THE EFFECTS OF AROUSAL INDUCED BY PHYSICAL EXERTION UPON MENTAL PERFORMANCE

by

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ABSTRACT

The purpose of this study was to investigate the relationship between physical exertion and mental performance and then to interpret this information in terms of arousal theories. More specifically, this study has attempted to determine the effect that physical exertion has upon mental performance and to determine what, if any, is the nature of this relationship between physical exertion and mental performance.

Varying degrees of physical exertion were induced, by bicycle ergometer riding at a rate of fifty revolutions per minute with a resistance of four kilograms. Treatment conditions of 0, 2, 4, 6, and 8 minutes of riding were randomly assigned to each of five consecutive days.

On completion of each daily exercise bout the subject performed a task designed to measure mental performance. This task required the subject to listen to a list of random numbers, prerecorded at one second intervals, with the objective of detecting a sequence of digits which occurred in the order "odd number - even number - odd number", and to respond by saying "yes" before the next digit was presented. The test consisted of 150 digits and the score was the number of series correctly identified out of a maximum of twenty-eight.

Twenty male students residing in campus dormitories volunteered as subjects.

The results, although not significant in terms of the effect of the physical exertion conditions, did tend to indicate that physical exertion had a positive effect upon mental performance. Further investigation of the results led to the conclusion that the effect of physical exertion upon mental performance cannot always be described by a simple inverted U relationship.

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CHAPTER I

INTRODUCTION TO THE PROBLEM

Activation can be described as the degree of neural activity of an individual at any given time and is manifested by a general drive to perform conscious functions. The terms activation and arousal are used synonymously.

Lindsley (1951), Hebb (1955), Malmo (1959), Berlyne (1960), Duffy (1962), and Corcoran (1965) have all expanded upon the basic premise of the Yerkes-Dodson law in describing arousal as a continuum ranging from low to high levels with an optimum degree of arousal for the execution of any particular type of behaviour lying within these extremes.

Hebb (1955) clarifies this concept of arousal by presenting a curve (Figure 1), described as an inverted U. This curve illustrates that as an individual's level of arousal increases from awakening to alertness there is a gradual increase in the effectiveness of performance until an optimal level of arousal is reached. If the arousal level continues to increase beyond this optimum there is a gradual decrease in performance.

Arousal has been attributed to several stimulus conditions including fear, anxiety, emotion, shock, noise, heat, and physical activity. Bills (1927) conducted experiments which indicated that

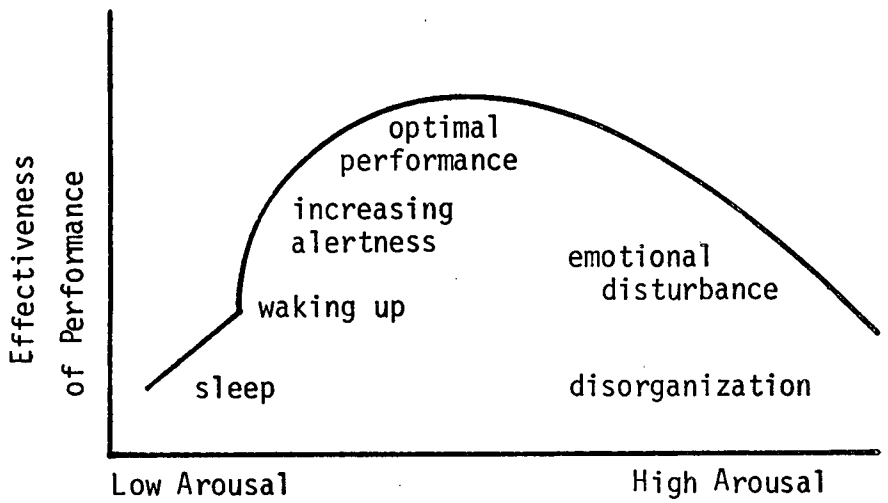

Figure 1 The relationship of arousal to performance (based on Hebb, 1955)

muscular exertion, induced by means of a hand dynamometer, positively affected the performance of various mental tasks such as learning paired associates or adding digits.

More recently, Stockfelt (1968) and Davey (1973) have conducted studies using a dynamic form of physical exertion, riding a bicycle ergometer, to induce varying degrees of arousal. Stockfelt (1968) suggests that the performance of his subjects on simple addition and subtraction problems was related to the degree of arousal and that this relationship took the form of an inverted U curve. Davey (1973) reported similar results when using a task designed to measure mental performance. This task required the subjects to respond to audible digits when they were presented in a predescribed sequence.

Evidence exists which indicates that levels of activation, induced by dynamic physical activity, can be interpreted in terms of existing arousal theories. Physical education, by its very nature, is concerned with physical exertion and if the stimulus of physical activity can be shown to influence behaviour, specifically, enhance mental performance, then physical educators should be aware of the effects of such a relationship. It is hoped that this study will contribute more information toward the understanding of the effects of physical activity upon mental performance, and help to make it a practical application among physical educators.

PROBLEM

The research in this area has provided evidence to suggest that physical exertion may be an important stimulus contributing to one's arousal level. This study was designed to further investigate the relationship between physical exertion and mental performance and then to interpret this information in terms of arousal theories.

More specifically,this study has attempted to determine the effect that physical exertion has upon mental performance and to determine what, if any, is the nature of this relationship between physical exertion and mental performance.

HYPOTHESES

In light of the present evidence relating to the problem, the following hypotheses were proposed for investigation:

(i) Varying the amounts of physical exertion differentially affected the level of arousal and thereby influenced mental performance.

(ii) The influence of physical exertion on mental performance corresponded to the inverted U hypothesis, i.e., increasing exertion improved performance until a maximum level of proficiency was obtained, beyond which the level of performance began to deteriorate.

DEFINITIONS

Activation: The degree of neural activity within an individual at any given time is referred to as his level of activation and is manifested by a general drive to perform conscious functions. The terms activation and arousal are used synonymously.

Mental Performance: Mental performance is defined as the individual's ability to perceive certain stimuli, process information from these stimuli, and respond appropriately to this processed information.

Physical Exertion: Physical Exertion is defined in this study as voluntary behaviour which induces activity of the skeletal musculature. The degree of activity and the quality of musculature concerned may vary.

Inverted U: This is a functional relationship between two factors which, when expressed graphically resembles an inverted U. In the context of this study the inverted U relationship refers to theories which have evolved from the Yerkes-Dodson law described by Eysenck (1963). According to this law, complex tasks are performed best when one's drive or motivation is relatively low, but optimal proficiency in simple tasks occurs when drive is high. As drive increased so does performance, to a point, continued increased in drive lead to poorer performance.

Ascending Reticular Activating System (ARAS): The ARAS is a network of neurons in the brain which seems to function through a network of diffuse fibers extending throughout the brain, especially to the cortex, the stimulation of which is responsible for the level of neural activity called activation. The main areas which seem to be associated with the ARAS are the reticular formation, the hypothalamus, and the limbic system. Recent evidence suggests that the ARAS can be functionally divided into two systems, ARAS I and ARAS II. ARAS I may be associated with activation levels initiated by stimulation of sensory afferents whereas activation levels associated with ARAS II may have been initiated by stimulation of emotions.

Reticular Formation: This is a core of nervous tissue located in the center of the brainstem, clustered around the central canal. It runs through the medulla, pons, and midbrain and connects, at its upper end, with the hypothalamus and thalamus. It consists of predominantly short nerve fibers, of small diameter, criss-crossing in all directions. Synapses and dendrites are abundant. The reticular formation is the primary location of arousal structures in the brainstem and midbrain (Wright et al., 1970).

The Limbic System: The limbic system comprises a functional unit composed of subcortical regions of the brain and seems to be involved with motivational and emotional behaviour. The exact way in which the limbic system subserves arousal is unknown, but it may be involved with ARAS II.

The structures usually included are: the cingulate and hippocampal gyri, hippocampus, amygdala, septum, epithalamus, and the dorso-medial and anterior thalamic nuclei.

The Hypothalamus: The hypothalamus is part of the arousal system located in the midbrain. This structure receives input from higher brain centers as well as from other internal organs of the body. It is thus in a critical position for integrating messages from the higher centers as well as those from internal organs (Sage 1971).

DELIMITATIONS

This study was limited by an inability to control for the effects of motivation on the subjects while they were being tested.

Physical exertion was induced by bicycle ergometer riding. The study was therefore limited to this specific type of activity.

This study was further limited to one test of mental activity to be used as a gauge for mental performance.

In addition this study was restricted to volunteer male college students residing in a university dormitory.

IMPORTANCE

It was anticipated that a re-examination of the effects of physical exertion on mental performance would supplement previous work and help to more accurately clarify the relationship existing between exertion and mental performance.

Duffy (1957) suggested that in different stimulus situations the same individual will differ in his degree of arousal. The importance of this study was that it attempted to control as many factors as possible that could cause differences in testing conditions. For this reason the testing was conducted at the same time each day and in surroundings familiar to the subject, a room in his student dormitory. Since normal daily activity could differentially affect the subjects' arousal levels, testing was conducted upon rising from bed between 6:30 and 8:00 am. Each of the treatment conditions, designed to induce arousal, were randomly assigned to different days to control for effects which could extend over minutes or hours and, to minimize learning effects the tests of mental performance were varied. Finally, the analysis was designed to reveal any differences which may have existed between the tests of mental performance, the days of the week, or the order in which the treatment conditions were administered.

Duffy (1957) further suggested that in the same stimulus situation there are differences between individuals in their degree of arousal. These differences, she said, tended to persist and could frequently be classified as characteristic of certain personality traits.

Recent studies have considered some of the factors which contribute to inter-individual differences and could occur when arousal is induced by physical exertion. Stockfelt (1968) distinguished between physically well-trained students and those who were in a relatively poor state of training and Davey (1973) felt that introversion and extraversion, and neuroticism and stability would affect arousal levels induced by physical exertion. Duffy (1957) went on to report that anxiety and aggressiveness may also be characteristics which affect arousal. It was thought that many factors which are, as yet, undefined also contribute to an individual's degree of arousal. For this reason it was felt that an important contribution could be made if this study included a subjective observation of each subject's results in an attempt to identify any inter-individual differences which may have occurred.

In summary, the importance of this study was threefold. Firstly, it has attempted to clarify the relationship between physical exertion and mental performance. Secondly, it attempted to control for as many factors as possible which could affect an individual and his level of arousal. Finally, the results for each individual were subjectively analyzed in an attempt to identify any inter-individual differences which might have occurred and were not evident as a result of the analysis of group data.

CHAPTER II

REVIEW OF THE LITERATURE

PHYSIOLOGICAL BASIS OF AROUSAL THEORIES

This review begins with a brief description of neural transmission and proceeds to outline the main stages in the development of the physiological theories which describe arousal.

There are two distinct kinds of activity in the nerve cell, the dendritic potential and the action potential. The dendritic potential does not function on an "all or none" basis but individual potentials summate until a certain threshold is reached. At this point the "all or none" action potential is initiated which accounts for nervous transmission. An increase in dendritic potential would facilitate prospective action potentials by decreasing the difference between the actual potential in the dendrite and threshold potential required for the action potential to be generated. In other words, if the dendrite potential is higher than normal it will require less subsequent afferent stimulation to initiate the action potential in that cell. It has been suggested by Li and Jasper (1953) that this dendritic potential often occurs separately from the afferent sensory stimuli and may make up the greater part of the electroencephalogram (EEG) record. The brain is therefore always active but this activity is not always transmitted.

This information regarding neural transmission clarifies the principles of neural activation presented by Lorente de Nó (1939) who stated that the transmission of neural impulses occurs in a closed chain of neurons,the functioning of which may be facilitated by impulses arising outside the brain (i.e. reticular activity system). Such impulses would have the effect of stimulating certain neurons subliminally and therefore make it possible for an impulse from within the chain to reach its required threshold potential,when alone, without the prior activity, it would have failed to do so. He further explains the deleterious effects of over-stimulation from impulses outside the chain as causing neurons in the chain to fail in response to stimulation if, owing to repeated activity, they acquire a high threshold. This failure to transmit the circulating impulses would mean cessation of activity in a cell assembly.

Hebb (1955) similarly felt that cortical synaptic function was facilitated by a diffuse bombardment of the arousal system. He differed, however, in that he felt that when the level of arousal was high, the greater bombardment may interfere with delicate adjustments involved with the sensory afferents, perhaps by facilitating inappropriate responses.

Moruzzi and Magoun (1949) provided evidence for the existance of a non-specific or diffuse projection system in the brainstem responsible for arousal and, whose functioning, makes cortical activity possible.

Further, they found that EEG changes, seemingly identical with those in the physiological arousal reactions, could be produced by direct stimulation of the reticular formation. They reported a generalized response, in cortical areas, which consisted of cessation of synchronized alpha discharge in the EEG and its replacement with low voltage *fast* activity, that is, alpha to beta activity. This suggested to them that cortical activity is mediated by neural connections between the reticular formation and the cerebral hemisphere. Similar responses could also be elicited by stimulation of the dorsal hypothalamus and subthalamic regions. Moruzzi and Magoun (1949) further reported that lesioning (mesencephalic transection) of the ascending reticular activating system (ARAS) resulted in an EEG pattern which resembled that of an intact brain in natural sleep. Sleep may therefore be due to elimination of arousal caused by the bombardment of cortical areas by information ascending from the reticular activating system.

The behavioral response to this stimulation of the ARAS in monkeys was investigated by Fuster (1958) who found that by stimulating the same region of the ARAS that produces the EEG recording of activation (beta waves) he produced improved performance in the trained ability to discriminate between objects of different geometric shapes. He further found that moderate intensities of stimulation increased the animal's efficiency but that greater intensities resulted in a deleterious effect.

It was proposed by Hebb (1955) that afferent stimuli are conducted via two pathways. The first, termed the cue function, transmits the information quickly and efficiently from the sensory nerve, to the sensory tract, through the corresponding nuclei of the thalamus and terminates in one of the sensory projection areas of the cortex. The second pathway is slow and inefficient as the information passes through a maze of fibers and synapses before the messages are delivered indiscriminately to wide cortical areas. They serve to tone, or arouse the cortex with a background of supporting activity that is necessary if the messages proper are to have their effect. Arousal, according to Hebb, is an energizer, not a guide, without which the afferent sensory information cannot exist. It is, in a sense, synonymous with a general drive state.

Findings by French (1957) support the theory by Hebb (1955) that two sensory afferent pathways exist. He found that sensory signals from all parts of the body go to the cortex by direct pathways but, on the way to the brain stem, they also stimulate the reticular formation. When the reticular formation is so stimulated it sends arousing signals to the cortex which can then interpret the signals being received directly (See Figure 2).

Recent investigations have provided some evidence which is inconsistent with the description of the reticular activating system provided to this point. Myers, Roberts and Domino (1964) demonstrated that animals could be behaviourally awake yet record slow wave activity when their reticular systems were under the influence

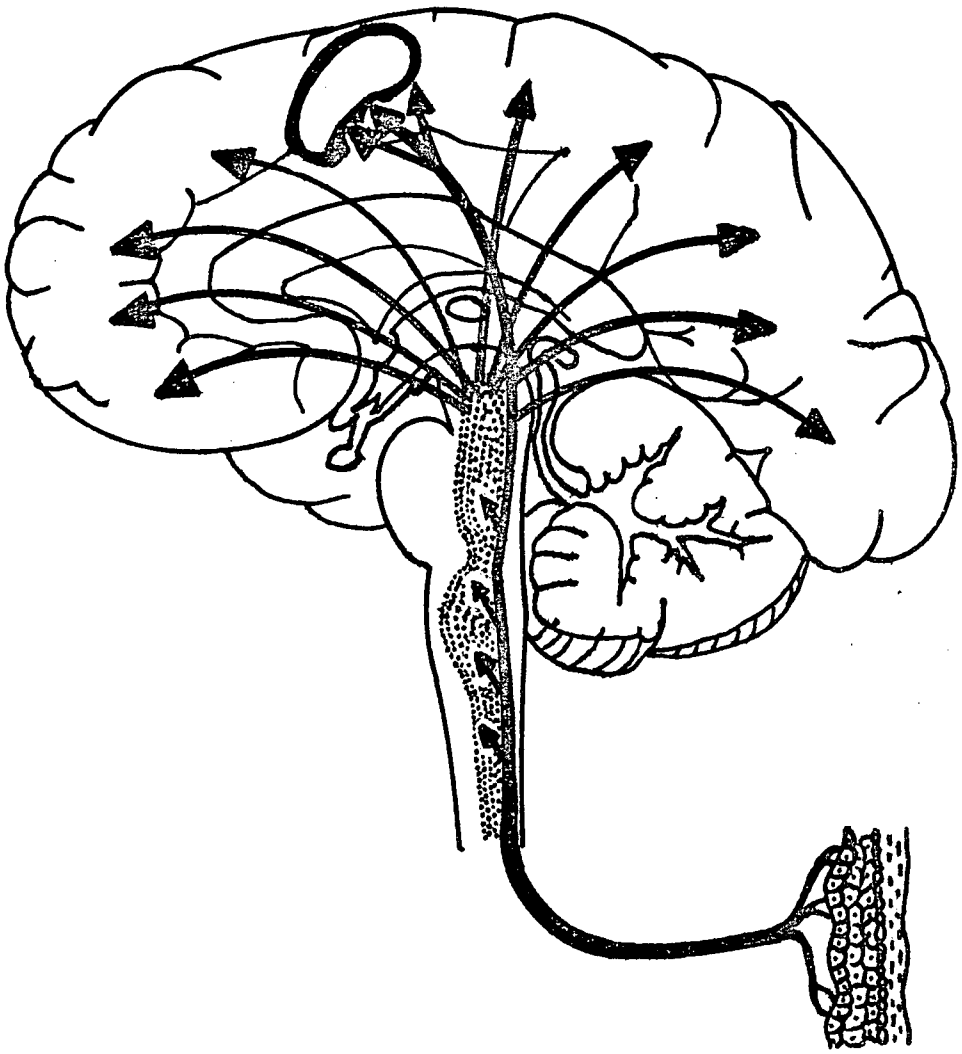

Figure 2 The RETICULAR FORMATION is the area stippled in this cross section of the brain. A sense organ (lower right) is connected to a sensory area in the brain (upper left) by a pathway extending up the spinal cord. This pathway branches into the reticular formation. When a stimulus travels along the pathway, the reticular formation may "awaken" the entire brain (arrows). (from French, 1957).

of atropine, a chemical which blocks neurologic activity. Furthermore, work by Chow and Randall (1964) has shown that lesions restricted to the reticular formation itself do not necessarily render animals comatose and that recovery may even occur. This recovery was illustrated by Villablanca (1965) who found that seven to eleven days after transection between the diencephalon and midbrain, low voltage, fast activity occurred, and by Doty, Beek, and Kooi (1959) who showed that animals with reticular lesions were able to perform complex behavioural conditioning tasks. Many instances of similar results have been provided by other workers.

It is apparent that the original concept of a single, ascending reticular activating system, described by Moruzzi and Magoun, is not sufficient to describe the events just discussed. It has been proposed, through studies of the limbic system, that a second arousal system is present. Samuels (1959) divided the reticular formation into two functional systems; the brain stem reticular formation and the diffusely projecting thalamic nuclei or limbic systems. When activated, they both would evidence desynchronization of resting alpha rhythms. Eysenck (1967) elaborated upon this concept by suggesting that cortical arousal can be produced by two distinct and separate pathways. One pathway, ARAS I, ascends directly from the reticular formation without involving the visceral brain. The second, ARAS II, involves the visceral brain and the hypothalamus. He further states that cortical arousal arising from visceral brain activity is produced by emotions whereas the reticular formation is responsible

for what Eysenck calls autonomic activation (i.e. from sensory afferents). Subsequent investigation by Routtenberg (1968) has led to a further refinement of this dual activating system theory which will be discussed later.

Kawamura, Nakamura and Tokizane (1961) produced evidence that the media forebrain bundle (MFB) system may be involved with arousal functions. They found that stimulation of the MFB at the level of the hypothalamus produced neocortical desynchronization and hippocampal theta activity (hippocampal arousal response). After transection they found that neocortical desynchronization from the reticular formation disappeared but the hippocampal theta activity remained. This observation provides a possible explanation of the results cited by Villablanca and suggests that if sufficient time is allowed for recovery this hippocampal system might be able to produce neocortical desynchronization similar to that produced by the reticular formation.

From this information it seems that arousal system I (AS I) is the primary system producing neocortical desynchronization and that destruction of it will reduce or eliminate neocortical desynchronization. Arousal system I must, therefore, be active for the production and selection of appropriate responses. These responses are more probable when AS I is active and less probable when it is inactive. Arousal system II (AS II) can, however, sufficiently stimulate the neocortex to maintain at least the wakefulness of the organism when AS I is damaged. Routtenberg (1968), goes on to suggest that AS I sustains the tonic influence with respect to neocortical

desynchronization. AS II appears to be more critical for maintaining basic "vegetative" activities. Each may contribute, in the other's absence, to the function of the other.

Routtenberg (1968) in reviewing data on self stimulation (Olds and Milner 1954) says that AS II is a reward system, and it reinforces or increases the probability that the response will reoccur, on the other hand, AS I organizes the response aspect.

Olds (1960) found that rats would voluntarily self-stimulate the hypothalamus but, if possible, try to escape dorsal midbrain (DM) stimulation. This indicated that separate regions within the midbrain mediate positive and negative reinforcement. Olds and Olds (1962) found evidence for one-way inhibition of posterior hypothalamic self-stimulation when a continuous DM stimulation was present. Brady (1958), on the other hand, found that stimulation of the septal rewarding site in the brain can reduce or even eliminate emotional aspects of an aversive stimulus. This suggests that possibly two rewarding sites, septal area and posterior hypothalamus, could produce opposite effects with respect to aversive stimulation. In general, septal stimulation tends to reduce the effects of aversive stimulation while hypothalamic stimulation tends to augment it.

Routtenberg (1968) has devised a schema (see Figure 3) to explain the functional difference between septal and hypothalamic areas although they both yield similar reward stimulation. He has attempted to organize anatomical and physiological findings with respect to behaviour. It can be seen that the septal area and hypothalamic area

AROUSAL SYSTEMS

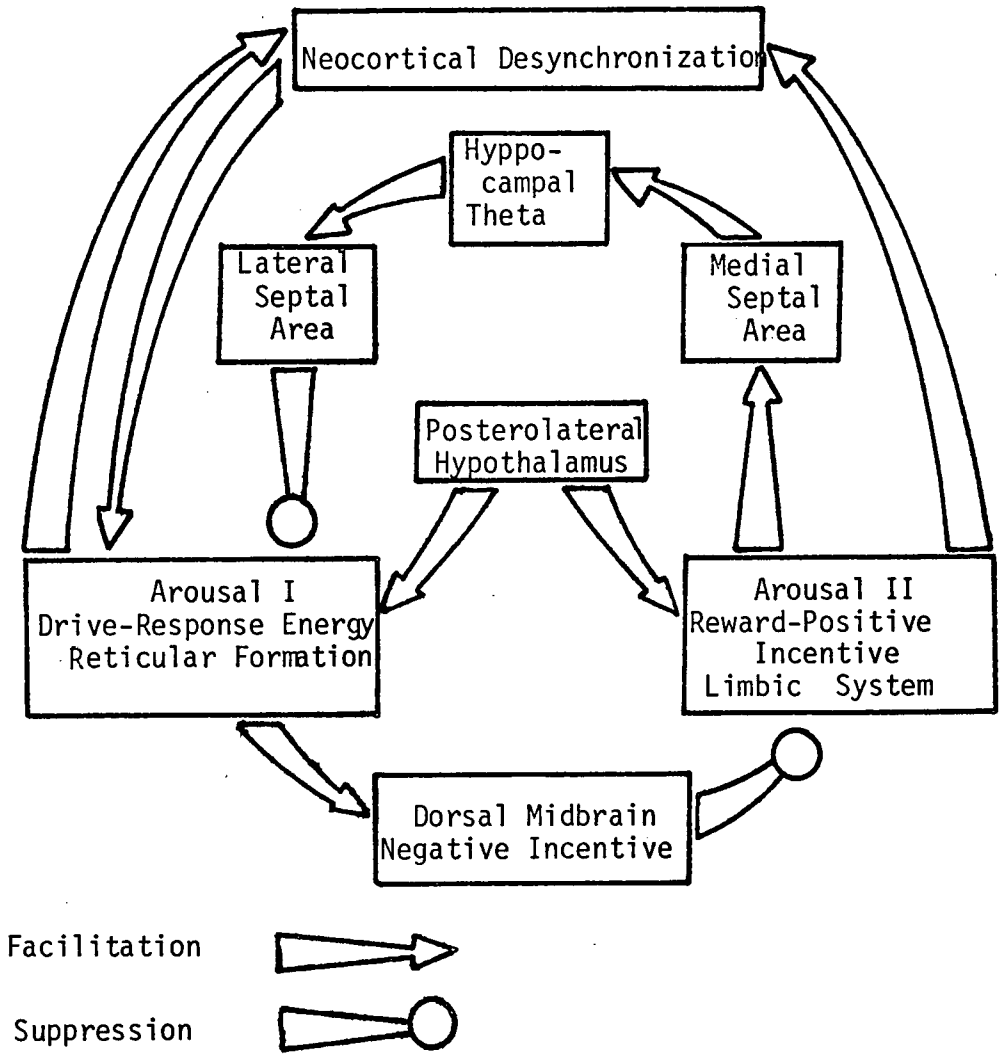

Figure 3 Routtenberg's schema to describe arousal systems

have different effects on AS I. The septal area dampens it whereas the posteriolateral hypothalamus activates it. Hypothalamic stimulation is rewarding because it suppresses AS I which results in suppression of the dorsal midbrain negative incentive which in turn ceases to suppress AS II. The net result is that AS II is activated. AS I suppression, arousal, or both lead to rewarding effects. This schema can help to explain the behavioural characteristics attributed to the arousal theory. Each of the two activation systems can suppress the other depending on the nature of the input. Both systems are constantly active and a reciprocal suppression of the imbalances of the other allows AS I and AS II to be in dynamic equilibrium. It is possible that high levels of activation may produce adversive stimulation in AS II which would cause inhibition of AS I activity and corresponding performance decrements. At more optimal levels of arousal the AS I activity would stimulate activity of the dorsal midbrain which would cause suppression of AS II, thus facilitating AS I activity and optimal performance.

In a more recent study Routtenberg (1971) has slightly elaborated his original concept of arousal. He cites evidence to suggest that the extrapyramidal system is involved with the activating systems and that it, together with the reticular formation, is involved in the organization of motor patterns. System I is therefore the motor execution system. In contrast, System II is associated with stimulus-processing. He states that both the extrapyramidal system and the

limbic receive sensory input from all major modalities. They are both in a significant position, therefore, to engage in the stimulus processing function suggested for System II.

Routtenberg (1971) further reports that the hippocampus plays an important roll in the activity of these two systems. The activity of System I and modulation of II is indicated by hippocampal desynchronization and the activity of System II and modulation of I is indicated by hippocampal theta activity.

This literature relating to the physiological description of arousal supports the notion that physical exertion may affect mental performance. Evidence suggests that afferent stimulation, from different parts of the body, arrives at locations in the lower brainstem and in turn provides stimulation, or arousal, to the cortex. This arousal is then responsible for the facilitation of various types of behaviour. More recent investigations suggest, however, that the mechanisms subserving arousal may be more complex than previously thought and that a second arousal system exists which may be stimulated by emotions. To date no studies have been conducted to investigate the interaction between these two systems when the stimulus of physical exertion has been used to influence mental performance.

THE EFFECTS OF AROUSAL INDUCED BY PHYSICAL EXERTION

The study of the effects of arousal induced by physical exertion, or exertion arousal, on mental performance was begun in 1927 by Bills who conducted an experiment which involved four female and five male advanced college students. His results showed that performance, as measured by the memorization of nonsense syllables, was facilitated by the squeezing of a hand dynamometer.

Inconsistant results, however, were found by other investigators. Zartman and Cason (1934) studied six male and twelve female subjects in further investigating the effects of exertion arousal on mental performance. The subjects were administered forty-eight short arithmetic problems. Twenty-four of them were answered while the subject depressed a pedal, with his right leg, which required a force of 25-40 pounds. The results showed neither a definite increase nor decrease in the efficiency of solving arithmetic problems.

An experiment by Block (1936) provided evidence to suggest that physical exertion has a negative effect on mental performance. Fifteen male college students were tested in a continuous addition task, the ability to make analogies, and the quality of syllogistic reasoning with and without the presence of induced muscle tensions. The tension condition required the subjects to squeeze hand dynamometers in both hands with a force of thirty-four pounds each, and to exert a pressure of forty-eight pounds against a pedal with the right foot.

Duffy (1932) conducted experiments which provided somewhat similar results to those of Block. She tested eighteen children between the ages of two years eleven months and three years eleven months on a task chosen to measure their ability to press a key when pictures of an automobile were shown amongst other randomly arranged pictures. At the same time hand dynamographs were held. She found that the results obtained from children who exerted a high degree of muscular tension while holding the dynamograph were usually associated with a performance of poor quality although she further suggests, on the basis of her limited data, that good performance most frequently occurred when the dynamograph was held with moderate to low degrees of muscular tension.

The conclusions of a more recent study by Corcoran (1965) can be applied to some of these earlier studies to offer a possible explanation for some of the apparently divergent data. He suggests (Figure 4) that if a person's arousal level increased from X_1 to X_2, performance could be shown to be facilitated from Y_1 to Y_2. Performance would remain the same if arousal increased from X_1 to X_3, or it would be reduced from Y_1 to Y_4 if arousal increased from X_1 to X_4. He says that as an individual's level of arousal is increased his ability to perform conscious functions also increases. A point, in this case X_2, marks the degree of arousal for optimum performance. Further increases beyond this point result in decreased quality of performance. Previous studies may be regarded as having explored

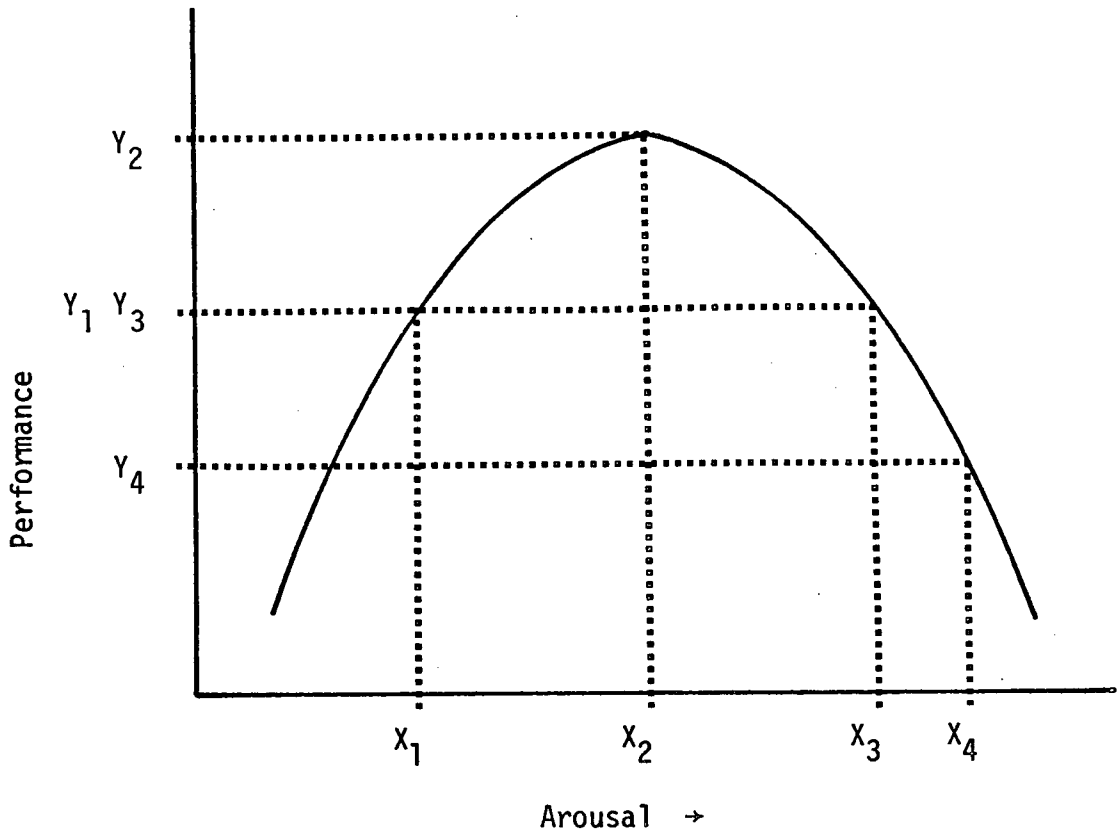

Figure 4 Corcoran's Inverted U

only one part of the whole range. Subsequent studies, however, began to consider the importance of investigating the resulting effects on performance caused by physical exertion conditions which were varied in intensity. When this approach was employed, investigators began to find evidence to suggest that the relationship between physical exertion and mental performance was of an inverted U nature.

Stauffacher (1937) tested forty university students in a study which covered a range of muscular tensions generated by lifting weights with an arm. Treatment conditions ranged from zero through one-quarter and one-half to three-quarters of the maximum weight that the subject could lift. He found that the learning of nonsense syllables was facilitated, and that the best results were obtained at one-half the maximum tension. Tensions of less than this, however, gave little or no evidence of facilitation of learning. In this experiment the orders of the treatments were randomized and one was administered daily for four consecutive days.

Courts (1939) conducted a similar study. He found, in testing sixty male college students, that memorization was progressively more efficient until an optimum tension was reached. Tension was induced by having the subjects squeeze a hand dynamometer. In this case the optimum tension was equivalent to one-quarter the measure of intensity at the end of thirty seconds of maximum effort on a preliminary trial.

A more recent study was conducted by Wood and Hokanson (1965) who divided the range of muscular exertion into five treatment

conditions: 0, 1/4, 1/2, 3/4, and maximum. This task consisted of lifting weights with the arms and supporting them at the side while performing a digit-symbol substitution task. The results indicate that tension, induced by one-half the maximum weight lifted, allowed for optimal performance while greater or lesser amounts result in sub-maximal performance (Figure 5). The subjects were forty male and sixty female undergraduate students who had a normal basal heart rate between seventy-two and ninety-two beats per minute. Heart rate was also monitored and used as an indicator of arousal.

These studies were all interpreted as being consistent with the inverted U hypothesis which predicts that performance on a learning task would be facilitated by increased levels of induced tension up to some maximum point, after which it would begin to fall off with further increases in tension.

In addition to the above studies several experiments have been conducted to investigate the effect of muscular tension on motor performance.

Freeman (1938), while testing ten male students, found that performance, measured by the frequency of finger oscillations, increased as muscular tension, induced by lifting against a leg lever increased until an optimum was reached. Further increases resulted in deterioration of the quality of performance. Freeman also found that after dividing his subjects into two different groups, different degrees of tension indicated optimal tensions for each group.

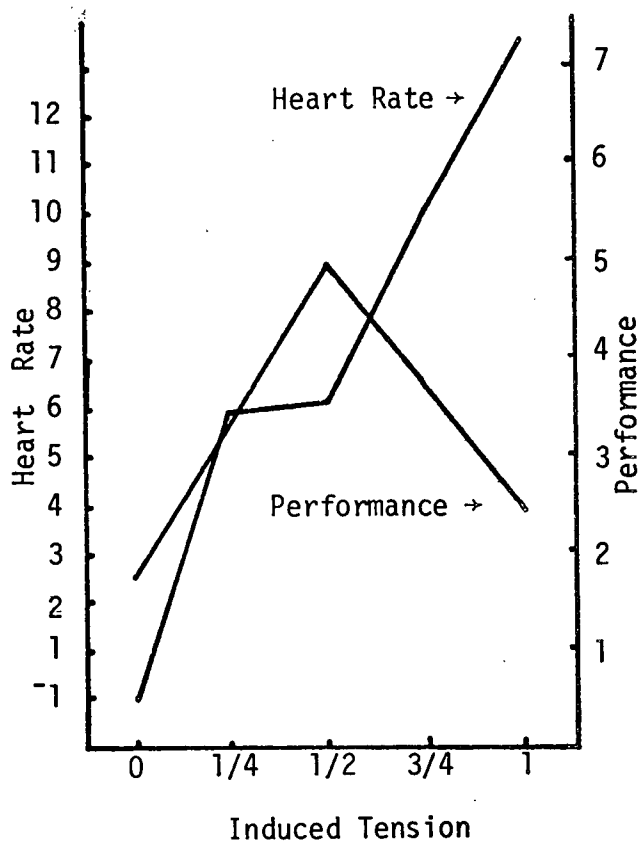

Figure 5 Wood and Hokanson's Inverted U

He felt that this could be accounted for by individual differences within such small groups.

Marteniuk (1968) conducted a further study to investigate the effects of induced muscular tensions on motor performance. In this experiment the subjects, forty-nine male college students, were required to press a reaction lever loaded with an adjustable coil spring which would enable the experimenter to vary the force necessary to push the lever. The task required the subjects to depress the lever at a given tension level, one of 0, 5, 10, 15 or 20 pounds, then, at a signal, they were to grab a suspended ball. Both reaction times and movement times were measured. The results indicated that reaction time was a function of induced arousal. The fifteen pound treatment condition was significantly faster than either the zero or twenty pound condition. Movement time, however, was not facilitated. There was instead, a linear trend toward slower speed with increased tension.

Marteniuk concluded that facilitation of reaction time, through the use of preliminary tension, could be accounted for by applying arousal theory to motor performance. Inhibition of movement time was probably caused by an increasing shift of attention from the movement phase to the reaction phase of the task at higher levels of tension.

Pinneo (1961), however, found results which differed from those of Marteniuk in that the inverted U relationship was not supported. In this case the subjects were required to perform a

tracking task which required the depression and release of a foot pedal at a constant speed with auditory signals to indicate variations. He found that errors in this task increased as muscle tension, induced by means of a hand dynamometer, increased over a series of increments. His subjects were thirty-eight male undergraduates ranging in age from eighteen to thirty years.

Up to this point the researchers have been concerned with the effects of static muscle tensions as a method of inducing arousal and the test of performance has been administered concurrently with the treatment condition of physical exertion. This design does not allow for the effects of interactions between the execution of the performance task and the exertion task. More specifically, decrements in performance, which have been reported to have occurred after some optimum has been reached, may have been due to attention being directed towards execution of the physical exertion task and not due to further increases in levels of arousal. This may, for example, explain the apparently divergent results obtained by Pinneo (1961).

More recently an alternative design in experimentation has been included in the investigations. Arousal has been induced by a variety of dynamic methods including running, bench stepping, and riding a bicycle ergometer and tests of mental performance have been administered after the period of exertion. In addition to reducing possible artifacts arising from the simultaneous execution of the performance task and the exertion task, this design has enabled the investigation of the prolonged effect of physical exertion on arousal over a period of several minutes.

McAdam and Wang (1967) studied the effect of mild physical exertion as a method of arousing an individual prior to a mental task. He used a combination of running, jogging, and walking to induce mild work but not fatigue. Immediately before and after exercise the 108 male adult subjects were administered a ten minute symbol substitution task. The results, although non-significant, tended to favour exercise before the mental task.

In 1966 Gutin conducted a study to test his hypothesis that increased physical fitness would have a positive effect on the ability to perform mental tasks after a period of physical and mental stress. The subjects were fifty-five male college students. After a pre-test consisting of physical and mental stress (Indiana motor fitness index II, push-ups, chins, standing broad jump, long addition, and subtraction), the subjects were administered mental tests in verbal comprehension, visual pursuit, verbal reasoning, and symbolic reasoning. During the following twelve weeks the test group underwent a physical development program designed to raise their fitness levels. At the end of this period both test and control groups were tested in the same fashion as before.

Gutin found no significant differences between his control group and the experimental group in ability to perform complex mental tasks. However, there was evidence of a moderate relationship between the degree of fitness improvement and mental task ability following stress.

A study by Gutin and DiGennaro (1968a) tested three treatment conditions to study the effects of physical exertion on mental performance. The treatments: rest, one minute of bench stepping, and five minutes of bench stepping, were preceeded and followed by five minute tests of simple addition. The fifty-eight male college students participating in this experiment were divided into two groups: those enrolled in a development class and therefore accustomed to step-ups and those not performing bench-stepping regularly. These groups were further divided into three treatment groups each of which would perform under a different condition.

The investigators found, amongst the subjects accustomed to step-ups, that the one minute group scored significantly worse than the zero minute group and the five minute group in speed of addition. There was also a trend, although non-significant, towards the conditioned subjects improving in accuracy of addition but the unconditioned group doing more poorly.

These results are difficult to explain in terms of the inverted U hypothesis, however, Gutin and DiGennaro suggest the possibility that subjects accustomed to the exercise may have found the five minutes of step-ups to have induced moderate rather than heavy ranges of activation. A specified degree of activation may, therefore, result in different degrees of activation depending upon the fitness of the subjects for the activity involved. They could not offer any explanation as to why the one minute group should have done worst of all in speed of addition.

A second study by Gutin and DiGennaro (1968b) investigated the effect of a treadmill run to exhaustion on the performance of long addition. Each of the subjects, seventy-two college students, acted as his own control. The experimental treatment consisted of a run to exhaustion on a treadmill while the control treatment had no exertion. These treatments were administered on alternate days. The test of performance--addition of ten digit columns--was given prior to, and after, the treatment condition for a period of four minutes during which time subjects were scored for both speed and accuracy.

The results showed that the exertion had a significant negative effect on accuracy for the total four minute test period as well as for the second and fourth minute of the test. The effect, however, was not negative during the first minute after exertion during which time there was no significant effect on the accuracy of addition.

Apart from the expected finding that numerical accuracy was hindered when preceeded by heavy muscular exertion, two other interesting factors were observed. First, the effect was not found to be negative during the first minute after exercise suggesting that exertion had a latent negative effect. Second, there was no trend observed showing improvement during recovery which would parallel the cardiovascular recovery. This was illustrated during the fourth minute after exertion where negative results were still observed. Fitness was again used as a variable when analysing the

data. It was found that the low fitness groups were more affected by the exertion than either high or medium fitness groups. Speed of addition, however, was not affected by exertion.

Neither of Gutin and DiGennaro's experiments refer to a mental warm-up prior to the task or to the subject's familiarity with the task.

Davey (1972), also conducted experiments to study the effects of strenuous physical exertion on mental performance. In this experiment twelve male undergraduate students acted as subjects, half as an experimental group and half as a control group.

The task chosen to measure mental performance incorporated a button pressing task in which the subject received auditory information in the form of a series of random single digit numbers (0-9) and was required to press corresponding buttons on a key board in the order in which he heard the numbers. During the fourth of a series of trial sessions a score was obtained and used as a pre-treatment score.

The treatment consisted of rest for the control group and physical activity for the experimental group, in the form of pedaling a bicycle ergometer at a set power ratio and a constant speed for thirty seconds. The bicycle ergometer was so constructed that 6,000 foot pounds of work was done by each subject. After the treatment the subjects repeated the task giving a post treatment score.

The results were found to show a significant improvement during the first and second minutes after exercise. A range of physical exertion levels were studied in an experiment conducted by Stockfelt (1968). Treatments consisted of 0, 25, 45, 65, 85, and again 0 percent of the maximum exertion that the individual could induce while pedaling a bicycle ergometer.

Three groups of subjects were tested: physiologically "well-trained" students, physiologically "poorly-trained" students, and physiologically "poorly-trained" non students who were not accustomed to mental work. In each group there were eight males and eight females between twenty and twenty-five years old.

The tests of mental performance were five series, each of forty mathematical problems comprised of simple addition and subtraction.

The order of the treatment conditions was randomized for each of the subjects except that the zero percent exertion trials were administered first and last. Between trials the subject rested until the heart pulse rate decreased to less than 100 beats per minute, or for at least five minutes.

The results (Figure 6) showed that there was a tendency for the well-trained students to score less well on the eighty-five percent exertion level. The differences for their other exertion levels were not significant. For non-students and poorly-trained students there were significant differences between the different exertion levels. Stockfelt suggest that the reason for this is that

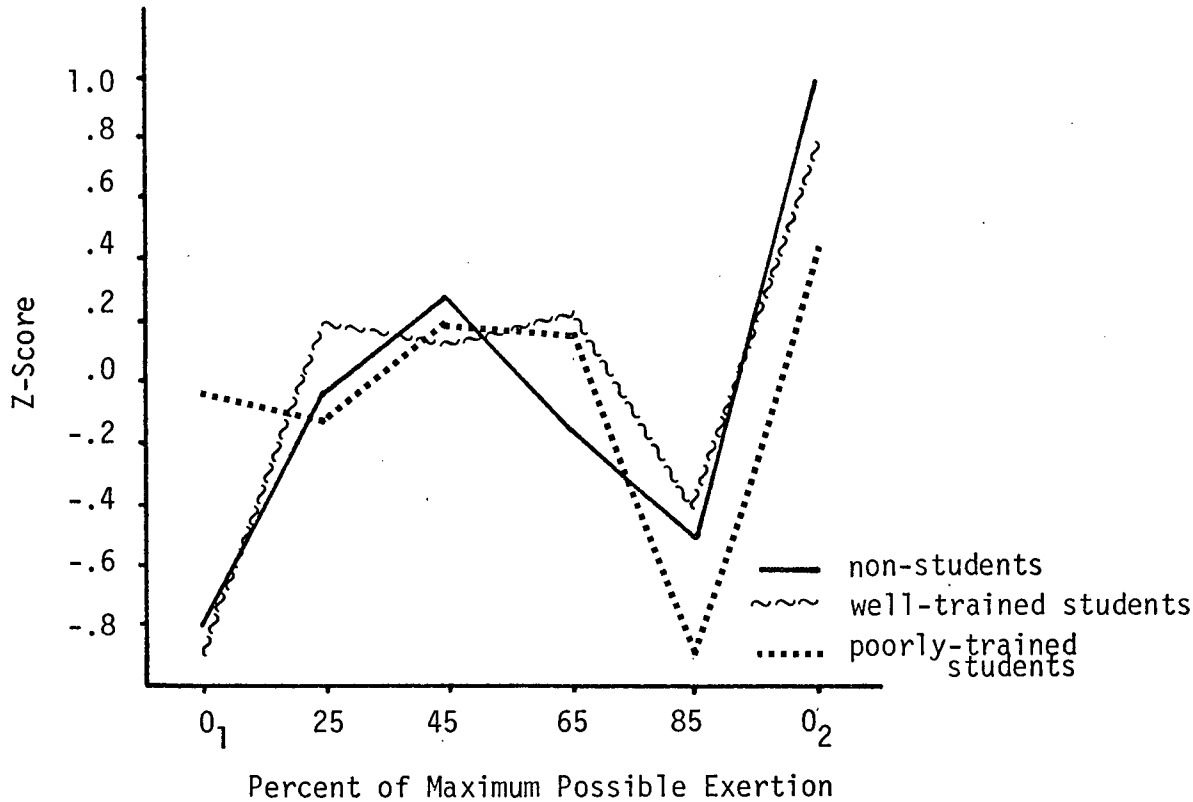

Figure 6 Mean Z-scores of the three groups as a function of percent of maximum exertion involved (Stockfelt 1968)

the performance curves over the exertion levels take the form of an inverted U with maximum performance at the level of forty-five percent exertion and a minimum at the level of eighty-five percent exertion.

Further investigation of Figure 6 shows that the scores for the final zero percent trial are higher than the initial zero percent trial. This indicated that there may be an accumulated arousal effect despite rest periods. Different results may have been obtained if each of the trials had been on a separate day.

Davey (1973) conducted a further study to examine the effect of physical exertion on mental performance. He also introduced the factors of introversion and extraversion, and neuroticism and stability to determine the effect, if any, that they might have an arousal induced by physical exertion.

Eighty subjects were divided into four groups of twenty based on their extreme scores on the Eysenck Personality Inventory, a test measuring personality in terms of extraversion and introversion, and neuroticism and stability.

Each subject was required to perform a series of treatment conditions involving 0, 1/2, 1, 2, 4 and 6 minutes of riding on a bicycle ergometer after which the mental performance of the subjects was measured. This involved short-term memory recall of random digits and the Brown and Poulton test which required the subject to listen to a series of random digits and detect sequences which occurred in the order of odd number, even number, odd number.

The short term memory scores were found to deteriorate significantly after the four and six minute exercise conditions but to remain constant with exertion of less than four minutes. The mental performance scores, as measured by the Brown and Poulton test, however, improved after 1/2, 2 and 4 minutes of exertion and deteriorated after six minutes of exertion. These results suggest that mental performance was consistent with the inverted U hypothesis, but, short term memory was not shown to be facilitated by physical activity.

Some interaction effects between personality variables were found to be significant. Introverts, with the same amount of exertion, seemed to deteriorate more, in mental performance, than extraverts. This finding is consistent with Eysenck's theory that introverts are more highly aroused, in a resting state, than extroverts, and that introverts reach their optimum level of performance earlier with increased arousal. There was no significant difference between stable subjects or those who tended to be more neurotic.

Davey did not, however, consider the prolonged, or carry-over effects of induced arousal. His treatment conditions were administered in order from the least to the most strenuous. Furthermore, only a brief period of thirty seconds of rest was allowed between the test and the following treatment condition. Verification of his results by experiments which attempt to control the possible prolonged effects of exertion arousal would, therefore, be desirable.

In summary, it can be seen that evidence to support the inverted U hypothesis has been found by many researchers. Stauffacher (1937), Courts (1939), Wood and Hokanson (1965), and Freeman (1938) all explained the results of their experiments in terms of the inverted U hypothesis. In these studies the investigators were concerned with the effects on mental performance caused by arousal induced by some kind of static muscle tension. In each case the subjects were given a test of mental performance while undergoing the physical treatment condition. Important information was gained from these works but further studies were required. It could have been that their results were caused by a shift in attention from the mental performance task to the physical treatment task, as it became more difficult, when both tasks were administered simultaneously. Also, it was thought that a more useful task would be one which involved some sort of dynamic physical activity involving larger areas of the body and closely resembling sports and physical education activities.

McAdam and Wang (1967), Gutin (1966), Gutin and DiGennaro (1968 a, b), and Davey (1972) used activities such as running, walking, jogging, push-ups, chins, standing broad jump, step-ups, and bicycle ergometer riding as means of inducing arousal. Further investigations were needed, however, as only portions of the range of the intensity of physical activity were studied and consequently the results indicated only part of the inverted U curve.

Stockfelt (1968) conducted a study which investigated a range of physical exertion levels. In doing so he found evidence to suggest that an inverted U relationship exists between physical exertion and mental performance. Evidence also appeared which predicted the possible cumulative effect of arousal, despite rest periods, indicating that further study, with each treatment condition being administered on a different day, would be desirable.

Davey's (1973) study of a range of physical exertion also supported the inverted U hypothesis but, failed to consider the cumulative effects of arousal. Verification of his results, by experiments which control for the possibility of prolonged effects of arousal, would be desirable.

This study was designed to add further refinements to the preceding work and to contribute to the clarification of the relationship between physical exertion and mental performance.

CHAPTER III

METHODS AND PROCEDURES

SUBJECTS

Twenty male students were selected from volunteers who resided in campus dormitories. This situation minimized pre-test activity by permitting testing immediately upon rising from bed. Each subject was required to complete one of five experimental conditions on five consecutive days.

MENTAL TASK

The Brown and Poulton Test (Davey, 1973) was selected on the basis of the following three considerations: (a) previous experience would be of no assistance, (b) the task would be free from learning effects during performance, (c) the task should be easily quantifiable. This task required continuous attention to auditory signals and involved memory spans of a few seconds, that is, it required the subject to listen to a list of numbers, pre-recorded at one second intervals (See Appendix B). The object was to detect a sequence of digits which occurred in the order "odd-even-

odd", and to respond by saying "yes" before the next digit was presented. The score was the number of series correctly identified. The series was formulated randomly from the numbers 1-9 with the restraint that no numbers would occur twice in succession.

The task was divided into two parts daily. Part one entailed a short, one minute practice trial to familiarize the subjects with the test each day. Part two was the test trial of two and a half minutes duration.

The test battery consisted of five sets of randomly generated digits and each subject was randomly assigned a different test set for each day of testing.

PHYSICAL TASK

It was desirable that the physical task be such that the amount of work done could be easily measurable and could be maintained for the desired lengths of time. This experiment also required that the change from physical exertion to mental performance should not interfere with the latter task. The work controls offered by the bicycle ergometer satisfied these requirements and it was, therefore, used to induce physical exertion. To induce sufficient effort a resistance of 4 kg was applied to the ergometer, and the subject was required to ride at the rate of fifty revolutions per minute. To vary the work done in each treatment condition the duration of

the exercise bout was varied. The five treatment conditions were 0, 2, 4, 6 and 8 minutes of exertion.

The subject's heart rate was monitored during the last fifteen seconds of each ride by the use of a stethoscope. The purpose of this was to confirm that the eight minute treatment condition was sufficiently demanding to induce a heart rate of approximately 180 beats per minute. This indicated to the investigator that the subjects were exposed to a full range of physical activity beginning with none and increasing steadily, by two minute increments, to the exhausting eight minute treatments. The resulting heat rates are listed in Appendix E.

EXPERIMENTAL DESIGN AND CONSIDERATIONS

The design of the experiment was such that as many as possible of the factors which could influence the results were considered and their effects were investigated in the analysis. These factors were:

(a) The treatment effect, or the effect of the various amounts of physical exertion.

(b) The order effect to determine if the order in which the subjects received their treatments made any difference.

(c) The day's effect to determine if any difference exists between the days of the week.

(d) The test's effect, to detect any differences that may have existed between the five tests of mental performance.

This study utilized a repeated measures design where each subject acted as his own control. To reduce the possibility that one treatment may affect the next, only one condition was tested each day. The sequence of these treatments was randomized and presented in five different orders as were the five different tests of mental performance.

A 5 x 5 Greco-Latin squares design (Figure 7) was chosen as being most suitable in light of the above requirements.

The subjects were assigned to four 5 x 5 Greco-Latin squares. $S_1 \ldots S_5$ represent the first five subjects. The second Latin square would be for $S_6 \ldots S_{10}$, the third for $S_{11} \ldots S_{15}$, and the fourth for $S_{16} \ldots S_{20}$.

$D_1 \ldots D_5$ represent the days from Monday D_1 to Friday D_5 on which the testing took place.

The letters within the squares represent the five treatment conditions: A, 0 physical exertion; B, 2 minutes; C, 4 minutes; D, 6 minutes; E, 8 minutes.

The numbers within the squares, 1. . .5, represent the different tests of mental performance.

A further experimental consideration was scheduling the testing between 6:30 and 8:00 am each morning (See Appendix C). This

	D_1	D_2	D_3	D_4	D_5
S_1	A_2	E_3	D_1	C_4	B_5
S_2	C_1	D_5	A_3	B_2	E_4
S_3	B_3	A_4	C_5	E_1	D_2
S_4	E_5	C_2	B_4	D_3	A_1
S_5	D_4	B_1	E_2	A_5	C_3

Figure 7 Greco-Latin Square Design
(replicated four times)

was done to standardize as much as possible the arousal levels of the subjects prior to being tested.

Due to the limited time suitable for testing each morning subjects 1. . .10 were tested during the first week of testing and subjects 11. . .20 were tested during a second consecutive week.

APPARATUS

The apparatus used for this experiment was: a Monarch bicycle ergometer, tape recorder, metronome, stop watch, and a stethoscope.

PROCEDURE

Instructions (See Appendix A), in the form of a written outline and personal interview, were given prior to testing. The subject arrived at the testing station and was instructed to take his position on the bicycle ergometer. He then excecuted the desired exercise task which entailed riding the ergometer for the specified length of time at a rate of 50 revolutions per minute. A stethoscope was positioned during the last 30 seconds of the ride and heart rate was monitored for the last fifteen seconds. Immediately upon completion of the exercise treatment a tape recorder, situated beside the subject, was turned on and the test of mental performance was initiated. During this time the subject remained positioned on the bicycle ergometer.

ANALYSIS OF DATA

The data was analysed with an ANOVA for a 5 x 5 Greco-Latin square to test the effects of the treatments and their order, the days, and the tests. Since no computer program was available that could provide all of the required information, the sums of squares for each of the effects were calculated separately using the UBC program BMD 08V. The mean squares and F ratios were then computed with a calculator.

In addition, the results for each individual were expressed graphically to permit further analysis of the data by subjective means. This subjective analysis resulted in a decision to segregate the data into two groups--that which was obtained during the first week of testing, and that obtained during the second week. The data for each week was then subjected to a separate one-way ANOVA to test for the effects of the treatments during Week one and then Week two. These calculations were carried out by another UBC computer program, BMD 02V, which provided a repeated measures analysis of variance with an orthogonal breakdown of each source of variation to test for trend.

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS

The results of this investigation regarding the relationship between mental performance and physical exertion are presented in this chapter. The initial phase of the analysis examined the raw scores compiled from all subjects observed during the two week testing period (See Appendix D for raw scores).

The mean scores of a maximum of twenty-eight on the tests of mental performance, were calculated for each testing order, exercise treatment, day of testing and mental performance test and are presented in Table I. This table illustrates that the mean score obtained in the first order of testing was 20.55, the mean score for the first treatment or 0 exertion was 18.25, the mean score on day one or Monday was 16.45, and the mean score obtained when using test one was 19.25.

The data was then subjected to an analysis of variance, the results of which are expressed in Table II. From this table it can be seen that:

(a) The effect of the order of presentation of the treatments was non-significant, ($F_{4,15} = .56$, $p > .05$).

(b) The effect of the various treatment conditions was non-significant, ($F_{4,68} = 2.32$, $p > .05$). In this case the critical F at the .05 level was 2.50.

TABLE I

Mean Scores Obtained from the Test of Mental Performance for Each Order, Treatment, Day, and Test

	1	2	3	4	5
Testing Order	20.55	18.25	17.05	22.30	20.30
Exercise Treatments	18.25	20.45	19.75	19.65	20.35
Days of Testing	16.45	20.40	20.25	21.15	20.20
Mental Performance Tests	19.25	20.05	19.55	20.80	18.80

TABLE II

Results of the Analysis of Variance Applied to Raw Scores Obtained from the Test of Mental Performance

Source	df	SS	MS	F	P
Order of Treatments	4	339.34	84.84	.56	>.05
S W Order	15	2265.65	151.04		
Exercise Treatments	4	61.84	15.46	2.32	>.05
Days of Testing	4	274.14	68.54	10.28	<.01
Mental Performance Tests	4	47.34	11.84	1.78	>.05
Error	68	453.28	6.67		

$F_{.05;4,15} = 3.06$

$F_{.05;4,64} = 2.50$

$F_{.01;4,64} = 3.60$

(c) The day's effect was significant at the .01 level, ($F_{4,68} = 10.28$, $p < .01$).

(d) The effects of using five different tests to measure mental performance was non-significant, ($F_{4,68} = 1.78$, $p > .05$).

The degree to which the effects of the treatments approached significance at the .05 level indicated that a more detailed investigation of the results might be appropriate in order to provide additional insight into the problem under investigation. The second phase of the analysis, therefore, treated the results of the first week of testing separately from those of the second week and required two separate analyses of variance.

The mean scores obtained for each of the treatment conditions are presented for Week one and Week two in Table III.

The results of the analysis of variance for the first week data are presented in Table IV. It can be seen that the effects of

TABLE III

Mean Scores Obtained from the Test of Mental Performance for the Exercise Treatments During Each of the Two Weeks of Testing

	0 min	2 min	4 min	6 min	8 min
Week 1	17.00	19.90	18.80	19.90	18.60
Week 2	19.50	21.00	20.70	19.40	22.10

TABLE IV

Analysis of the Treatment Effects for Week 1

Source	df	SS	MS	F	P
Subjects	9	1599.16	177.68		
Exercise Treatments	4	56.92	14.23	1.38	>.05
Error	36	388.68	10.80		

$F_{.05;4,36} = 2.63$

the treatment conditions were non-significant ($F_{4,36} = 1.38$, $p > .05$). Furtherfore, the results of the trend analysis,(Table VI) indicate that the linear, quadratic, and cubic effects inherent in the data are all non-significant.

The results of the analysis of variance for the Week 2 data are expressed in Table V. Here again the effects of the treatment conditions were non-significant ($F_{4,36} = 1.37$, $p > .05$). The results of the trend analysis, Table VI are also non-significant.

Note: Subject 13 was considerably less physically capable than the others. The result was that he was unable to perform the same treatment conditions as the others and these were therefore modified to 0, 2, 3, 4, and 5 minutes of exertion. It was decided that this subject was quite exhausted after five minutes and his results would, therefore, not be inconsistent with those of the others.

TABLE V

Analysis of The Treatment Effects for Week 2

Source	df	SS	MS	F	P
Subjects	9	933.62	103.74		
Exercise Treatments	4	50.52	12.63	1.37	>.05
Error	36	340.77	9.45		

$F_{.05;4,36} = 2.63$

TABLE VI

Results of the Trend Analysis for Week 1 and Week 2

Week 1	MS	F	P
Linear	10.24	.95	>.05
Quadratic	27.46	2.55	>.05
Cubic	2.56	.24	>.05
Remainder	16.66		
Total	10.80		
Week 2			
Linear	12.96	1.37	>.05
Quadratic	1.40	.15	>.05
Cubic	33.64	3.56	>.05
Remainder	2.52		
Total	9.45		

$P_{.05;1,36} = 4.11$

The mean scores of the heart rates, recorded in Appendix E, indicate that there was a rapid increase from the resting rate of 17.5 beats per fifteen seconds to 36.2 beats for the last fifteen seconds of the two minute exercise treatment. Further increases in the exercise requirements resulted in gradual increases in heart rates until a maximum mean of 46.4 beats was recorded during the last fifteen seconds of the eight minute treatment. This indicated that the subjects had been subjected to strenuous physical activity, particularly during the treatment condition consisting of eight minutes of bicycle ergometer riding.

DISCUSSION

Analysis showed that there was no difference between treatment conditions. The hypothesis: "Varying the amounts of physical exertion will differentially influence mental performance," is not supported, and can, therefore, not be accepted on the basis of these results. The results did, however, tend towards significance with an F ratio for treatments being 2.32 when the critical F ratio at the .05 level was 2.50. These results are expressed graphically in Figure 8. Observation of this figure reveals that physical exertion prior to the mental task has appeared to alter performance. In each case the mean scores of mental performance were higher when preceded by exercise than they were after the treatment condition consisting of no exercise. This tendency towards significance could indicate that although the hypothesis could not be accepted, it should not automatically be rejected,as limitations within the experimental design have resulted in the failure to control all the factors which could influence mental performance other than physical exertion.

The order and tests effects were both non-significant. This is interpreted to mean that the order in which the subjects received their treatment conditions made no difference. It also indicates that there were no differences between the tests in degree of difficulty.

The day's effect was, however, significant at the .01 level. Examination of the mean scores (Table I) reveals that day one,

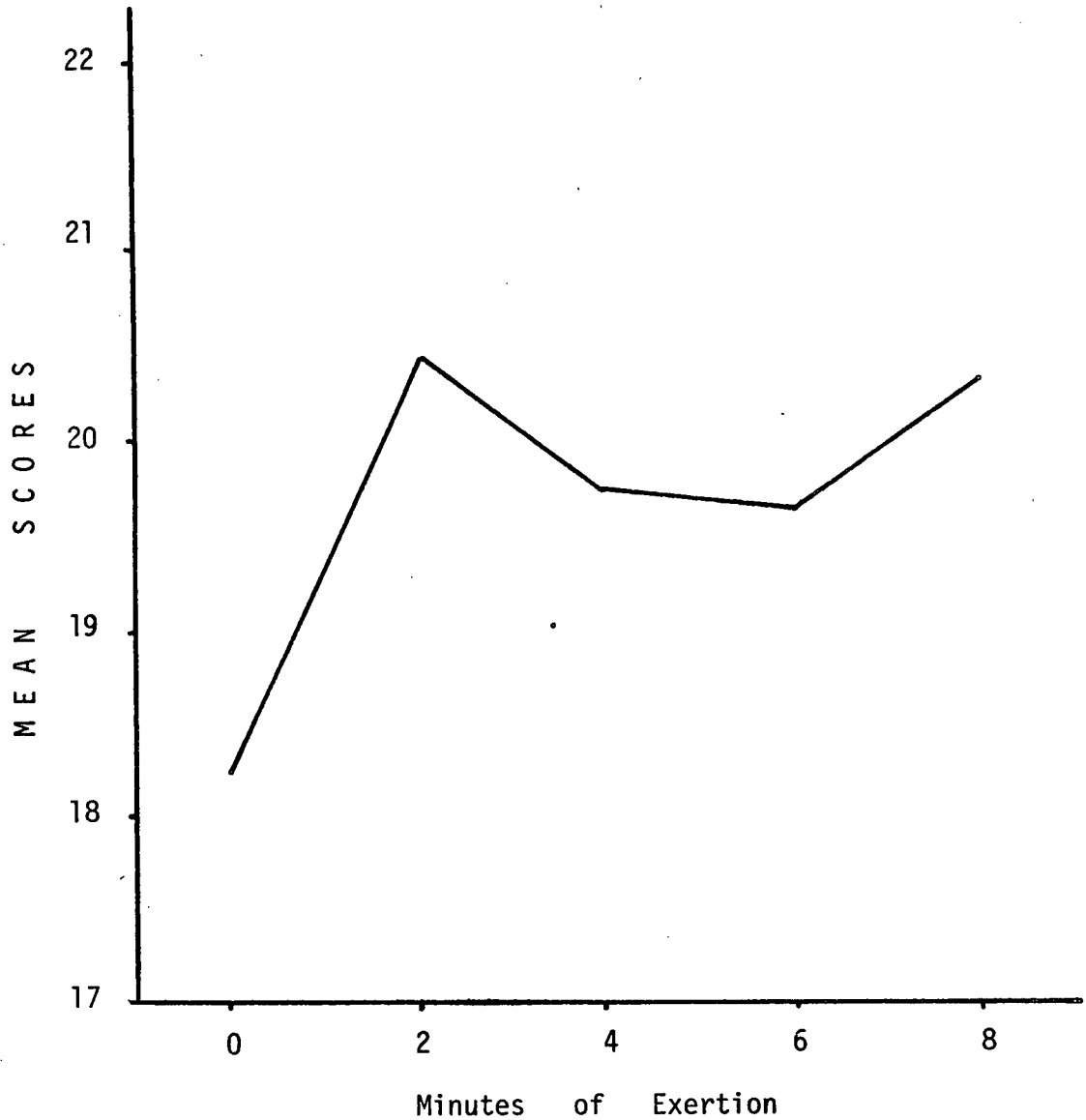

Figure 8 Mean scores of mental performance for the five treatment conditions

or Monday, of each week had a much lower mean score than the other days, all of which were similar. This was interpreted to mean that the students were not adequately prepared for their first testing session. It appears that more than one minute of practice would be necessary for the subjects to become familiar with this test. Perhaps more accurate results would have been obtained if the subjects had each undergone a practice trial during the week prior to testing. Observation of the mean scores indicates that only one trial was necessary to stabilize the scores. The randomizing of treatments distributes the day's effect evenly amongst the treatment conditions, but it is uncertain how it has affected the analysis of the results. For example, Figure 9 shows the graph of each subject's individual performances. Subject two scored particularly poorly after his third treatment condition which was undertaken on day one. This is entirely opposite to the expected response and this descrepancy could, therefore, be due to the novelty of the testing situation on day one.

A second factor which could have influenced the results was that several of the subjects' scores were perfect or nearly perfect on one or more of the tests. The individual graphs for subjects 7, 8, and 19 (Figures 9 and 10) show high scores with little fluctuation for each treatment. This could mean that some subjects have a particular aptitude for this type of test or, that it was generally too easy. The degree of difficulty could possibly have been increased by speeding up the presentation of digits from one per second to one every 3/4 or even 1/2 a second.

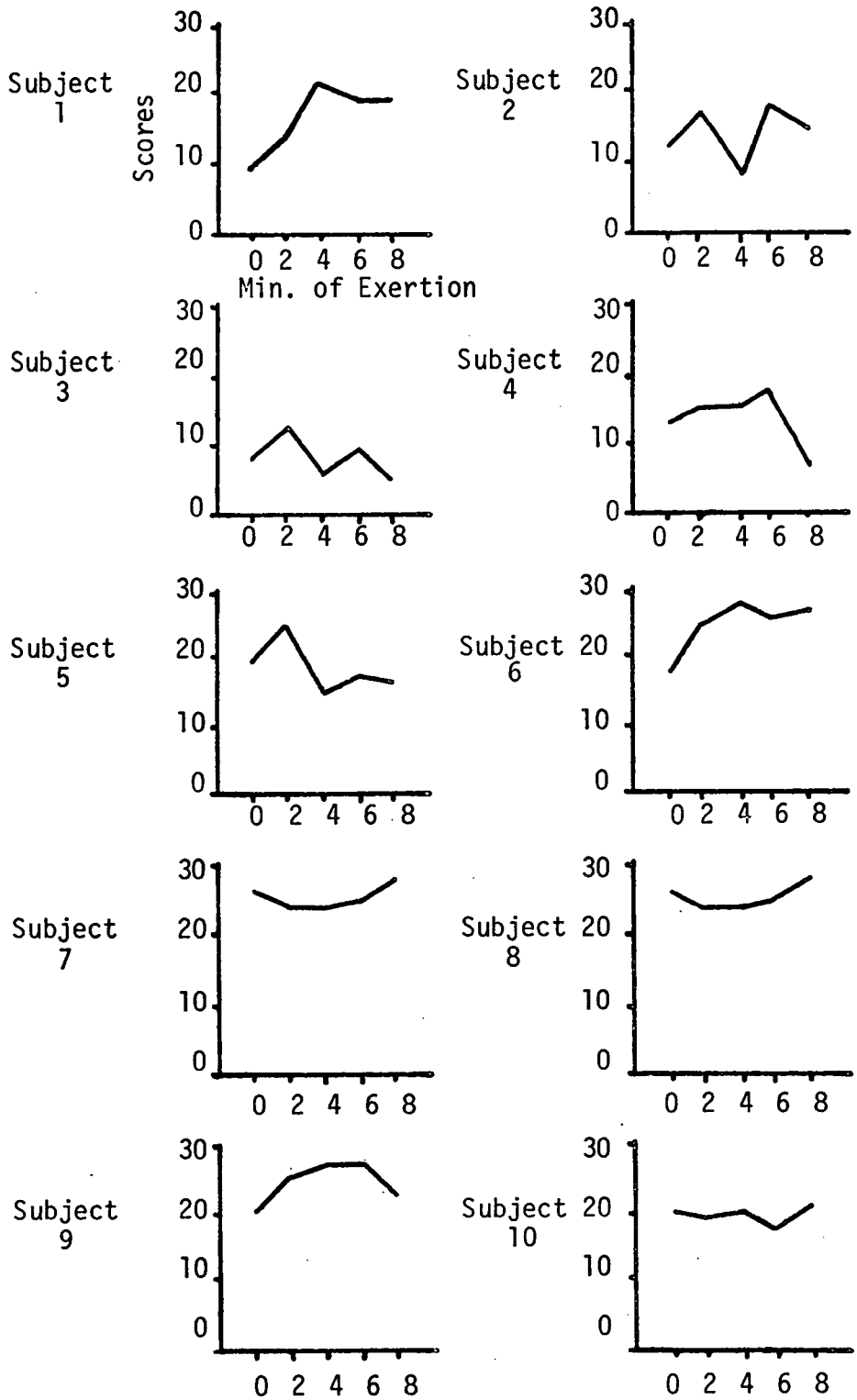

Figure 9 Individual scores obtained from the test of mental performance (Week 1)

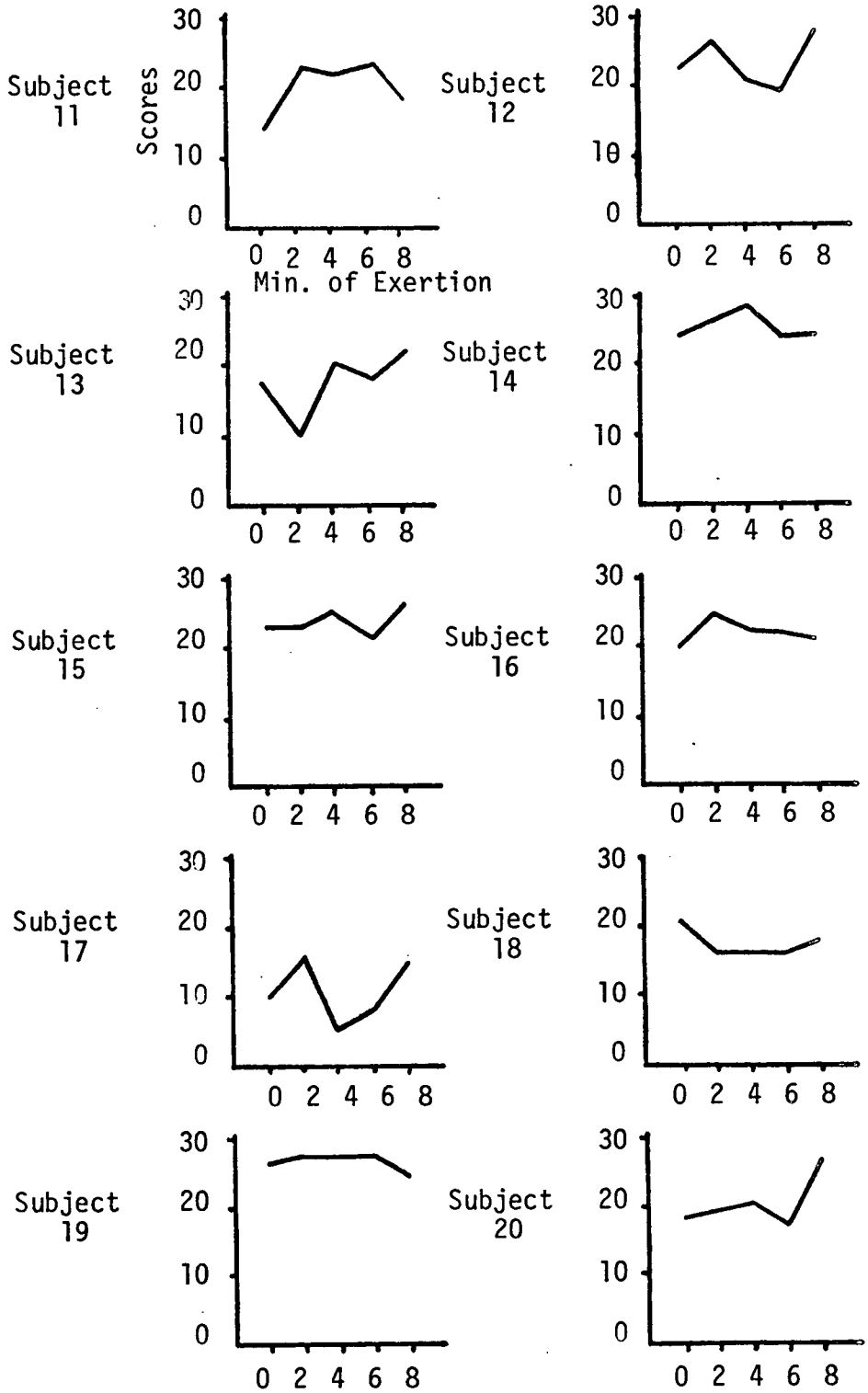

Figure 10 Individual scores obtained from the test of mental performance (Week 2)

The second hypothesis: "The influence of physical exertion on mental performance will be of an inverted U nature" must also be rejected. On the basis of the results in this study it must be accepted that the influence of physical exertion on mental performance will not always be of an inverted U nature or, that the experimental procedures (some of which have been mentioned previously) have resulted in inconclusive results.

The nearness to significance of the effects of the treatments, however, indicated that a more detailed investigation of the results was in order. Inspection of the graphs of individual scores (Figures 9 and 10) revealed that the behaviour of many individuals could indeed be described by an inverted U relationship even though the highest scores, that is, the peak of the curves, varied amongst individuals.

Closer examination revealed some interesting trends and provided a basis for further analysis. Some graphs showed improved scores after the fifth treatment condition, which was contrary to predicted behaviour. This was particularly evident during the second week of testing where six of the ten graphs showed improvement after the most exhausting treatment condition. It was thought, on the basis of these observations, that the subjects tested during the second week may have reacted differently to the treatment conditions than the subjects who were tested first. The two weeks of testing were, therefore, analyzed separately.

Analysis of the treatment effect again yielded non-significance for both Week one and Week two (Tables IV and V). A trend analysis done for each week also yielded non-significance (Table VI). It did, however, suggest that there was a much greater quadratic effect during the first week but a shift to a larger cubic effect during the second week.

The second week's results, although non-significant, do tend towards showing a significant cubic effect with a calculated $F_{1,36} = 3.56$ and critical $F_{.05;1,36} = 4.11$. Graphic presentation of the scores (Figure 11) illustrates this effect. During Week two there is a distinct change in direction of the graph to describe the fifth treatment condition which appears to be responsible for the tendency toward a cubic relationship during this week. A corresponding change is not observed in the presentation of the mean scores for Week one.

This result is opposite to what was expected and probably contributed greatly to the non-significance of the overall results. It is, therefore, important to speculate as to why such results were obtained.

Observations during testing sessions indicated that the subjects during the second week of testing were very aware of the exhausting nature of the fifth treatment condition (riding the bicycle ergometer for eight minutes). They had been instructed not to discuss the experiment amongst themselves but this request was difficult for young subjects, living in such close quarters as the campus dormitories, to adhere to.

Most of the subjects appeared to be very competitive and anxious to perform well even though they did not receive any

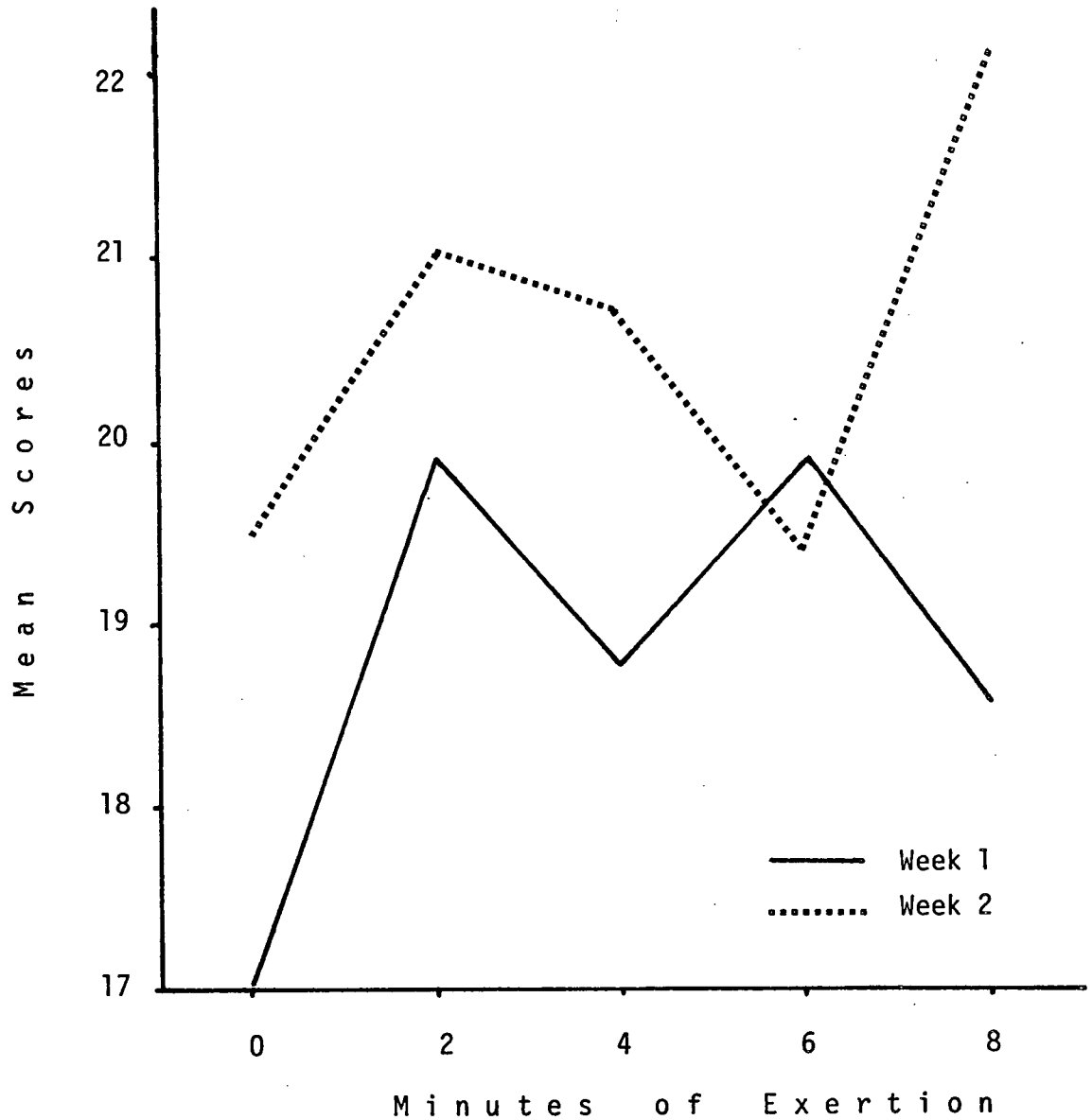

Figure 11 Mean scores of mental performance for the five treatment conditions obtained during Week 1 and Week 2

knowledge of results. The outcome was that many subjects were particularly keyed up and became highly motivated, or aroused when informed that they were to perform the eight minute ride which was rumoured to be very difficult. Subjective evaluation revealed therefore that the second group of subjects was much more highly motivated to do well on the fifth treatment condition during the second week than were those tested during the first week.

The importance of these observations of the effects of physical exertion on mental performance is that they may be explained in terms of some of the more recent theories of arousal which have not been considered in the literature relating arousal to physical exertion.

Samuels (1959) and Eysenck (1967) both suggest that two distinct pathways exist which produce cortical arousal. Eysenck described the first arousal system (AS I) as ascending directly from the reticular formation which was stimulated by sensory afferents. The second arousal system (AS II), he suggested, involves the limbic system and the hypothalamus and is stimulated by emotions. Routtenberg (1968) expanded this concept and suggested that AS II may also be a reward system.

In terms of this study it would seem that AS I may have been activated by sensory afferents resulting from physical exertion. According to Routtenberg (1968) high levels of activation could produce adverse stimulation in AS II which would cause inhibition of

AS I and result in corresponding performance decrements. This would have been the expected result. It seems possible, however, that the high level of motivation and incentive of subjects during the second week could have resulted in the positive stimulation of AS II. This could have caused more efficient levels of arousal during the fifth, or most exhausting, of the treatment conditions.

It seems, therefore, that in practical situations AS II, stimulated by emotions or reward, may make an important contribution to the overall degree to which an individual may be aroused. In this study, differing motivations, which may provide one of these stimuli to AS II, were not anticipated and therefore not measured. It was only in the explanation of the possible factors which have influenced the results, in a way that was not expected, that motivational levels were suspected to be very important in contributing to arousal. If this is true it could explain why some athletes continue to perform brilliantly when apparently exhausted, whereas, less motivated athletes may demonstrate behaviour predictable by the inverted U hypothesis. Perhaps the increased arousal attributed to high motivation compensates for the expected performance decrement as a result of increasing fatigue.

Future research will be required to investigate the effects of motivation and reward on arousal. Nevertheless, the tentative suggestions of this study, which lie within the bounds of current arousal theories, indicate that performance may not always follow a simple inverted U curve as levels of physical exertion are increased.

CHAPTER V

SUMMARY AND CONCLUSIONS

Activation, or arousal, has been described as the degree of neural activity of an individual at any given time and is manifested by a general drive to perform conscious functions. Furthermore, it has been said that as an individual's level of arousal increases there is an increase in his effectiveness of performance for any particular type of behaviour. If the arousal level continues beyond this optimum, a gradual decrease in performance is predicted and is described as an inverted U relationship.

Arousal has been attributed to several stimulus conditions including fear, anxiety, emotion, shock, noise, heat, and physical activity. Evidence also exists which indicates that levels of activation, induced by dynamic physical activity, can affect mental performance.

PROBLEM

This study was designed to further investigate the relationship between physical exertion, of a more practical nature, and mental performance and then to interpret this information in terms of arousal theories.

The hypotheses under investigation were:

(i) Varying the amounts of physical exertion differentially affected the level of arousal and thereby influenced mental performance.

(ii) The influence of physical exertion on mental performance corresponded to the inverted U hypothesis, i.e. increasing exertion improved performance until a maximum level of proficiency was obtained, beyond which the level of performance began to deteriorate.

This study was limited to bicycle ergometer riding as a method of inducing physical exertion. The study was also limited by an inability to control for the effects of the motivation of the subjects while they were being tested. A further limitation was the use of one test of mental activity to be used as a gauge for mental performance.

SUBJECTS

Twenty male students residing in campus dormitories volunteered as subjects.

METHODS AND PROCEDURES

Each volunteer was subjected to one of five different physical exertion treatments on each of five consecutive days. These treatment conditions were randomly assigned to five different orders and consisted of riding a bicycle ergometer for 0, 2, 4, 6, and 8 minutes at a rate of fifty revolutions per minute with a resistance of four kilograms. This resistance was applied to ensure that sufficient effort, to exhaust the subjects after eight minutes of riding, would be induced. A stethoscope was positioned during the last thirty seconds of the ride and heart rate was monitored for the last fifteen seconds. (Appendix E indicates that during this treatment the heart rates of all subjects reached 176 beats per minute or greater).

On completion of each daily exercise bout the subject performed a task designed to measure mental performance. This task required the subject to listen to a list of random numbers, prerecorded at one second intervals with the objective of detecting a sequence of digits which occurred in the order "odd number - even number - odd number", and to respond by saying "yes" before the next digit was presented. The score was the number of series correctly identified. Furthermore, the task was divided into two parts daily. Part one was a short one minute practice trial to familiarize the subjects with the test each day. Part two was the test trial of two and one half minutes duration which consisted of 150 digits. Five different sets of digits were randomly assigned to each of the testing sessions.

All treatments and tests were administered between 6:30 am and 8:00 am daily during two consecutive weeks of testing.

The subjects were assigned to four 5 x 5 Greco-Latin squares enabling simultaneous randomizing of the order of the treatments, the tests of mental performance, and the day's effect.

ANALYSIS OF DATA

The data was analyzed with an ANOVA for a 5 x 5 Greco-Latin squares to test for the effects of the exercise treatments and their order, the days of testing, and the different tests of mental performance. The sums of squares for each of the effects were calculated with the UBC computer program BMD 08V. The second phase of the analysis incorporated two one-way ANOVA's to test the effects of the exercise treatments during Week 1 and then Week 2. These calculations were carried out by another UBC computer program, BMD 02V, which provided a repeated measures analysis of variance with an orthogonal breakdown of each source of variation to test for trend.

RESULTS AND DISCUSSION

Analysis of variance yielded no significant difference between the various treatment conditions. These results did, however, tend towards significance and are expressed graphically in Figure 8. Inspection of this figure indicated that physical exertion prior to the mental task seemed to alter performance. In each case the mean

scores of mental performance were higher when preceded by exercise than they were after the treatment condition consisting of no exercise.

The order of treatments and test administered effects were also non-significant.

The effect of the day was, however, significant. This seemed to be due to particularly low scores obtained on day one of testing, or Monday of each week, and was interpreted to indicate that the subjects were not adequately prepared for their first testing session.

The degree to which the effects of the treatments tended towards significance indicated that a more detailed investigation of the results might provide more insight into the problem under investigation. Therefore, inspection of the individual's graphs of performance scores (Figures 9 and 10) was undertaken and revealed differences between those scores obtained during Week 1 and those obtained during Week 2 of testing. Consequently, a separate analysis of variance for each week's data was conducted, but yielded no significant differences.

A trend analysis of the data also yielded non-significance but did suggest that there was a greater quadratic effect during the first week, but a shift to a larger cubic effect during the second week. This cubic relationship is contrary to the expected inverted U relationship which would be described by a significant quadratic effect. It was felt that this unexpected result could possibly be accounted for by the subject's strong motivation to do

well on the treatment condition which required a strenuous eight minute ride.

Recent theories, which predict that arousal is a result of components from two activating systems, indicate that the effects evident may well have been stimulated by emotions or reward as it was expected that high exertion would result in low mental performance. This could account for the high mental performance scores observed after the most exhausting of the treatment conditions. These results suggest that stimulation of a second arousal system which deals with emotions may be sufficient, at times, to alter individual behaviour in such a way that the effects on performance cannot always be described in terms of a predictable inverted U relationship.

CONCLUSIONS

On the basis of the results obtained in this study the hypothesis: "Varying the amounts of physical exertion will differentially affect the level of arousal and thereby influence mental performance" cannot be accepted. However, as these results did tend toward significance in terms of the effect of the physical exertion conditions, and they indicated that physical exertion seemed to have a positive effect upon mental performance, further research in this area would be desirable before this hypothesis is completely rejected.

The second hypothesis: "The influence of physical exertion on mental performance will correspond to the inverted U hypothesis," that is, increasing exertion will improve performance until a maximum level of proficiency is obtained, beyond which the level of performance will begin to deteriorate, is also unsupported and, on the basis of the results must be rejected. It is concluded, therefore, that the effect of physical exertion upon mental performance cannot always be described by a simple inverted U relationship.

These conclusions are, however, contrary to those found in other similar studies. Stockfelt (1968) utilized the bicycle ergometer to induce exertion of 0, 25, 45, 65, 85, and 0 percent of the individual subject's maximum. His test of mental performance was comprised of forty mathematical problems involving simple addition and subtraction. The results indicated support for the inverted U hypothesis. Davey's (1973) study also supported the inverted U hypothesis. He found that mental performance scores, as measured by the Brown and Poulton test, improved after 1/2, 2, and 4 minutes of bicycle ergometer riding, but deteriorated after six minutes of exertion. Davey, however, grouped his subjects according to their tendencies towards extraversion, intraversion, neuroticism and stability.

The inconsistency between the results and conclusions of this study and other similar studies indicate that there is a great deal yet to be learned about the relationship between arousal, included by physical exertion, and mental performance. The effects

of motivation on arousal levels may prove to be very important but further research investigating the interaction between motivation, mental performance, and physical exertion is required. Experiments which could control motivation and others which could selectively induce high motivational levels would be desirable.

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APPENDIX A

INSTRUCTIONS TO STUDENTS

INSTRUCTIONS TO SUBJECTS

You are taking part in a scientific experiment which will investigate one aspect of how physical exertion affects you. A full explanation of results will be sent to you upon completion. During the test period you are requested to follow the instructions carefully to ensure the credibility of the experiment.

1. You have been assigned a test time between 7 and 9 AM. It is important that if you wake before this time that you remain as inactive as possible. Preferably try to go to sleep again or, at least, stay in bed.

2. When your time comes you will be requested to come to the test site and to sit on a bicycle ergometer. If you have any questions or do not understand any of the instructions, ask at this time for clarification.

3. You will be asked to start peddling in time with a metronome at the rate of one revolution per beat, i.e.: each time the metronome beats, your right foot should be at the bottom of the revolution, or straight down.

4. You will be asked to stop at a given time, known by the experimenter. Remain sitting on the ergometer.

5. A tape recorder will be switched on and you are to listen to this. You will hear a series of numbers at one second intervals. Your task will be to detect a sequence of digits which occur in the order "odd-even-odd," and to respond by saying "yes" before the next digit is presented. i.e. if you hear ". . . 7,4,9,..." (that is "odd-even-odd") you respond "yes". If you hear 7,4,9,2,3, you must respond "yes" after 9 and after 3. In these five numbers there are two "odd-even-odd" sequences, the 9 being in both of them. i.e. 7,4,9, and 9,2,3.

6. You are to refrain from discussing the experiment with fellow students until the testing is complete.

7. You will be called each day at the same time for a total of five tests (Monday to Friday). The tests will average about five minutes each and range from about two minutes to ten minutes.

Thank you very much for participating in this experiment. Your effort is greatly appreciated.

APPENDIX B

SAMPLE SCORE SHEETS

SAMPLE SCORE SHEETS

Test Number 1

Treatment _____

Subject _____

Heart Rate (last 15 sec) _____

6 1 7 6 3* 4 3* 7 3 9 7 5 4 1* 4 9* 3 7 1 9 4 5* 8 5 9 5 9 8 4 3 4 9* 3 2

4 8 7 6 5* 6 5* 6 8 2 8 6 5 3 9 8 7* 5 8 4 3 6 8 3 5 1 5 2 6 3 8 2 5 9 6

2 3 5 3 4 1* 8 3* 9 2 5* 7 5 8 4 8 6 1 3 6 7* 4 6 3 8 2 6 9 3 4 2 5 4 1*

4 1* 5 1 4 9* 5 1 4 3* 9 2 3* 2 5* 8 3* 1 8 1* 8 1* 7 9 5 7 4 3* 8 5* 3 9

6 9 7 3 4 1* 7 5 7 5 8 5* 3 1 4

Total Number Correct Responses _____

Test Number 2

Treatment _____

Subject _____

Heart Rate (last 15 sec) _____

3 9 1 7 9 8 3* 8 1* 7 3 1 9 4 5* 3 5 3 4 1* 2 8 7 2 9* 5 8 2 7 2 8 9

1 9 2 1* 8 1* 9 3 4 5* 2 1* 2 4 7 3 7 5 8 7* 8 2 9 4 1* 5 3 9 7 2 9*

4 3* 7 9 2 3* 1 2 5* 8 7* 2 4 8 9 4 9* 4 3* 4 5* 2 8 6 1 4 9* 1 6 1*

7 8 9* 3 8 2 7 8 6 7 1 6 4 8 3 4 5* 9 5 9 3 2 4 3 5 3 2 3* 8 1* 8 7*

4 5* 6 8 2 8 2 4 7 2 3* 8 4 6 2 4 8 1 8 4 7 1 9 2 4

Total Number Correct Responses _____

Test Number 3

Treatment _____

Subject _____

Heart Rate (last 15 sec) _____

4 2 8 2 4 8 2 7 4 5* 4 7* 5 4 5* 3 6 5* 9 4 7* 8 6 9 8 7* 1 2 1* 5

9 1 2 7* 3 6 2 6 1 2 8 2 3 4 6 9 1 6 1* 2 1* 2 3* 8 4 2 7 3 7* 6 4

1* 6 7* 8 9* 5 7 8 3* 9 3 2 3* 4 9* 3 2 4 8 3 4 1* 3 8 7* 6 7* 3 5

8 3* 9 8 3* 5 4 8 7 8 6 9 3 2 9* 5 6 4 6 4 5 3 6 3* 2 6 2 3 4 6 4 7

4 8 4 6 1 4 3* 5 3 8 6 5 9 5 6 1* 7 8 4 9 5 7 8 7* 4 5* 2

Total Number Correct Responses _____

Test Number 4

Treatment _____

Subject _____

Heart Rate (last 15 sec) _____

3 8 1* 8 3* 2 3* 5 3 4 2 3 9 5 9 5 4 3* 8 4 1 7 6 8 7 2 8 3 9 8 7*

1 6 1* 9 4 1* 6 8 2 5 4 3* 4 9* 4 9* 8 4 2 7 8 5* 2 1* 3 2 9* 2 4

9 5 4 1* 2 7* 9 4 3* 9 3 6 4 9 4 2 3 9 7 2 7* 4 1* 6 7* 9 5 4 8 2

1 9 6 7* 3 6 4 6 9 6 2 7 8 3* 7 1 9 2 5* 3 2 8 1 3 8 5* 3 7 4 8 2

4 8 2 5 6 8 3 4 6 5 4 9* 6 9* 2 4 7 9 5 4 3* 5 1 5 4 3* 9 6 1*

Total Number Correct Responses _____

Test Number 5

Treatment _____

Subject _____

Heart Rate (last 15 sec) _____

8 9 2 1* 2 3* 6 2 5 7 8 7* 4 7* 3 5 1 2 7* 2 3* 2 1* 3 9 2 4 1 3 9

6 5* 1 4 5* 9 8 1* 8 6 3 9 1 8 2 9 3 2 9* 4 1* 2 4 2 3 6 3* 1 2 6

1 6 5* 9 8 5* 4 6 3 8 6 5 8 5* 6 7* 5 4 5* 4 6 4 5 2 8 4 1 5 3 2

5* 4 1* 2 5* 4 1* 7 1 9 8 4 1 5 9 2 6 1 3 1* 4 5* 4 5* 8 1* 4 3* 9

8 4 9 8 6 5 7 9 2 8 7 2 4 8 6 2 1 5 4 6 3 9 8 9* 4 6 8 1 2 6 4

Total Number Correct Responses

_____

APPENDIX C

TESTING SCHEDULE

TESTING SCHEDULE

Due to the varying lengths of treatments and degrees of promptness, the subjects were assigned to the following time periods. When a subject completed his test the next subject was called to the testing station.

Week 1

Subjects	
1, 2, 3	6:30-7:00 AM
4, 5, 6	7:00-7:30 AM
7, 8, 9	7:30-8:00 AM
10	8:00 AM

Week 2

Subjects	
11, 12, 13	6:30-7:00 AM
14, 15, 16	7:00-7:30 AM
17, 18, 19	7:30-8:00 AM
20	8:00 AM

APPENDIX D

RAW SCORES

RAW SCORES
FOR EACH TREATMENT CONDITION

(Maximum 28)

Subject	Treatments				
	A (0 min)	B (2 min)	C (4 min)	D (6 min)	E (8 min)
1	9	14	22	19	19
2	12	17	8	18	14
3	8	12	6	9	5
4	13	15	15	17	7
5	19	24	15	17	16
6	17	24	27	25	26
7	26	24	24	25	28
8	26	24	24	25	28
9	20	26	27	27	22
10	20	19	20	17	21
11	14	22	23	22	18
12	22	26	21	19	27
13	17	10	20	18	22
14	24	26	28	24	24
15	23	23	25	21	26
16	20	25	22	22	21
17	10	16	5	8	15
18	21	16	16	16	18
19	26	27	27	27	24
20	18	19	20	17	26

APPENDIX E

HEART RATES

HEART RATES

MEASURED DURING THE LAST 15 SECONDS OF EACH TREATMENT CONDITION

Subject	Treatments				
	A(0 min)	B (2 min)	C (4 min)	D (6 min)	E (8 min)
1	-	37	38	40	45
2	-	38	38	43	45
3	-	35	38	38	46
4	20	39	35	43	46
5	14	38	40	45	50
6	-	39	40	40	48
7	-	36	41	41	44
8	-	31	34	49	-
9	21	35	41	45	47
10	17	36	43	47	44
11	12	37	40	41	45
12	14	39	45	45	45
13	22	26	42	46	48
14	-	42	44	43	47
15	16	36	42	38	46
16	14	-	47	-	-
17	23	40	38	45	48
18	21	38	28	46	48
19	13	39	45	46	45
20	18	26	43	48	48
Mean	17.3	36.2	40.1	43.6	46.4