THE EFFECTS OF PROLONGED IMMOBILIZATION OF THE BODY UPON INTELLECTUAL PROCESSES

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by

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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.

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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 retarda-

tion 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.