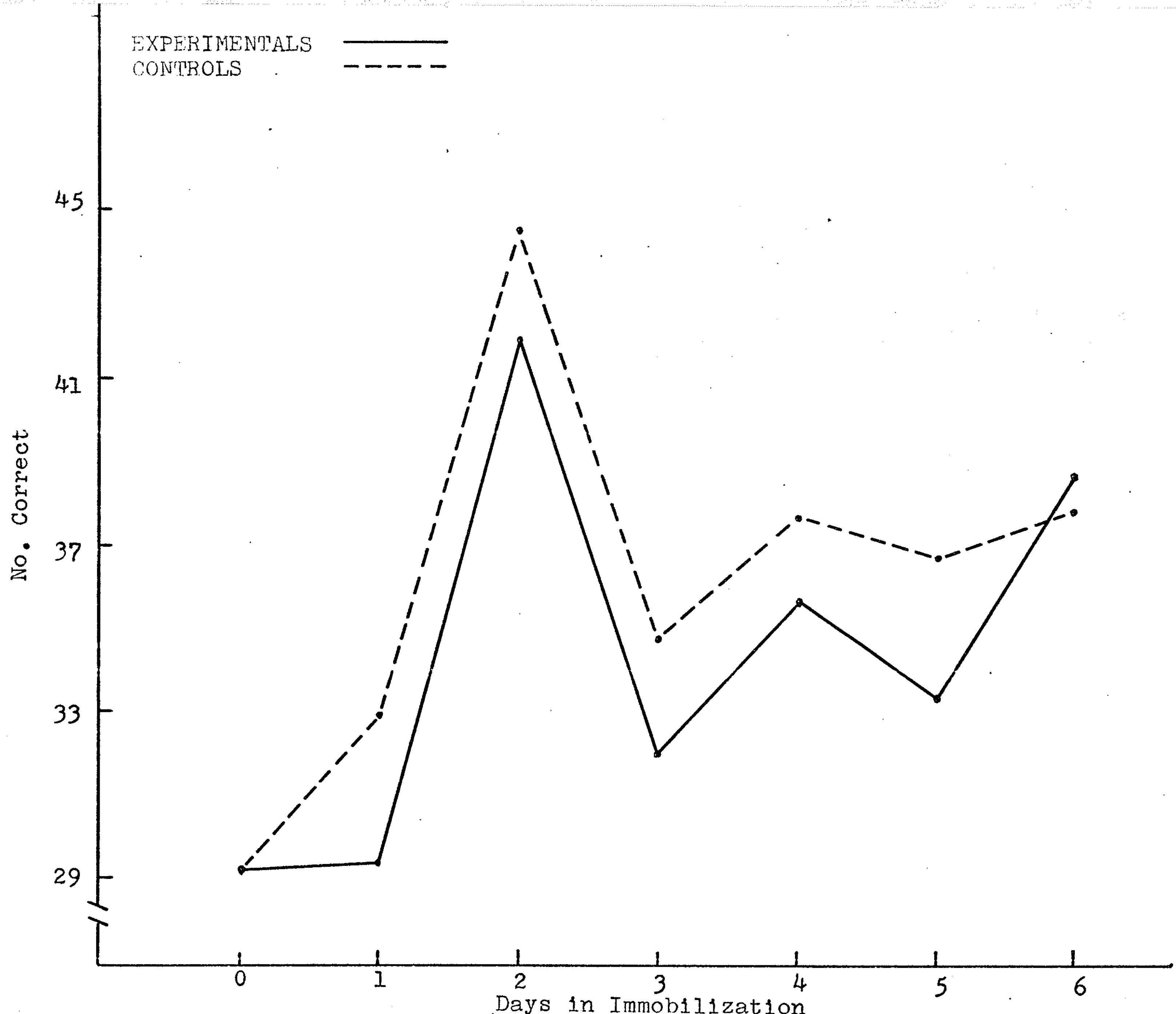

FIGURE 6. MEAN SCORES: SPACE RELATIONS

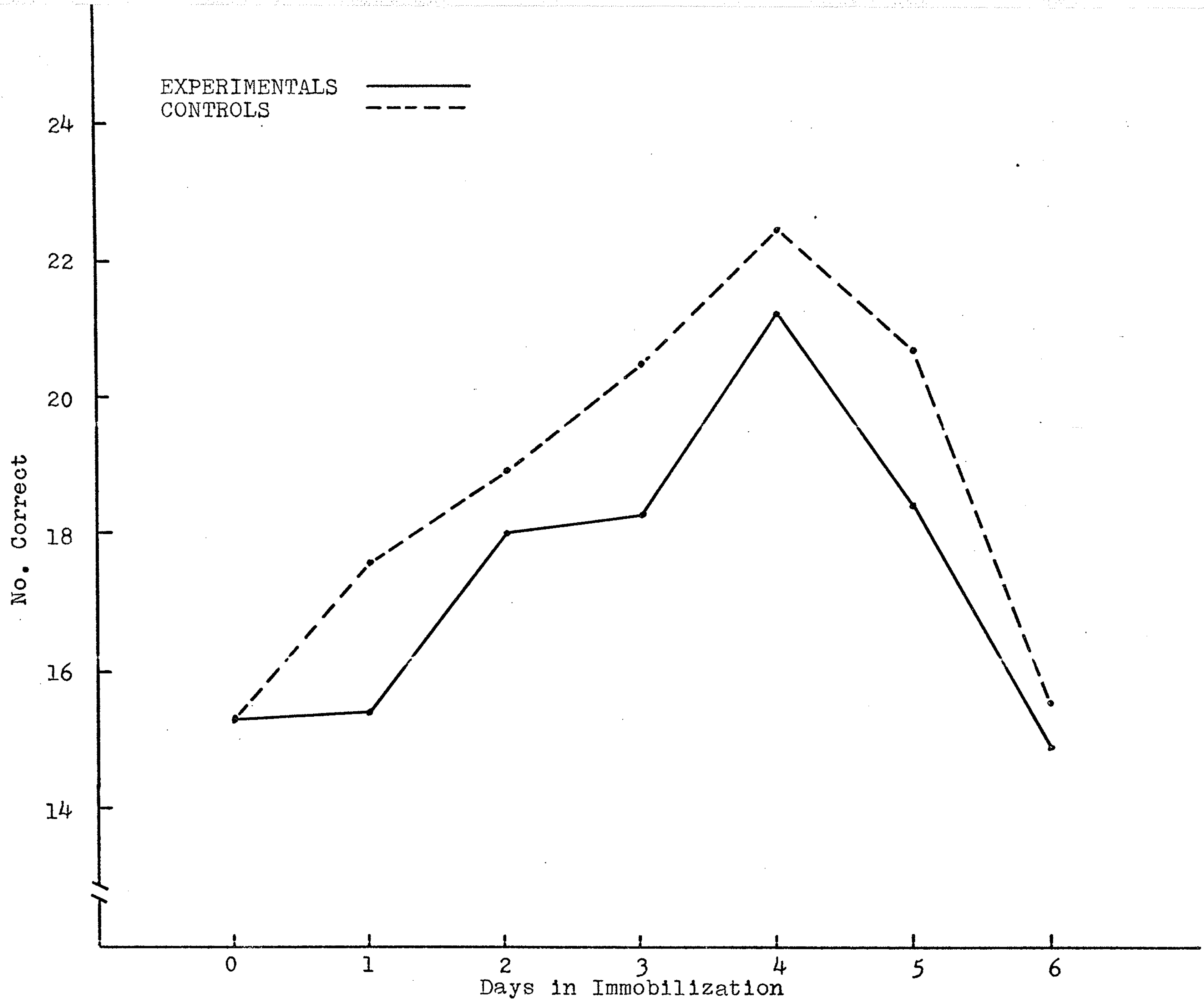

FIGURE 7. MEAN SCORES: NUMERICAL REASONING.

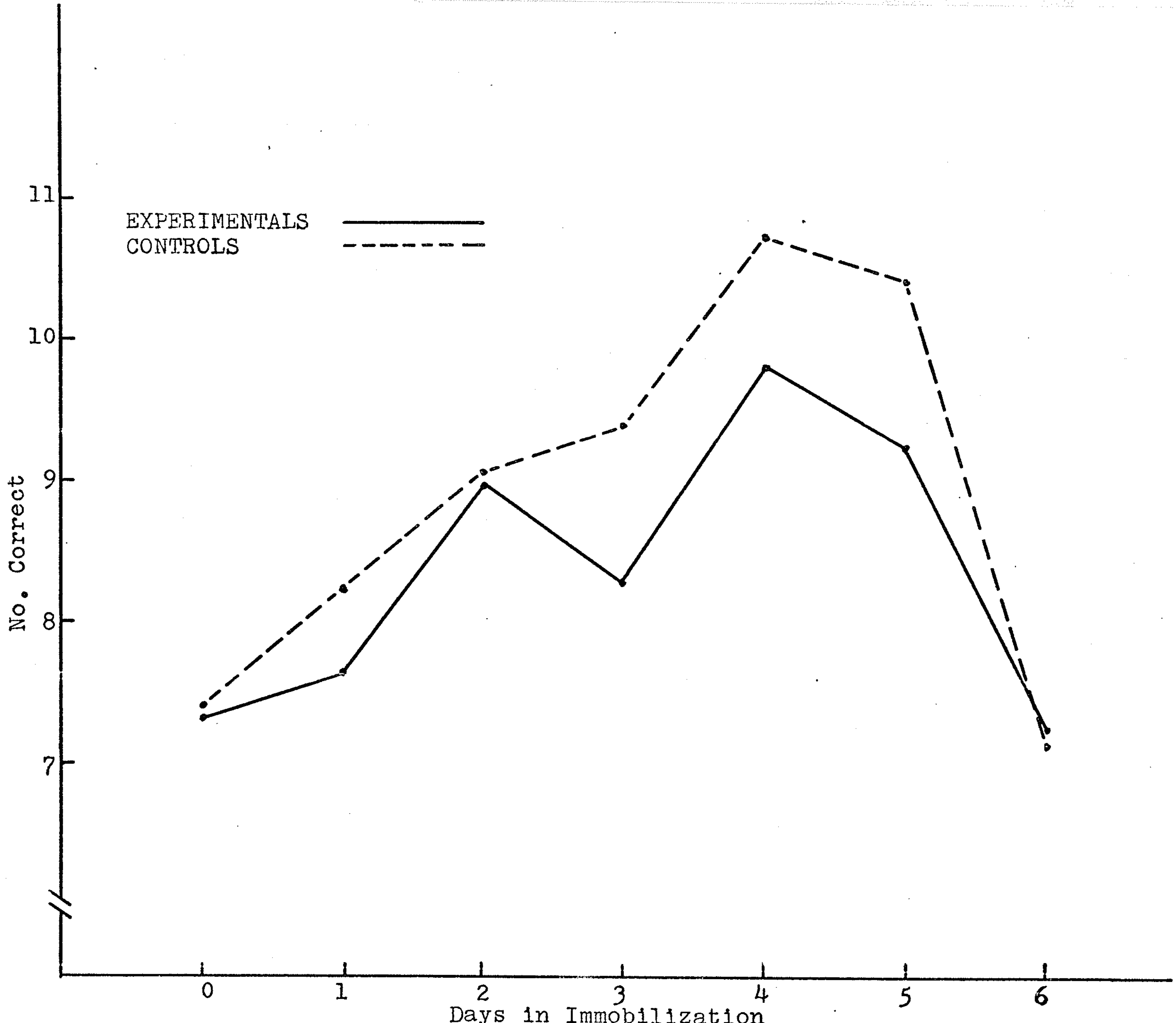

FIGURE 8. MEAN SCORES: VERBAL REASONING.

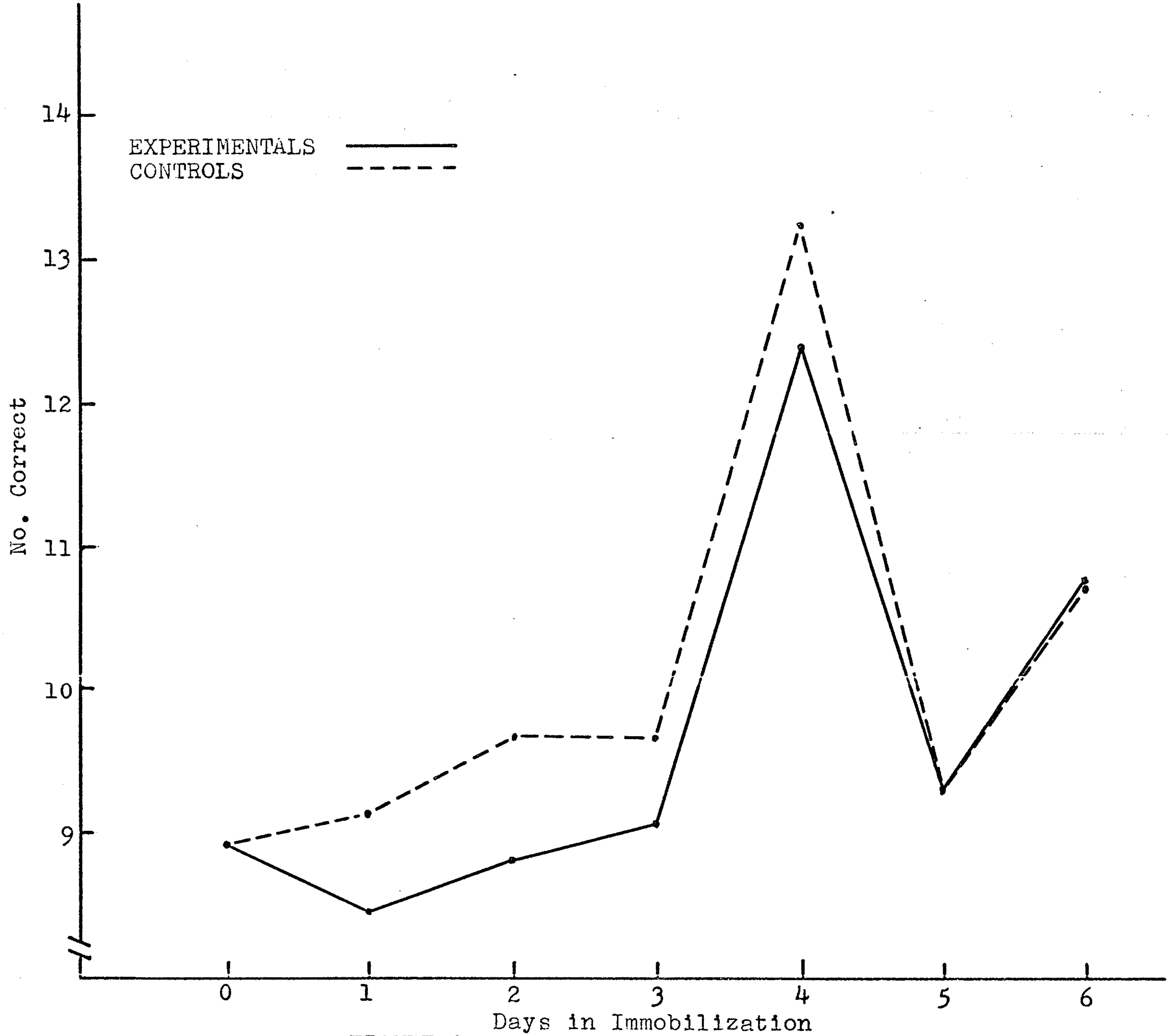

FIGURE 9. MEAN SCORES: ABSTRACT REASONING.

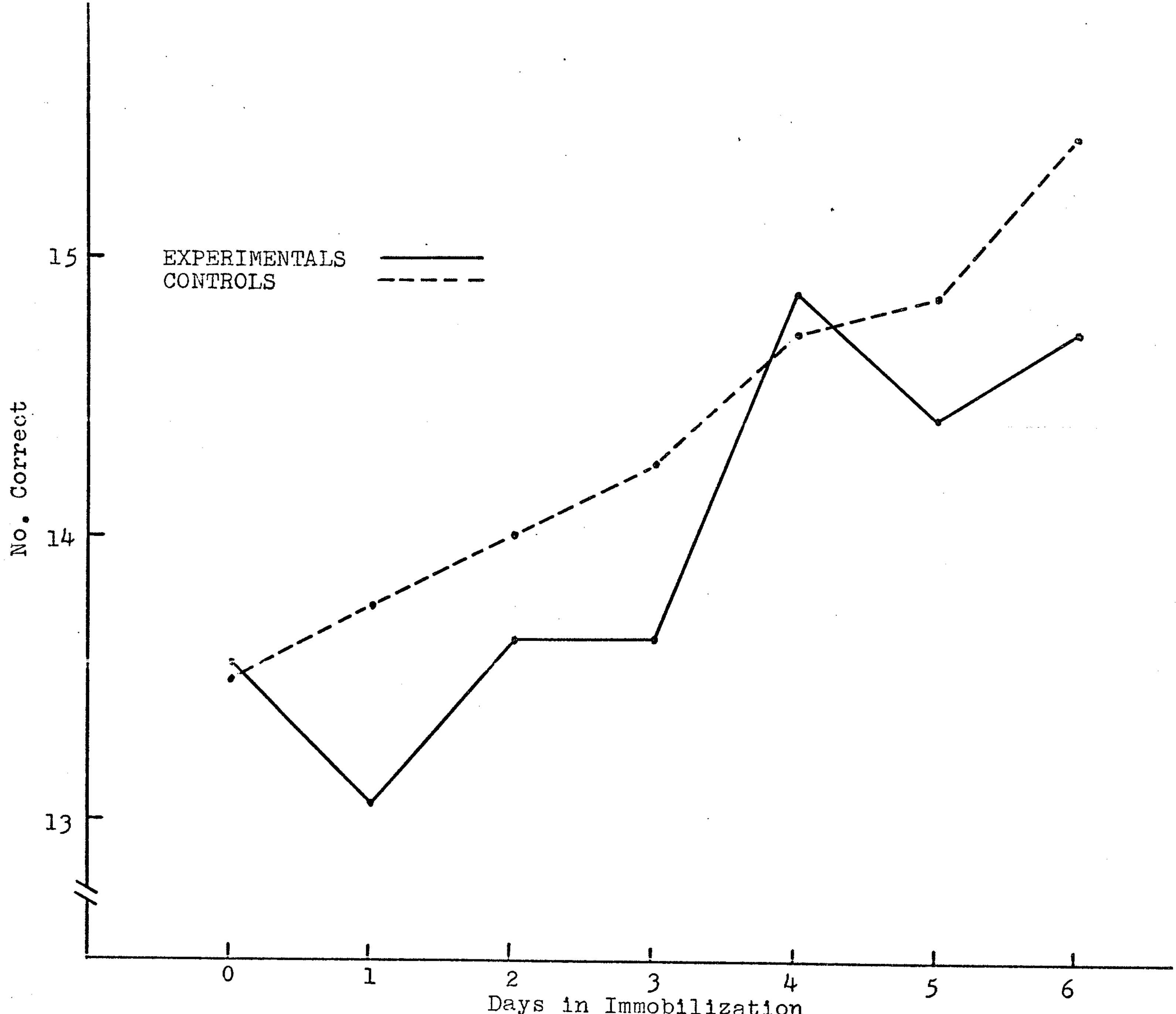

FIGURE 10. MEAN SCORES: DIGIT SPAN

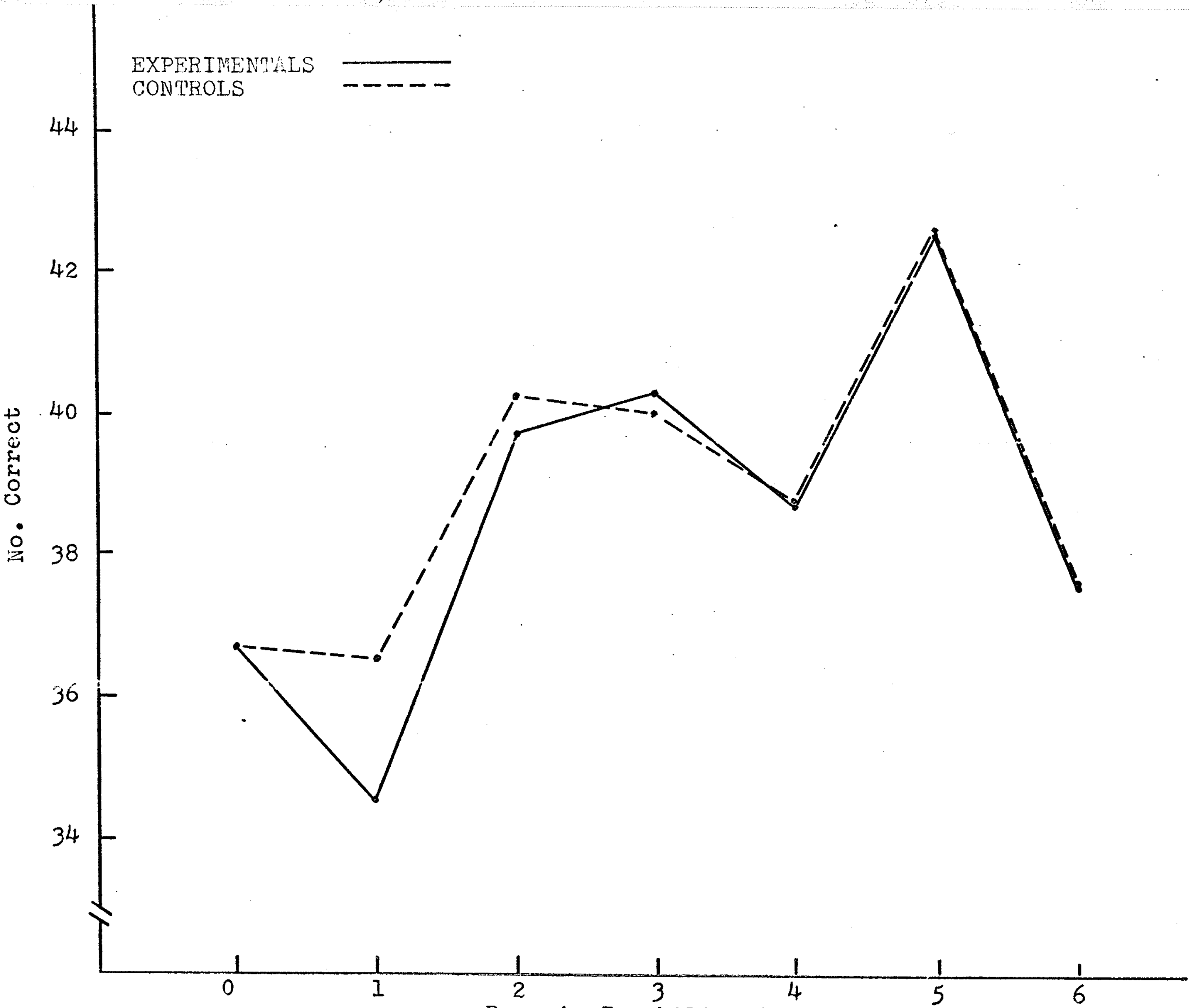

FIGURE 11. MEAN SCORES: NUMBER FACILITY

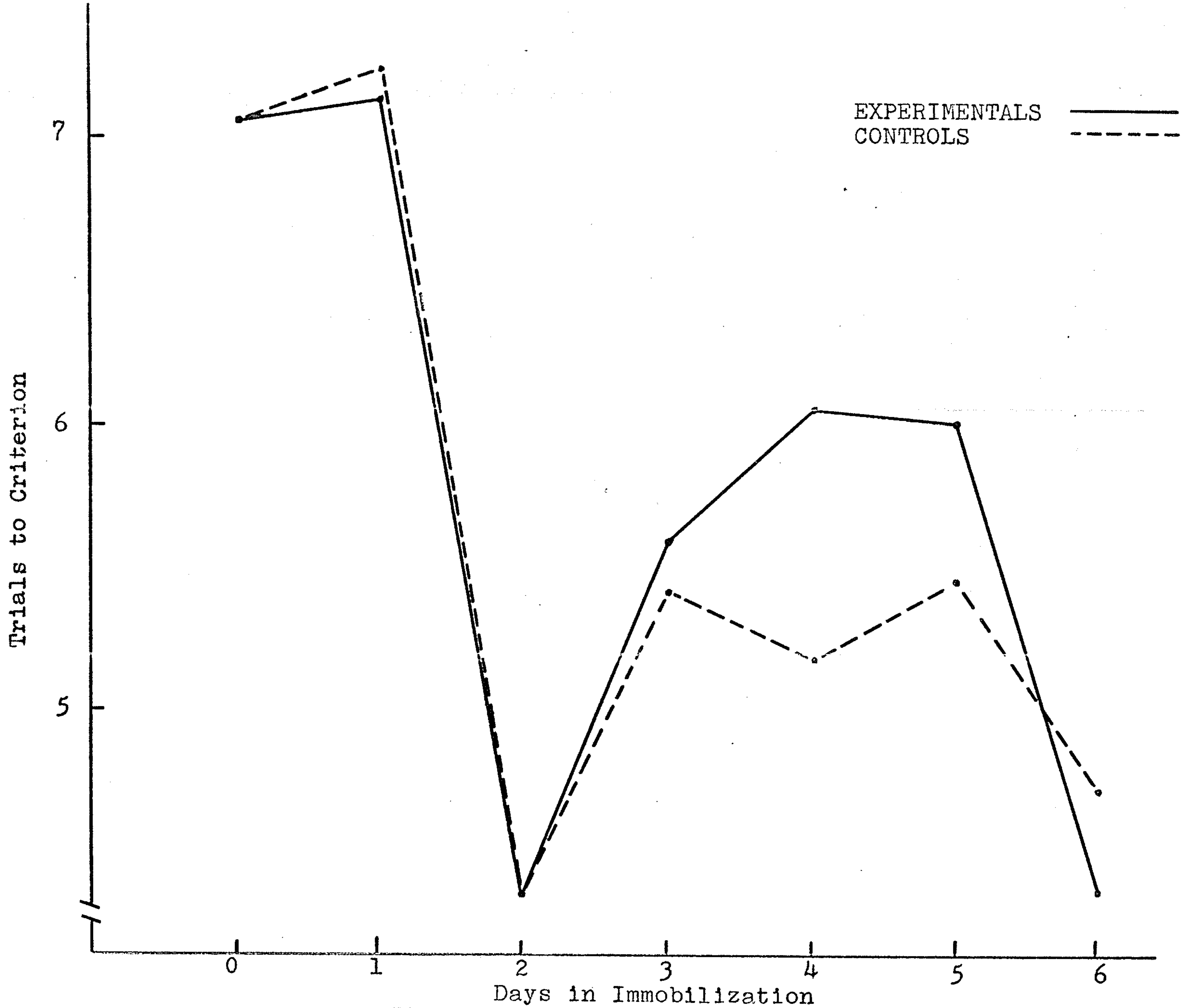

FIGURE 12. MEAN SCORES: ROTE LEARNING.

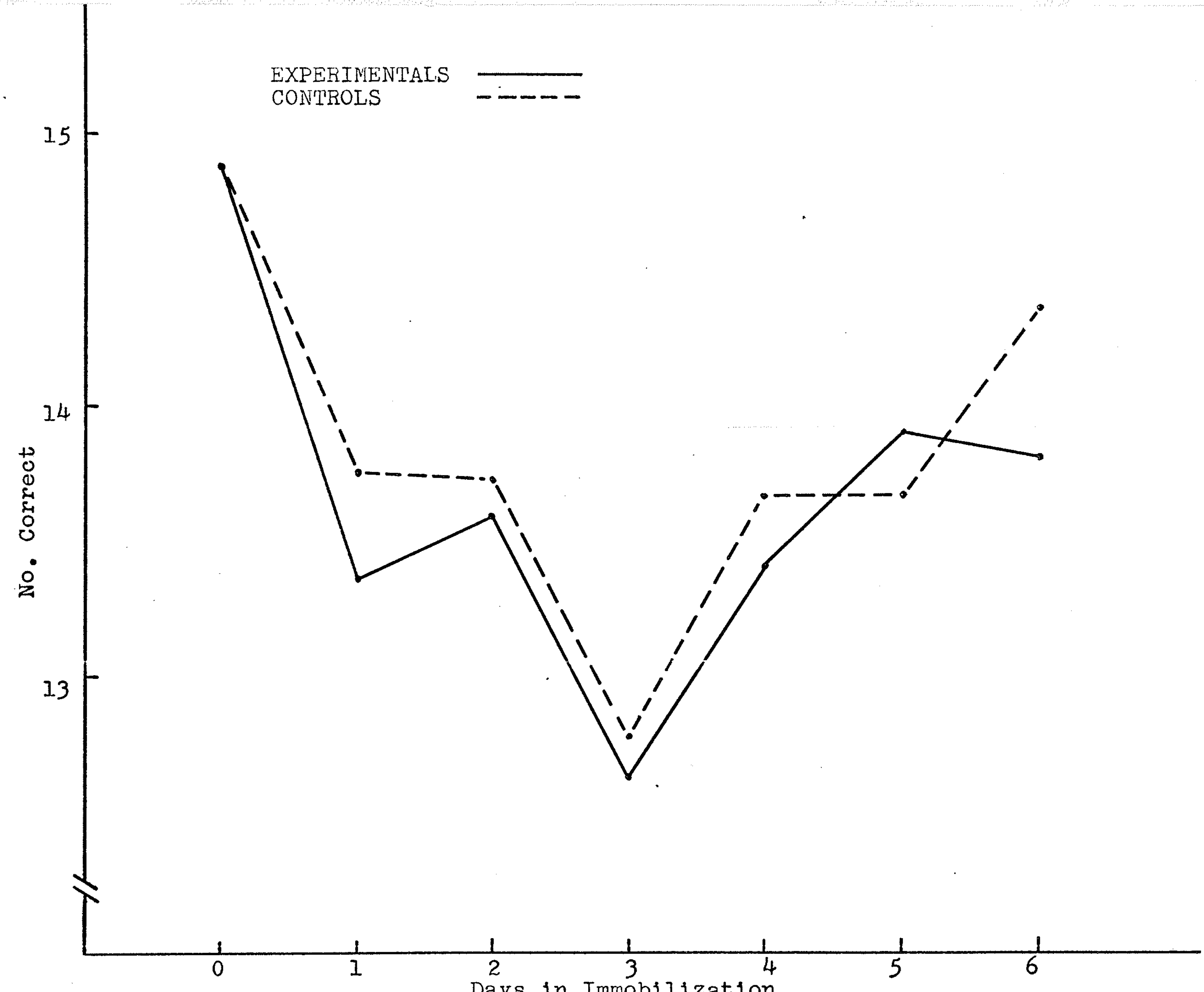

FIGURE 13. MEAN SCORES: RECOGNITION

TABLE I. Values of t and p for the Battery of 12 Intellectual Tests.

Test	n	t	p
Perceptual Ability	22	4.32	$<.001$
Recall	22	2.83	.01
Verbal Fluency	22	2.14	$.05 > p > .02$
Dexterity	21	1.97	$.10 > p > .05$
Space Relations	20	1.97	$.10 > p > .05$
Numerical Reasoning	22	1.77	$.10 > p > .05$
Verbal Reasoning	22	1.31	$> .20$
Abstract Reasoning	22	1.00	$> .30$
Digit Span	22	1.00	$> .30$
Number Facility	20	0.75	$> .40$
Rote Learning	22	0.41	$> .60$
Recognition	22	0.34	$> .70$

imental and control groups, i.e. on perceptual ability, recall, and verbal fluency. Performance differences bordered on statistical significance on another three tests, namely dexterity, space relations, and numerical reasoning. Finally, on the last six tests of the battery there were no significant differences between the two groups of subjects i.e. on verbal reasoning, abstract reasoning, digit span, number facility, rote learning, and recognition.

An examination of the 12 graphs indicates the presence of some degree of impairment as early as the first day of immobilization. Furthermore, in a number of cases there appears to be little or no relationship between degree of intellectual impairment and duration of immobilization. This is best seen in Figures 4,5, and 10. There is also evidence that on the last testing day the performance curves of the two groups of subjects converge, at least for some of the abilities (see Figures 4,8,9, and 11). The significance of these facts will be discussed later.

II. DISCUSSION OF RESULTS

This study has demonstrated that reducing the level and variability of tactile-kinesthetic stimulation via immobilization can produce a disturbance in intellectual performance. These effects cannot be attributed to visual and auditory restrictions because none were imposed. Furthermore, it has previously been demonstrated (Zubek et al., 1962) that the recumbent position, maintained for a week, exerts no significant effect on our intellectual measures.

The results obtained indicate further that prolonged immobilization produces a differential effect on the various abilities appraised i.e. some are impaired while others are not. Although it was shown that the performance of experimental subjects was poorer than that of the controls on all tests, only on three tests, (recall, perceptual ability, and verbal fluency), was this difference in performance statistically significant. However, since the deficit on several other abilities was almost significant, it is possible that had a larger sample been used, the decreased scores may have been statistically reliable.

These results on the effects of prolonged immobilization are quite different from those reported in the earlier study from this laboratory in which a 24 hr. period of severe restriction was employed (Zubek _et al._, 1963). Here, no intellectual deficits were found. Furthermore no particular trends were evident. This apparent discrepancy may be due to the employment, in this experiment, of a much longer period of immobilization together with the precautions taken to eliminate pain. It is known that pain is a particularly effective alerter of the reticular activating system (Samuels, 1959). What is puzzling in this experiment, however, is the presence of intellectual deficits as early as the first day of the seven day period. In the light of the negative results of the earlier 24 hr. experiment this would not be expected.

It is possible, however, that intellectual performance would have been impaired in the earlier experiment if the test battery had been administered during immobilization rather than after it. Some support for this view is offered by Myers, Murphy, and Smith (1961) who reported "moderate" impairments of various primary mental abilities <u>during</u> sensory deprivation. However, "when cubicle subjects were given the objective test battery shortly <u>after</u> leaving the cubicles, there was no evidence of any decrement in intellectual efficiency in comparison either with their pre-confinement achievement or with controls." Time of test administration may therefore be a factor.

Further support for this hypothesis is available in the present study. Inspection of several of the graphs shows a tendency for the performance curves of experimental and control subjects to converge on the last testing day. This suggests that had tests been administered only before and after the week of immobilization, there might have been little evidence of impairment. It is difficult to explain this phenomenon of convergence of performance on the last testing day. One would expect, if the effects were cumulative, that the curves would diverge even moreso than on the earlier days. A possible explanation of this phenomenon, however, may lie in the motivational state of the subjects. Realizing that their prolonged period of immobilization is almost over, they may be exerting greater effort in their performance than previously. Observations of their mood changes would seem to be in keeping with this hypothesis. They appear to be in much brighter spirits upon realizing that the end of the experiment is near. It would obviously be necessary to obtain some measure of daily motivational changes in order to support this hypothesis.

The findings of the present study are supported by what little relevant behavioral literature there is. For example, Goldman (1953) has demonstrated that subjects who were strapped in a special chair which prevented movements of the limbs, trunk, and head showed a significant increase in the duration of the autokinetic effect in relation to a control condition. Unfortunately, no other perceptual processes were measured. More recently, Riesen (1961) has shown that deficits of visual-spatial performance can occur in kittens and primates that were merely restrained in holders. Although reared in a normal visual environment they were deprived of the opportunity to move about freely. Finally, bodily movements are essential for re-adaptation following optically-produced disarrangements of the visual field (Held, 1961).

These effects of prolonged immobilization resemble in many ways those obtained in the prolonged visual and auditory deprivation experiments carried out in our laboratory (Zubek _et al._, 1960; Zubek _et al._, 1962) and elsewhere (Heron, 1961; Vernon _et al._, 1961; Myers _et al._, 1961). Some valid comparisons can be made since identical tests and durations were used in most cases. The differences that are present lie largely in the magnitude of the effects. First, many of the same abilities are impaired e.g. verbal fluency (Heron, 1961; Zubek _et. al._,1962), recall (Zubek _et al._, 1960), and perceptual ability (cancellation) (Zubek _et al._, 1960; 1962). However, immobilization does not seem to affect as wide a range of intellectual tasks as does visual and auditory deprivation (Zubek _et al._, 1960; 1962). Second, certain abilities seem to be immune to both immobilization and visual and auditory isolation e.g. rote learning, digit span, and verbal reasoning (Zubek _et al._, 1960; 1962). Finally, in both types of experiments the degree of deficit in a number of abilities seems to be independent of the duration of immobilization or of visual and auditory deprivation.

It is possible that our effects and their resemblance to the "deprivation" phenomena would have been even greater if a more severe condition of immobilization had been employed. The fact that all of the volunteers endured the week quite easily and that there were no failures indicates that our procedure was not particularly stressful. Furthermore, it would appear to be less stressful than prolonged isolation where approximately a third of the volunteers fail to endure periods longer than four days (Myers _et al_., 1961; Hull and Zubek, 1962).

It seems likely that the performance changes obtained in this experiment are mediated by the same neural mechanisms that are believed to be involved in the classical visual and auditory deprivation phenomena, i.e. a disturbance of the activity of the ascending reticular activating system as a result of a decrease in the level and variability of sensory input (Heron, 1961; Lindsley, 1961). In the present experiment, however, the decreased variability of input is from the tactile-kinesthetic (and vestibular) rather than visual and auditory senses. Interference with these sense modalities alone may be sufficient to produce certain behavioral changes especially in the light of several reports pointing to the "powerful excitatory influence of somatic sensory excitation" upon the reticular activating system (Bernhaut _et_ al., 1953; French, 1960).

In addition to this non-specific reticular system, it appears that the specific sensory systems may also be involved in these behavioral effects (Sprague et al., 1961). On the basis of extensive physiological studies, Sprague et al., (1961) concluded that "without a patterned input to the forebrain via the lemnisci, the remaining portions of the central nervous system, which include a virtually intact reticular formation "seem incapable of maintaining normal, integrated behavior. It would thus appear, at the present state of knowledge, that perhaps both the specific and non-specific systems are involved, but to different degrees, in producing the various deprivation phenomena- whether of visual, auditory, or kinesthetic origin.

These results have important implications for the numerous sensory and perceptual deprivation experiments in which subjects are instructed to lie quietly, often for long periods of time (Fiske, 1961). They raise the possibility that the behavioral deficits reported in these studies may be as much, or more, a function of restricted motility as of reduced visual and auditory input. These findings are also relevant for the treatment of hospitalized patients, particularly those whose condition is such that it requires prolonged immobilization in a cast or iron lung. Adverse psychological effects may occur if appropriate measures to stimulate bodily activity are not taken. The results are also relevant to the "man in space" program in which the inhabitants of the space capsule are confined to extremely limited quarters and must be strapped down particularly for taking off and landing operations. Finally, these results have some relevance for the centuries old practices of swaddling and cradling of infants. Although these practices have now virtually disappeared, they still exist among some peasants of Central Europe and Italy, as well as in Lapland and in certain North American Indian tribes (Dennis, 1940). In the light of our data it is possible that these practices may produce some degree of intellectual retardation.

CHAPTER IV

SUMMARY AND CONCLUSIONS

In view of the almost total lack of data on the role of motor activity in behavior, an experiment was carried out, the object of which was to determine the effects of a week long period of immobilization of the body upon intellectual functioning. A group of 22 male university students were employed. They were given a battery of tests measuring 12 different intellectual abilities, before and at daily intervals during a seven day period of immobilization. The same tests were also administered to a group of 40 control subjects at the same time intervals.

The results indicated that the experimentals performed worse than the controls on all 12 tests administered during immobilization. Of these 12 tests, three were impaired significantly i.e. perceptual ability, recall, and verbal fluency. The deficits bordered on statistical significance for three other tests, namely dexterity, space relations, and numerical reasoning. The remaining abilities were not impaired significantly. Generally speaking, the amount of performance deficit seems to be independent of the duration of immobilization.

The results of this study are similar in many respects to those obtained in the prolonged visual and auditory deprivation experiments carried out at this laboratory and elsewhere. However, not as many intellectual abilities seem to be impaired. Perhaps if the conditions of immobilization had been more severe the similarity might have been greater.

It seems very likely that the same neural mechanisms are involved in both types of experiments, namely the non-specific reticular activating system as well as the specific sensory systems of the brain. It is believed that a disturbance of the activity of the reticular activating system occurs as a result of a decrease in the level and variability of sensory input, (visual, auditory or kinesthetic). Furthermore, it has been found that the functioning of the specific sensory systems is affected by a lack of patterned input to the forebrain via the lemnisci.

The findings of this thesis have several implications. They raise the possibility that many of the typical deprivation phenomena may be as much a function of restricted motility as of reduced visual and auditory input. These findings are also relevant to the hospital situation where individuals may be immobilized for long periods of time in casts or iron lungs, and to space travel where individuals are required to function optimally under conditions of severely restricted mobility. Finally, these results are relevant to the centuries old practices of swaddling and cradling of infants.

BIBLIOGRAPHY

Asher, R.A.J. Dangers of going to bed. Brit. Med. J., 1947, 2, 967-968.

Bartlett, R.G., Jr. Stress adaptation and inhibition of restraint-induced (emotional) hypothermia. J. Appl. Physiol., 1956, 8, 661-663.

Bartlett, R.G., Jr. Effects of restraint on oxygen consumption of the cold-exposed guinea pig. J. Appl. Physiol., 1959, 14, 46-48.

Bartlett, R.G., Jr., Bohr, V.C., Foster, G.L., Miller, M.A., and Helmendach, R.H. Gross muscular activity and temperature regulation in the restrained rat. Amer. J. Physiol., 1954, 179, 343.

Bartlett, R.G., Jr., Bohr, V.C., and Helmendach, R.H. Comparative effect of restraint (emotional) hypothermia on common laboratory animals. Physiol. Zool., 1956, 29, 256-259.

Bartlett, R.G., Jr.,Bohr, V.C., Helmendach, R.H., Foster, G.L., and Miller, M.A. Evidence of an emotional factor in hypothermia produced by restraint. Amer. J. Physiol., 1954, 179, 343-345.

Bartlett, R.G., Jr., Helmendach, R.H., and Bohr, V.C. Effect of emotional stress, anesthesia, and death on body temperature of mice exposed to cold. Proc. Soc. Exptl. Biol. Med., 1953, 83, 4-5.

Bartlett, R.G., Jr., Helmendach, R.H., and Inman, W.I. Effect of restraint on temperature regulation in the cat. Proc. Soc. Exptl. Biol. Med., 1954, 85, 81-83.

Bartlett, R.G., Jr., and Register, U.D. Effect of cold and restraint on blood and liver non-protein sulfhydryl compounds. Proc. Soc. Exptl. Biol. Med., 1953, 83, 708-709.

Beigel, H.G. The influence of body position on mental processes. J. Clin. Psychol., 1952, 8, 193-199.

Benton, J.G., and Kriete, B.C. Rehabilitation of long-term respirator patients. J. Chron. Dis., 1956, 4,516-526.

Bernhaut, M., Gellhorn, E., and Rasmussen, A.T. Experimental contributions to problems of consciousness. J. Neurophysiol., 1953, 16, 21-35.

Brodie, D.A., and Hanson, H.M. A study of the factors involved in the production of gastric ulcers by the restraint technique. Gastroenterol., 1960, 38, 353-360.

Brodie, D.A., Marshall, R.W., and Moreno, O.M. Effect of restraint on gastric acidity in the rat. Amer. J. Physiol., 1962, 202, 812-814.

Burlingham, D. Notes on problems of motor restraint during illness. In Loewenstein, R.M. (Ed.), Drives, affects, behavior. New York: International Univ. Press, 1953, pp. 169-175.

Courtney, J., Davis, J.M., and Solomon, P. Sensory deprivation: the role of movement. Percept. Mot. Skills, 1961, 13, 191-199.

Cuthbertson, D.P. The influence of prolonged muscular rest on metabolism. Biochem. J., 1929, 23, 1328-1345.

Deitrick, J.E. The effects of immobilization on metabolic and physiologic functions of normal men. Bull. New York Acad. Med., 1948, 24, 364-375.

Deitrick, J.E., Whedon, G.D., and Shorr, E. Effects of immobilization upon various metabolic and physiologic functions of normal men. Amer. J. Med., 1948, 4, 3-36.

Dennis, W. Infant reactions to restraint: an evaluation of Watson's theory. Trans. N.Y. Acad. Science., 1940, 2, 202-218.

Dennis, W., and Dennis, M.G. Cradles and cradling practices of the Pueblo Indians. Amer. Anthropol., 1940, 42, 107-115.

Dennis, W., and Dennis, M.G. The effect of cradling practices upon the onset of walking in Hopi children J. Genet. Psychol., 1940, 56, 77-86.

Erickson, M.H. Psychological significance of physical restraint to mental patients. Amer. J. Psychiat., 1949, 105, 612-614.

Fiske, D.W. Effects of monotonous and restricted stimulation. In Fiske, D.W., and Maddi, S.R. (Eds.), Functions of varied experience. Homewood: Dorsey Press, 1961, pp. 106-144.

Forgays, D.G., and Forgays, J.W. The nature of the effect of free-environmental experience in the rat. J. Comp. Physiol. Psychol., 1952, 45, 322-328.

Frankel, H.M. Effects of restraint on rats exposed to high temperature. J. Appl. Physiol., 1959, 14, 997-999.

Freedman, S.J., and Greenblatt, M. Studies in human isolation. Tech. Rep., 59-266, Wright-Patterson Air Force Base, Ohio, WADC Aero-Medical Lab., 1959.

Freedman, S.J., and Pfaff, D.W. The effect of dichotic noise on auditory localization. Abstract of paper presented at Eastern Psychol. Ass., Philadelphia, April, 1960.

French, J.D. The reticular formation. In Field, J. (Ed.), Handbook of physiology, section 1: neurophysiology, Vol. II. Baltimore: Williams and Wilkins, 1960, pp. 1281-1305.

Gilman, T.T., and Marcuse, F.L. Animal hypnosis. Psychol. Bull., 1949, 46, 151-165.

Gilman, T.T., Marcuse, F.L., and Moore, A.U. Animal hypnosis: a study in the induction of tonic immobility in chickens. J. Comp. Physiol. Psychol., 1950, 43, 99-111.

Goldman, A.E. Studies in vicariousness: degree of motor activity and the autokinetic phenomenon. Amer. J. Psychol., 1953, 66, 613-617.

Greenacre, P. Infant reactions to restraint: problems in the fate of infantile aggression. Amer. J. Orthopsychiat., 1944, 14, 204-218.

Held, R. Sensory deprivation: facts in search of a theory. Exposure history as a factor in maintaining stability of perception and coordination. J. Nerv. Ment. Dis., 1961, 132, 26-32.

Heron, W. Cognitive and physiological effects of perceptual isolation. In Solomon, P., et al. (Eds.), Sensory deprivation. Cambridge: Harvard Univ. Press, 1961, pp.6-33.

Hill, J.C., and Robinson, B. A case of retarded mental development associated with restricted movements in infancy. Brit. J. Med. Psychol. 1929, 268-277.

Hull, J., and Zubek, J.P. Personality characteristics of successful and unsuccessful sensory isolation subjects. Percept. Mot. Skills, 1962, 14, 231-240.

Hymovitch, B. The effects of experimental variations on problem-solving in the rat. J. Comp. Physiol. Psychol., 1952, 45, 313-321.

Jasper, H.H. Electroencephalography. In Penfield, W., and Erickson, T.C., Epilepsy and central localization. Springfield: Thomas, 1941, pp. 380-454.

Krus, D.M., Werner, H., and Wapner, S. Studies in vicariousness: motor activity and perceived movement. Amer. J. Psychol., 1953, 66, 603-608.

Krusen, F.H. The abuse of rest as a therapeutic agent. Postgrad. Med. J., 1947, 2, 84-89.

Lavenda, N., Bartlett, R.G., Jr., and Kennedy, V.E. Leucocyte changes in rodents exposed to cold with and without restraint. Amer. J. Physiol., 1956, 184, 624-626.

Leiderman, H., Mendelson, J.H., Wexler, D., and Solomon, P. Sensory deprivation, clinical aspects. Arch. Int. Med., 1958, 101, 389-396.

Levy, D.M. On the problem of movement restraint - tics, stereotyped movements, hyperactivity. Amer. J. Orthopsychiat., 1944, 14, 644-671.

Lindsley, D.B. Common factors in sensory deprivation, sensory distortion, and sensory overload. In Solomon, P., et al. (Eds.), Sensory deprivation. Cambridge: Harvard Univ. Press, 1961, pp. 174-194.

MacKinnon, W.B. Use and abuse of rest in orthopedic treatment. Canad. Serv. Med. J., 1955, 11, 607-614.

Megel, H., Keating, F.M., and Stern, J.A. Effect of elevated ambient temperature and vibration upon the rectal temperature of the restrained rat. Aerospace Med., 1961, 32, 1135-1139.

Mendelson, J., and Foley, J.M. An abnormality of mental functions affecting patients with poliomyelitis in a tank-type respirator. Trans. Amer. Neurol. Ass., 1956, 81, 134-138.

Mendelson, J., Solomon, P., and Lindemann, E. Hallucinations of poliomyelitis patients during treatment in a respirator. J. Nerv. Ment. Dis., 1958, 126, 421-428.

Menguy, R. Effect of restraint stress on gastric secretion in the rat. Amer. J. Digest. Dis., 1960, 5, 911-916.

Mowrer, O.H. A note on the effect of repeated hypnotic stimulation. J. Abnorm. Soc. Psychol., 1932, 27, 60-62.

Myers, T.I., Murphy, D.B., and Smith, S. Progress report on studies of sensory deprivation. U.S. Army Leadership Human Research Unit, Presidio of Monterey, California, March, 1961.

Norman, J.F. Abuse of prolonged rest in the aged. Minnesota Med., 1945, 28, 803-806.

Page, J.D. Kayak hunting and space flight. Amer. Psychol., 1959, 14, 655.

Peszezynski, M. Use and abuse of rest in physical medicine and rehabilitation. Postgrad. Med., 1957, 21, 626-630.

Poirier, L.J., Ayotte, R.A., Lemire, A.P., Gauthier, C., and Corbeau, J.P. Influence of immobilization on the metabolic and hematological blood picture of the normal Rhesus monkey. Rev. Canad. Biol., 1955, 14, 129-143.

Poirier, L.J., Corbeau, J.P., Lemire, A.P., and Ayotte, R.A. Blood picture of spinal and bitemporal monkeys under the influence of immobilization. Amer. J. Physiol., 1956, 187, 193-198.

Powers, J.A. Abuse of rest as a therapeutic measure in surgery, early post-operative activity and rehabilitation. J. Amer. Med. Ass., 1944, 125, 1079-1083.

Register, U.D., and Bartlett, R.G., Jr. Effect of cold and restraint on tissue non-protein sulfhydryl compounds in methionine-deficient rats. J. Biol. Chem., 1955, 212, 741-745.

Riesen, A.H. Sensory deprivation: facts in search of a theory studying perceptual development using the technique of sensory deprivation. J. Nerv. Ment. Dis., 1961, 132, 21-25.

Samuels, I. Reticular mechanisms and behavior. Psychol. Bull., 1959, 56, 1-25.

Siegel, P.S., and Alexander, I.E. A further observation on the effect of physically-enforced inaction on the activity level of the rat. J. Genet. Psychol., 1948, 72, 57-62.

Sprague, J.M., Chambers, W.W., and Stellar, E. Attentive, affective, and adaptive behavior in the cat. Science, 1961, 133, 165-173.

Taylor, H.L., Erickson, L., Henschel, A., and Keys, A. The effect of bed rest on the blood volume of normal young men. Amer. J. Physiol., 1945, 144, 227-232.

Taylor, H.L., Henschel, A., Brozek, J., and Keys, A. Effects of bed rest on cardio-vascular functions and work performance. J. Appl. Physiol., 1949, 2, 223-239.

Vernon, J., Marton, T., and Peterson, E. Sensory deprivation and hallucinations. Science, 1961, 133, 1808-1812.

Walter, W.G. The living brain. London: Duckworth, 1953.

Whedon, G.D. Management of the effects of recumbency. M. Clin. North Amer. 1951, 35, 545-562.

Whedon, G.D., Deitrick, J.E., and Shorr, E. Modification of the effects of immobilization upon metabolic and physiologic functions of normal young men by the use of an oscillating bed. Amer. J. Med. 1949, 6, 684-711.

White, S.G., Ralston, W.C., and Carne, H.O. The effects of age and bed rest on plasma fat particles as measured by a fat tolerance test. Gastroenterol., 1951, 18, 355-360.

Zubek, J.P., Aftanas, M., Hasek, J., Sansom, W., Schludermann, E., Wilgosh, L., and Winocur, G. Intellectual and perceptual changes during prolonged perceptual deprivation: low illumination and noise level. Percept. mot. Skills, 1962, 15, 171-198.

Zubek, J.P., Aftanas, M., Kovach, K., Wilgosh, L., and Winocur, G. Effects of immobilization of the body on intellectual and perceptual processes. Canad. J. Psychol., in press.

Zubek, J.P. Sansom, W., and Prysiazniuk, A. Intellectual changes during prolonged perceptual isolation (darkness and silence). Canad. J. Psychol., 1960, 14, 233-243.