Effects of Various Levels of Fatigue on the Speed and Accuracy of Visual Recognition.

Robert Lewis Johnson
Louisiana State University and Agricultural & Mechanical College
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EFFECTS OF VARIOUS LEVELS OF FATIGUE ON THE SPEED AND ACCURACY OF VISUAL RECOGNITION

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EFFECTS OF VARIOUS LEVELS OF FATIGUE
ON THE SPEED AND ACCURACY OF VISUAL RECOGNITION

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
In partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The Department of Health, Physical, and Recreation Education

by

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December, 1979
Acknowledgements

The author wishes to thank Dr. Jerry Thomas, Dr. Mike Stone, Dr. Dick Magill, and Dr. Bob Mathews for the time and effort put into this investigation.

A special thanks to Dr. Jack Nelson whose leadership and guidance in this endeavor were invaluable.
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ABSTRACT

Thirty-six volunteer subjects participated in an investigation to examine the effects of various levels of fatigue on recognition memory. The subjects, who were required to learn certain items, were divided into two groups based on memory set size. The memory set items consisted of dot patterns of the Garner-Clement variety. These memory set items as well as alternates (items never seen by the subjects) were presented via a tachistoscopic slide projector. The items were of five types; (1) target items of high goodness, (2) target items of low goodness, (3) alternate items of high similarity to target items of high goodness, (4) alternate items of high similarity to target items of low goodness, and, (5) alternate items of low similarity to both types of target items. Upon presentation of each item a digital response time counter would begin to register. The subjects responded to each item by depressing a telegraph key which stopped the response time counter. Correctness of response as well as response times were recorded for each item. All subjects completed the above procedure while under the influence of fatigue induced by pedaling a cycle ergometer. Fatigue levels were no fatigue, 80% of PWC_{170} for six minutes, and 100% of PWC_{170} for six minutes. The subjects responded to each item presentation concurrent with the pedaling of the cycle ergometer.

The results indicated that fatigue of the type and intensity employed does not significantly effect overall recognition time. There was, though, a significant difference in response times between
the target items with the high goodness items showing the better response times. Among the lures, the lure which was dissimilar to both target items had the fastest response time.

Regression analysis was used to fractionate memory into component stages. An arousal effect in the form of an inverted U was noted in the comparison stage of memory. It was also noted that an intermediate level of fatigue hindered performance in other stages of memory. The fact that opposite effects were revealed in these stages of memory may have contributed to the fact that no overall effects on recognition time were shown.
CHAPTER I

INTRODUCTION

Success in motor performance is dependent upon many variables. One such variable is how quickly the performer recognizes stimuli and processes information about the stimuli. Additionally, the performer must separate the relevant from the irrelevant stimuli which may be presented simultaneously.

Snodgrass, Luce, and Galanter (1967) maintain that the major portion of the increased time and variability of complex reaction time scores over that of simple reaction time scores is caused by an increase in the amount of time for the process of recognition. Recognition of stimuli is internal and falls within the framework of human information processing. There are currently several models or flow charts which depict the human information processing system (Crowder, 1976, ch. 2; Martiniuk, 1976, p. 5; Singer, 1975, ch. 3). While these conceptualizations differ in both design and terminology, they possess basic similarities in that they all utilize the sensory, perceptual, decision, and effector central control mechanisms.

The human has innate difficulty in processing excessive amounts of information simultaneously. Difficulty or delay in processing time has been determined to be of central origin and may be due to the increasing complexity of the task which affects either the perceptual or decision mechanisms (Welford, 1959). A delay at either of these two functions would have a detrimental effect on the response time of the performer.
Task complexity may be increased if either the difficulty of a single task is increased or the performer is required to complete two or more tasks simultaneously. In both cases, a greater demand is placed on the total processing capacity of the performer.

The ability to perform is an interaction between one's physical and mental capabilities. Thus, along with competing mental tasks one often has to cope with the demands of physical tasks with regard to available processing space. Kahneman (1973) pointed out that when an individual is performing concurrent physical and mental tasks no decrement will be shown in either task until the processing capacity of the individual is exhausted, but as the demands of one task increase and begin to exceed certain limits the performance on one or both of the tasks begins to deteriorate.

In athletics and other forms of physical activity, the performer is often required to perform certain mental tasks while under stressful physiological conditions such as different levels of fatigue. The stress imposed by the physiological demands may interfere with the recognition of stimuli, both relevant and irrelevant. Since recognition demands increase with increased complexity of stimuli, perceptual demands plus the added demands of rigorous physical exercise may exceed the total processing limits of the individual in certain situations. This could be detrimental to performance of the physical task, the mental task, or both depending upon the circumstances. It was the purpose of this study to investigate the effects of physical fatigue on the speed and accuracy of visual recognition.
Review of Literature

Theories of Selected or Divided Attention

One of the earliest theories of divided attention was the limited channel theory (Davis, 1957, 1959; Welford, 1959). The basic assumption underlying the limited channel theory is that there is a single channel through which one signal can be cleared at a time. It is assumed that (1) there are a number of sensory input mechanisms capable of receiving and storing data for a short period; (2) a number of effector mechanisms contain both control and perceptual elements capable of carrying out a series of actions; and, (3) most importantly, there exists a single channel decision mechanism between the two (see Figure 1).

According to this theory, sensory data may be collected and stored for a brief period until the channel is cleared. When two stimuli are presented simultaneously, the increase in reaction time latencies are accounted for by the brief storage period (Welford, 1959). Delay of refractory period is experienced regardless of whether the inputs are of the same or of different modality (Davis, 1959).

![Figure 1. Flow model of the limited channel theory.](From Kahneman, 1973, p. 6.)

Deustch and Deustch (1963), while still following the single, limited channel concept, proposed that the bottleneck in processing was not between the sensory registration and storage as proposed earlier,
but between the perceptual analysis and the response selection (see Figure 2). Consequently, the perceptual mechanism performs the function of separating the relevant stimuli from the irrelevant stimuli.

**Figure 2.** Flow model of the limited channel theory proposed by Deustch and Deustch. (From Kahneman, 1973.)

An alternative to the single limited channel theory is the multi-channel theory (Allport, Antonis, & Reynolds, 1972). The multi-channel theory postulates that there are special purpose computers termed processors and stores, which operate in parallel fashion. In some cases, the computers are capable of accepting only one message at a time. In this paradigm, processing will be suppressed only to the extent that the same processors are involved in dual processing. While hypothesizing a multi-channel mode of information processing the multi-channel theory does not deny the single channel capacity of the brain. The single channel capacity of the brain will be enhanced to the extent the subject is concentrating on just one particular task.

Dissatisfaction with the preceding models led to the postulation of the limited channel model (Kahneman, 1973; Moray, 1967). The previously mentioned theories assumed the existence of structural bottlenecks within the system. A capacity model (see Figure 3) assumes that there is a general limit on man's ability to perform mental work and that the limited capacity can be allocated with considerable freedom among concurrent activities. Different activities impose different
demands on the limited capacity of the system. When the demands placed on the system exceed its capacity, performance falters or fails entirely. The activity can fail either because there is not enough capacity to meet the demands or because the allocation policy channels available capacity to other activities (Kahneman, 1973).

Physiological factors may have direct influence on the system. The allocation policy may be influenced by these physiological factors. Fatigue and sleep deprivation apparently increase the difficulty of continuous performance and the motivated subject compensates by increased effort (Kahneman, 1973). High arousal within the subject causes allocation to be concentrated on the dominant aspects of the situation at the expense of other aspects (Kahneman, 1973, p. 38).

Allocation of attention with the limited capacity model is of prime consideration in dealing with motor performances. The variability of responses when dealing in a dual task paradigm may be accounted for within this allocation policy.

Memory Load and Reaction Time

Sternberg (1969) has shown that reaction time increases linearly with increasing numbers of items in the memory set. Using from one to six items, Sternberg concluded that reaction time increases by approximately 38 msecs with the addition of each new item into the memory set. Sternberg (1969) regressed response time across memory set load and concluded that the resultant slope represented the comparison stage of memory and the intercept represented all those events which occur just once, such as the encoding of stimuli and the organization and execution
Figure 3. Capacity model. (From Kahneman, 1973, p. 10.)
of the motor response. Sternberg (1969) further explained that when two or more regression lines (each constructed using different types of stimuli) were compared differences in slopes would be interpreted as the effects these different stimuli had on the comparison stage of memory. Also, any difference in the slopes would reflect the effects the stimuli had on the other events associated with memory.

Physical Exercise and Vision

Vision has been shown to be affected by physical activity. Krestovnikov (1951), citing a series of Russian studies, reported a significant increase in visual acuity and field of vision following a 1,000 meter run. Maximum increase in acuity was noted immediately following the run in a majority of the individuals participating in a follow-up study. Krestovnikov (1951) also reported that athletes, specifically basketball, soccer, and hockey players had an increased visual field following competition. These findings are somewhat in conflict with the findings of Tussing (1940) who noted both a marked improvement and a marked impairment of vision in athletes following a football practice. A more recent study Vlahov (1977) supports the reports made by Krestovnikov (1951). Vlahov, using the Harvard Step Test as the mode of exercise, determined that following the completion of this test visual acuity was improved.

Tachistoscopic detection is also influenced by various levels of physical exercise (Goldwater & Zirul, 1973). Tachistoscopic detection was affected in an inverted U fashion following various periods of side straddle hops up to a maximum of 100 seconds. It was suggested that
physical activity may serve as an attention diverting device.

Arousal and Mental Performance

Performance in different activities has been studied within at least two conceptual frameworks, the inverted U (Hebb, 1949) and the signal detection framework (Welford, 1975). It has generally been concluded that arousal induced by increased muscular tension or white noise has a facilitating effect on the performance of various mental tasks (Dornic & Stelmach, 1974; Hamilton, Hockey, & Quinn, 1972; Hockey & Hamilton, 1970; Welford, 1963). A Hebbian or inverted U relationship has also been demonstrated between performance on a mental task and the level of arousal within the subject (Stennett, 1958). Auditory stimulation or arousal by the use of white noise also facilitates the perception of stimuli presented on a tachistoscope (Andraessi, 1965).

Sleep Deprivation and Mental Performance

Fatigue due to sleep deprivation has been found to affect various types of mental performance. Immediate recall of word lists showed a significant impairment after one night sleep loss while a delayed picture recognition task showed no significant deficit (Williams, Giesking, & Lubin, 1966). This finding led the authors to deduce that the sleep loss caused difficulty in the formation of the memory trace rather than in storage or retrieval of the material.

Two nights of sleep loss impaired the speed but not the accuracy of mathematical problems (Loveland & Williams, 1963; Williams & Lubin, 1967). The subjects completed the required mathematical addition and subtraction problems after sleep loss with approximately the same
accuracy as during a trial prior to sleep loss, but their speed at this task was significantly hampered. After three complete days of sleep loss, both the speed and the accuracy of these mental tasks were significantly undermined (Wilkinson, 1962).

The complexity of the mental task has also been shown to be an important variable when measuring the effects of sleep loss. The more complex the task, whether it is a card sorting task or choice reaction task, the greater the deterioration in performance when compared to less complex tasks measured over the same period of sleep deprivation (Daftuar & Sinaa, 1972; Wilkinson, 1964).

Exertion and Mental Performance

The research pertaining to exertion and mental performance has involved a variety of tasks and different levels of exertion. The Hebbian or inverted U hypothesis has been used as a framework or basis for much of this research.

Physical exertion has been shown to have an effect on mental performance. For instance, light physical effort has been determined to enhance short memory (Dornic, Borg, & Ohlsson, 1973). Although no reference was made to fatigue, the results may be an indicator of how the early stages of fatigue affect mental performance. Burgess and Hokanson (1964) determined that lifting the same amount of weight for various periods of time under various levels of exertion affected performance on a digit symbol task in an inverted U fashion. More complex tasks have also been affected in the same manner. An inverted U relationship was found when mathematical problems were worked under various levels of
exertion on a bicycle ergometer (Stockfeldt, 1970). The subjects performed at different percentages of their previously determined maximum workloads. The subjects pedaled for five min. at these predetermined percentages before being tested. It was determined that the best performance resulted when the subjects performed at a level equal to 45 percent of their maximum and poorest when they worked at 85 percent of their maximum. Davey's (1973) results were in agreement, indicating a significant improvement in mental performance following moderate exercise and a significant decrease in performance with severe exertion. Davey also concluded that intermediate levels of exertion affected different people in different ways, i.e., mental performance is related to subject or personality variables, and these may affect performance also. Stauffacher (1937), on the other hand, noted a linear relationship between increased exercise and decreased mental performance. As the load of concomitant exercise (pulling weights) increased, the performance on memorizing nonsense syllables decreased.

Exception to the above findings was taken by Flynn (1972), who found no significant differences in treatments when various levels of exertion were used in conjunction with a mathematical task. However, Flynn used elementary school boys as subjects instead of adults which had been used in the preceding studies.

Girondo and Pellegrini (1976) hypothesized that medium effort may act as an attention diverting device. The researchers determined that certain levels of physical exercise do not affect levels of attention. In this study one group of subjects viewed a film at rest and another group viewed the same film while pedaling a cycle ergometer.
Both groups were tested for recall at the completion of the film. No significant difference was shown between the two groups in the amount of information recalled and the authors concluded that exercise at this level did not serve as an attention diverting device.

Exhaustion has been shown to produce a significant negative effect on the performance of certain mental tasks. Gutin and DiGennaro (1968) found that extreme exhaustion from treadmill walking had a significant negative effect on accuracy performance in long addition. No adverse effects were noted on the speed of computation.

The physical condition of the subjects apparently is related to mental performance during periods of exertion. Gutin and DiGennaro (1968) and Stockfeldt (1970) noted that there was a tendency for the unconditioned subjects to perform worse than the conditioned subjects while under the same exercise conditions.

The complexity of the task has been shown to have an effect on the performance of mental tasks under fatiguing situations. Simple tasks such as pressing a button to a visual stimulus are not affected by various levels of exertion (Meyers, et al., 1969; Shore, 1958). Conversely, Levitt and Butin (1971) found that when the heart rate exceeds 175 beats per minute the performance on a five choice reaction time task deteriorated. The authors concluded that tasks using considerable information processing will be performed best at a low exercise induced activation while those requiring little or no information processing will be performed best at a high exercise induced activation. Sjoberg (1977) noted essentially the same phenomenon. Sjorberg had subjects pedal on a cycle ergometer at prescribed workloads for a period of 10.5 minutes.
Reaction time measures were taken the last five minutes of each bout. It was determined that more complex reaction time tasks were performed best at lower heart rates (workloads) and that simple tasks were performed best at higher heart rates. Generally, the inverted U was shown for all levels of task difficulty over various exercise levels.

Pattern Recognition

Chekosky and Whitlock (1973) have shown that pattern goodness and pattern similarity are significant factors in the recognition of learned patterns. Chekosky and Whitlock used patterns which had been previously classified as to their goodness (Garner & Clement, 1963). Pattern goodness was determined by having subjects classify and arrange, based on a prearranged criteria, a group of 90 dot patterns into groups based on similarity. These dot patterns consisted of five dots each with no more than three dots going either horizontally or vertically (see Appendix A). It was determined that the better patterns were those that were classified into the smaller groups by the subjects. This was due to the fact that they were less related to other patterns. Conversely, those patterns found to be of poorer quality were those that were placed into larger groups. Basically, these patterns placed into the larger groups were difficult to distinguish from others in that group. Also, the better patterns were found to have fewer alternatives. That is, when a basic pattern is rotated 90 degrees or reflected in a mirror, the better patterns have fewer changes. For example, the pattern . . . is considered good because no matter how it is rotated or reflected the same pattern still exists. At the other end of the continuum, when the
pattern . . . is rotated and reflected, eight different patterns are yielded. Garner and Clement (1963) found a correlation of .83 between the size of the pattern groups and the goodness rating given by the subjects.

Chekosky and Whitlock (1973) found that response times for good patterns were significantly faster than for poor patterns for correct yes responses when used in a recognition paradigm. When an alternate pattern was presented, the response times were faster for those patterns which were dissimilar to the target item than for highly similar alternates.

Summary of Related Literature

Three theories of divided attention were postulated. All three address the problem of competing activities and too much information bombarding the system at one time. Of the three, the limited channel model (Kahneman, 1973; Moray, 1967) appears to have the most credence due to its consideration of allocations of attention. This theory discounts the more structured hypothesis of bottlenecks within the system and advocates a more flexible method of distribution of attention. This theory also takes into account physiological effects on the total amount of attention available.

Arousal by other means such as white noise or mild muscular tension has a facilitory effect on mental performance (Dornic & Stelmach, 1974; Hamilton, Hockey & Quinn, 1972; Hockey & Hamilton, 1972; Welford, 1963). Auditory stimulation also enhances the perception of visual stimuli (Andraessi, 1965). A Hebbian or inverted U relationship was
found when various levels of arousal were employed in a mental task (Stennett, 1957).

Fatigue, induced by either sleep loss or physical exertion, affects mental performance. The finding that a treadmill run to exhaustion had a negative effect on the accuracy but not the speed of a mathematical task (Loveland & Williams, 1963; Williams & Lubin, 1967). The disagreement may be explained in at least two ways: one, it may be that the fatigue incurred from sleep loss is quite different from physical fatigue induced by treadmill running; secondly, the methodology in the studies differed. Subjects in the Gutin and DiGennaro study were allowed only a certain amount of time to complete the task, thus, the speed of performance was held constant while the accuracy was allowed to fluctuate.

Light physical effort facilitates memory (Dornic, Borg, & Ohllson, 1973) and the inverted U relationship was found when the same mental work was performed at various levels of exertion. On the other hand, Stauffacher (1937) found a linear relationship between levels of physical exercise and decreasing mental performance and Girodo and Pelegrini (1976) found that concomitant physical exercise has no effect on recall memory. Davey (1973) also concluded that an intermediate amount of exertion had different effects on different people, hypothesizing that mental performance is directly related to personality and subject variables. Physical exertion as a variable was considered by Gutin and DiGennaro (1968) and Stockfeldt (1970). Both studies concluded that the better conditioned subjects performed mental tasks better than the poorer conditioned subjects during the period of exertion.
Task complexity has also been shown to affect performance. Simple reaction time was not affected during various levels of exertion (Meyers et al., 1969; Shore, 1958; Sjoberg, 1977), but the performance on a five choice reaction time task significantly decreased at heart rates about 175 beats per minute (Levitt & Gutin, 1971). It was further concluded that tasks requiring little information processing may be better performed at a high level of exercise induced activation (EIV) while those requiring considerable information processing are performed best at a low level of EIA (Levitt & Gutin, 1971). Along the line of task complexity was the work of Chekosky and Whitlock (1973). These researchers, using dot patterns, found that the better patterns were recognized faster than the poorer patterns and that the reaction time for highly similar stimuli was poorer than that of less similar stimuli. Task complexity may be increased by adding more items. Sternberg (1969) reported a linear relationship between reaction time and the number of items in memory.

Lastly, many mental tasks require the use of vision. Krestovnikov (1951) and Vlahov (1977) have shown that heavy exercise has the temporary effect of improving visual acuity. Various levels of physical activity affect tachistoscopic detection. Goldwater and Zirul (1973) found the inverted U relationship when tachistoscopic detection was completed at various levels of exercise.

It may be said that a relationship does exist between physical activity and mental performance. This relationship shows that various levels of exertion may affect mental performance. Physical exertion has been shown to both facilitate and hinder mental performance. The
literature concerning physical activity and mental performance is somewhat confusing and there appear to be discrepancies in the findings. The discrepancies center around the effects, if any, of physical exercise on mental performance, which may be explained in two ways. First, various methods or tasks were employed to activate the subjects and the methods employed different frequencies and durations. Secondly, different mental tasks were employed, which may involve different mechanisms of the brain and thus not be measuring the same phenomenon.

Statement of the Problem
The literature contains many studies concerning mental performance and physical exercise. There is some difficulty in comparing the results of these studies primarily due to differing methodology employed. It was the primary purpose of this study to investigate the effects of physical fatigue on the visual recognition of previously learned material. Within this framework was an examination of varying memory set size and complexity of the mental task in conjunction with the varying levels of physical exertion.

Research Hypotheses
1. An arousal effect in response time will be demonstrated as the level of fatigue increases and there will be a significant decrease in response time between the control subjects and those exercising for the 100% of $\text{PWC}_{170}$ level.
2. There will be no significant decrease in correctness as a result of fatigue.
3. There will be a significant difference in target response
time with the target pattern classified as "good" showing the better response time.

4. There will be a significant difference in response time of the target pattern lures with the lure which is highly dissimilar having the faster response time.

5. There will be a significant difference in the overall response time with regard to number of items in memory group with the two-item showing faster response time than the six-item group.

Operational Definitions

Visual Recognition Task - In this study the visual recognition task involved the identification of previously learned dot patterns of the Garner-Clement variety (Garner & Clement, 1963) presented via a slide presentation (see Appendix A).

Physical Fatigue Task - Physical fatigue is a rather nebulous term. There is no specific definition of this term but there is general agreement as to what it encompasses (Astrand & Rodahl, 1977; Bartlett, 1963; Christensen, 1960; Dill, 1942; Simonson, 1971). Bartlett (1953) proposes an idea which appears to include the considerations of the above mentioned researchers. Bartlett states:

Fatigue is a term used to cover all those discernable changes in the expression of an activity which can be traced to the continuing exercise of that activity under its normal conditions, which can be shown to lead, either immediately or after delay, to deterioration in the expression of that activity, or more simply, to results within the activity that are not wanted.
Physical fatigue is not an all-or-none proposition in that it may occur to various degrees, and the results of this fatigue may not be readily observable. Within the framework of this definition the subjects will be fatigued. This fatigue task will be administered by having the subjects pedal a cycle ergometer at a prescribed workload for a set period of time.

**Response Time** - The response time was the total time between the presentation of the slides and the pressing of the telegraph key to stop the response timer.

**Correctness of Response** - Correctness of response was defined as to whether the subjects correctly identified the target items as ones that had been previously learned and identified the lures as items that had never been seen.

**Physical Working Capacity 170** - Physical Working Capacity 170 was defined as the amount of work on a bicycle ergometer necessary to elicit a heart rate of 170 beats per minute.

**Assumptions**

1. The mental capacities of the subjects were within the normal range for university students.
2. All subjects understood the directions.
3. The mental task employed was representative of the type of mental task utilized in actual athletic performances.
4. The physical task employed was representative of the levels of exertion commonly experienced in athletic situations.
5. All subjects were equally motivated.
Limitations

1. The subjects may not have had equal knowledge of the learned material.

2. There may have been difference in learning of the target items.

Significance of the Study

The study of response selection has been used in the past largely to substantiate, refute, or add to theories concerning human information processing. The theories have been studied using single input, more than one input of the same modality, and more than one input of differing modalities. One of the methods used in certain cross modality studies in the manipulation of the strength or intensity of one or more of the inputs. A rise in the strength or intensity of one or more of the inputs has been shown in certain instances to have a detrimental effect on tasks concerning alternate inputs.

The detrimental performance on alternate tasks may be explained quite well by the allocation theory (Kahneman, 1973) in that the limits of an individual's processing capacity have been exceeded. An individual may optimally perform two concomitant tasks so long as his processing capacity is not exceeded; but once this capacity is overloaded possibly by an increase in intensity of one of the two tasks, performance decreased on both tasks (Kahneman, 1973). This processing capacity may be exceeded not only by an increase in intensity of mental inputs or tasks but also by an increase in intensity of physical inputs or tasks.
The implications are widespread. There are numerous times when individuals need to function mentally at a high level while under some form of physical stress, particularly in the form of various levels of fatigue. In this case, the physical demands of the situation are in competition with the mental demands of the situation for allocation of attention.

Specifically, in the case of athletics, mental demands are in constant competition with the physical demands of the activity (Kahne-man, 1973). For the most part, the mental tasks remain constant while the physical demands increase. In many athletic situations, the performer must first recognize a situation (mental) and then react to it (physical) (Martiniuk, 1974). The fact that a performer is slow to react may be due to several factors, one of which is physical fatigue. However, the increase in reaction time may also be a sign of decreased mental performance. The performer may be physically able to react appropriately to a situation if he were able to recognize it in time. Visual recognition of stimuli plays a vital role in all athletic events and it is necessary to learn what effects, if any, physical fatigue has on the visual recognition of items previously learned.

Lastly, the literature surveyed made no reference to recognition and physical fatigue of the type employed in this study. In previous studies other mental tasks were employed in conjunction with physical fatigue or exertion (Burgess & Hokanson, 1964; Davey, 1973; Dornic, Borg, & Ohllson, 1973; Stockfeldt, 1970). It may be that previously employed mental tasks are not the equivalent of item recognition or require the same type of mental processing, and thus are not affected
by physical exercise in the same manner. This study will add to the literature concerning the relationship of physical performance to mental performance.
CHAPTER II

METHODS

Selection of Subjects

Subjects for this study were 36 students (15 male and 21 female) enrolled in basic activity classes in the Department of Health, Physical, and Recreation Education Education at Louisiana State University, Baton Rouge, Louisiana, during the spring of 1979. Mean physical characteristics of the male subjects were: age, 22.00 (±2.47) yrs; height, 179.48 (±5.78) cm; and weight 74.65 (±6.58) kg. For females the mean values were: age, 22.05 (±3.77) yrs; height, 165.29 (±5.06) cm; and weight, 56.81 (±5.68) kg. As far as could be determined, all subjects had 20/20 vision and had no physical or mental impairment which would have affected performance.

Apparatus

The materials used in this study consisted of the following:

Slide Projector

A Lafayette Instruments Company 41610 slide projector, equipped with a special tachistoscopic lens, was utilized. Kodak Ektachrome slides were made of all dot patterns used. These were shown via the slide projector.

Reaction Timer

A Lafayette Instruments Company KT 800 Reaction Timer model
was used. This reaction timer adapts to the model 4160 slide projector and provides a measurement of the correctness of response given and a digital reading of the response time measured to .01 seconds. The reaction timer starts simultaneously with the presentation of each slide.

**Telegraph Key Set**

A Lafayette Instruments Company telegraph key set was used. The left key was marked with a "no" and the right key with a "yes." The telegraph key set was attached to the cycle ergometer and connected to the reaction timer. Depressing either of the two keys following the presentation of a slide stopped the reaction timer.

**Cycle Ergometer**

A Monark cycle ergometer was used to administer the $P_{WC_{170}}$ test to each subject, and to induce the different fatigue levels.

**Metronome**

An electric metronome was used to establish and maintain a pedaling rate on the cycle ergometer.

**Snellen Eye Chart**

A Snellen Eye Chart was used to test the vision of each subject.

**Projection Screen**

A projection screen was used positioned in front of the bicycle ergometer for the presentation of dot patterns.

**Stopwatch**

A stopwatch accurate to .01 seconds was used to time the subjects each minute while on the cycle ergometer.

**Digital Counter**

A digital counter was used to measure the rate (pedal revolutions
per minute) at which the subjects pedaled the cycle ergometer.

**Procedures**

**Fitness Evaluation and Establishment of Workload**

Prior to the actual testing, the subjects (n = 36) were administered a PWC$_{170}$ test. The administration of this test was in accordance with previously established methods (deVries, 1971) (see Appendix B). Physical Working Capacity of PWC is defined as the maximum level of work of which an individual is capable, and the PWC$_{170}$ test is a valid method of predicting this level from submaximal heart rate measures (deVries, 1974). It has been known that heart rate increases linearly with increasing workloads. The PWC$_{170}$ test estimates the maximum level of work of an individual by having the individual work at two separate submaximal workloads and obtaining a heart rate measure at each workload. These two points are recorded on a graph (deVries, 1974) and a straight line drawn between the two. This line is extrapolated to a point on the graph corresponding to a heart rate of 170. From this point a workload which would elicit this heart rate of 170 is obtained.

It has been previously established that an individual's cardiovascular fitness level affects mental performance when working during periods of exertion (Gutin & DeGennaro, 1968; Stockfeldt, 1970). To control this factor, the present study employed three percentages of the workload that would elicit a heart rate of 170. The percentages 0, 80, and 100 were used.
Establishment of Groups

The subjects (n = 36) were randomly divided into two equal groups. The two groups performed similarly with one exception. The two item group (n = 18) had two items (dot patterns) in memory and the six item group (n = 18) had six items (dot patterns) in memory. The two item group had one item in memory with a high goodness rating and one item in memory with a low goodness rating while the six item group had three of each. The goodness of the items was in accordance with Garner and Clement, 1963 (see Appendix A).

On the morning of the testing both groups were presented the items they were required to learn and asked to study them. The two item group was allowed three minutes of study (1.5 minutes per item) and the six item group was allowed nine minutes for study. The subjects were provided a pencil and a sheet of paper for self testing.

At the end of the first study session, the study items were collected and the subjects given a blank sheet of paper. The subjects in the two item group were given 20 seconds to correctly recall and reconstruct the previously learned items; and the subjects in the six item group were given 60 seconds. This test was considered a measure of learning. All subjects who correctly completed the recall task in the allotted time were allowed to leave. Subjects making errors were given an additional two minutes of study and again required to complete the recall task. All but six subjects completed the learning task in the initial learning period. The time for study and learning was held constant to account for effects of overlearning (Singer, 1975).

Later on the same day the subjects reported to the testing area.
Prior to the testing, the subjects read and signed an informed consent form. Information pertaining to height, weight, age, and vision were recorded at this time. The subjects were again tested on recall.

**Experimental Treatments**

Three treatments with regard to level of fatigue were used with the two item group and the six item group. Low fatigue consisted of having the subjects pedal for six minutes with no resistance; intermediate fatigue consisted of the subjects pedaling for six minutes at a workload of 80 percent of that which would elicit a heart rate of 170; and high fatigue consisted of having subjects pedal for six minutes at the workload that would elicit a heart rate of 170 (100%). A fourth treatment, consisting of nine randomly selected subjects randomly selected from the original 36, was conducted in order to determine if having to complete a mental task while concurrently pedaling a cycle ergometer at a prescribed rate had a detrimental effect on the pedal rate. These nine subjects pedaled for eight minutes at a workload equal to that of the high fatigue level group but without having to respond to visual stimuli.

All 18 subjects in either group were exposed to all fatigue levels with the order of presentation counterbalanced using all possible combinations to avoid a learning or order effect. The items used in the two item presentation consisted of one target item of high goodness, presented 12 times; one target item of low goodness, presented 12 times; two lures which are of low similarity to both targets, presented three times each; three lures highly similar to the good item, shown three
times each; and three lures which are of low similarity to the poor item, shown three times each. This resulted in a total of 48 slides.

The slides used for presentation to the six item group consisted of three targets of high goodness and three targets of low goodness, each shown four times; two lures of low similarity to all of the target items, each shown three times; and one lure of high similarity to each one of the targets, each shown three times. This methodology also involved a total of 48 items. All items for both groups were randomly arranged in the slide tray for presentation. Since the same items were used in all three exertion level treatments, the order of the slides was randomly arranged twice more.

The subjects were individually tested on the visual recognition task. First, the seat on the ergometer was adjusted to fit each subject's limb length. The telegraph key was attached to the handle bars of the cycle ergometer. Each subject was instructed to take note of the keys marked "yes" and "no." The subject was instructed to place his or her dominant hand equidistant between the two keys and told that upon commencement of testing, slides would appear on the screen and that one of the two telegraph keys was to be depressed as soon as the subject recognized the slide. A verbal warning preceded each slide by approximately one second and the slides were presented as rapidly as possible. All were given the same verbal instructions:

Respond as quickly as possible by depressing the "yes" key or the "no" key as soon as you are sure you do or do not recognize the slide.

For the low fatigue group the slide presentation commenced upon
completion of the verbal instructions. For the intermediate and high fatigue group slide presentation started during the last 2.5 minutes of the ergometer exercise. Response time and correctness of response for each slide was recorded. A micro-switch connected to the impulse center placed under one of the pedals of the cycle ergometer enabled the recording cumulative pedal RPM at the completion of every minute of ergometer work for the duration of each treatment.

Heart rates were recorded at the completion of Treatment Three. These were obtained by palpation of the carotid artery. The mean heart rate for Treatment Three was 166.75 (±5.50) beats per minute. This value reflected a satisfactory $\text{PWC}_{170}$ measure.

**Statistical Analysis of Data**

Means and standard deviations were computed for all variables. For statistical analysis, the correctness of response data were arranged in a series of 12, 3 x 3 Latin squares. The first six squares represented the two item group and the last six squares represented the twelve item group. Each square contained all three fatigue levels for three subjects. This design was utilized to reduce any effects of the order in which each subject was tested as well as the day on which each subject was tested. The columns within squares represented the day that the subjects were tested and the rows within squares represented the order of the fatigue levels. A 5 x 3 x 36 split plot analysis of variance was used on the dependent variables response time to assess the effects that took place as a result of the fatigue. Significant effects were later tested using orthogonal comparisons. A 2 x 8 factorial
analysis of variance was used to determine if any difference existed between the high fatigue group who had a concurrent mental task and the high fatigue group who had no concurrent task. Lastly, analysis of regression using response time as the dependent variable was used to establish regression lines between the two item group and the six item group. The slope and intercept for each regression line were estimated for treatments one through three.
CHAPTER III

RESULTS

Correctness of Response Data

Table 1, Appendix C presents the data concerning the percentages of correct responses. Since the percentage of correct responses was 88.9% as compared to 11.1% for incorrect responses, it was assumed that random guessing did not occur. As a result, both correct and incorrect responses were considered together.

Statistical Analysis

Two similar 3 x 5 x 36 split plot analyses of variance were used to analyze the dependent variables of response time and correctness of response. The data were arranged in 12 separate 3 x 3 Latin Squares with squares 1-6 representing the two item group and squares 7-12 representing the six item group. Any significance differences in either analysis were tested using orthogonal comparisons.

Three separate but similar analyses of regression were used to obtain slope and intercept for each of the three fatigue levels between the two item group and the six item group. Independent t tests were used to test differences between intercepts.

Analysis of variance was employed to determine if any difference existed between the pedal rates of the high fatigue group with mental task (100% of $\text{PWC}_{170}$ concurrent with item identification) and the high fatigue group without mental task (100% of $\text{PWC}_{170}$ with no con-
current task).

**Response Time**

A summary of the analysis of variance and appropriate orthogonal comparisons for the dependent variable response time is presented in Table 1. Response times were shown to be significantly different when the 12 Latin Squares (two item group compared to six item group with day and order effects collapsed) were compared $F(11,24) = 7.80, p \leq .05$. Orthogonal comparison revealed that there was a significant difference between the two item group (squares 1-6) and the six item group (squares 7-12) $F(1,24) = 11.81, p \leq .01$ with the slower mean response time evidenced in the six item group. This indicates that response time is affected by the number of items in memory. The fatigue effect as well as the Group X Fatigue interaction were found to be non-significant (see Appendix C, Table 2 for means and standard deviations of response times for each fatigue level). The changes in mean response time across fatigue levels is shown graphically in Figure 4.

A significant difference was found between the types of items presented $F(4,288) = 74.00, p \leq .01$ indicating that task complexity affects recognition time. Using orthogonal comparisons, significant differences were noted between item Types 1 and 2 $F(1,470) = 49.53, p \leq .01$ with Type 1 having the faster response time and between Types 4 and 5 $F(1,470) = 6.43, p \leq .01$ with Type 4 having the faster response time. When the targets (Types 1 and 2) were compared to the lures (Types 3, 4, 5) a significant difference was also shown $F(1,470)=$
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<td>24</td>
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<td>.141</td>
<td>6.73**</td>
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</table>

* Squares are 12 Latin Squares. Squares 1-6 represent the 2 item group and squares 7-12 represent the 6 item group.
Figure 4. Changes in mean response time across fatigue levels.
6.73, p ≤ 0.01 with the targets demonstrating the faster response time (see Table 1 for a summary of all orthogonal comparisons). Means and standard deviations for all item types are presented in Appendix C, Table 3.

A significant Group X Type interaction was found F (44,288) = 1.73, p ≤ 0.01. Figure 5 illustrates this interaction. It can be seen that although all response times increase from the two item group to the six item group, they do not increase equally. The response time for item Type 1 (target item of high goodness) increases at a greater rate than the other items. A significant Fatigue X Type interaction was also found F (8,288) = 2.37, p ≤ 0.05. This interaction is shown graphically if Figure 6. Figure 6 shows that item response time for item Type 5 (lure of high similarity to target of low goodness) increases almost linearly across treatments while all other items improve at the intermediate level of fatigue before getting worse. Also, item Type 2 (target item of low goodness) shows a greater increase in response time between the intermediate and high levels of fatigue than does any other item. Means and standard deviations for each item type by fatigue level are shown in Appendix C, Tables 4, 5, 6.

Analysis of Regression for Response Time

Analysis of regression was employed for each of the three fatigue levels in order to obtain slope and intercept. Response time was used as the dependent variable and regression lines were constructed between the two item group and the six item group. A summary of these analyses appears in Appendix D, Tables 2, 3, 4. The low fatigue
Figure 5. Changes in response times for all types of items between groups.
Figure 6. Mean response times for all types of slides across levels.
group demonstrated the lowest intercept (.58 sec) with the high fatigue group next (.68 sec) and the intermediate fatigue group having the highest (.71 sec). The lower the intercept the faster the time for those activities in memory which occur only once (Sternberg, 1969). The slopes for the low, intermediate, and high fatigue groups were .035, .002, and .022, respectively. The regression lines for each of the three fatigue treatments appear in Figure 7. Independent t tests were performed to determine if the intercepts were significantly different. The intercepts for the low fatigue group and the intermediate fatigue group demonstrated the only significant difference \( t (1,178) = 3.84, p \leq .05 \), indicating that the intercepts for all other groups were essentially the same. Mean differences in response time for the comparison stage in memory (Sternberg, 1969) for each treatment were obtained by subtracting the mean response time value for the two item group from that of the six item group. The values for the low fatigue group, the intermediate fatigue group, and the high fatigue group were .14 sec., .01 sec., and .09 sec., respectively.

**Fatigue and Correctness of Response**

Percentages of correct responses were calculated for each of the three fatigue levels. The percentage of correct responses for the low fatigue group (pedaling at no resistance), the intermediate fatigue group (80% of PWC_{170}), and the high fatigue group (100% of PWC_{170}) were 90%, 89%, and 88% respectively (see Appendix C, Table 7 for a summary of correct and incorrect responses). These data indicate that for all fatigue levels the subjects followed the verbal direction given
Figure 7. Regression lines for fatigue levels.
and that fatigue of the levels employed in this study has a minimal
effect on correctness of response.

Pedal Rate

A summary of the analysis of variance for the dependent variable
pedal rate is presented in Appendix D, Table 1. Pedal rates were shown
to be significantly different between the group pedaling the cycle at
the 100% of $PWC_{170}$ level while responding to stimuli and the group pe­
daling at the same rate but without having to respond to stimuli $F$
$(1,344) = 27.3, p < .05$ in favor of the non-responding group. The mean
pedal rate of the responding group was 56.89 rpm's and for the non­
responding group 58.72 rpm's. A significant difference was also shown
between the times the rates were measured $F$ $(7,344) = 5.03, p \leq .05$.
The pedal rates were measured at the completion of each minute of ped­
aling and showed a decrease in rate as each minute elapsed. The means
for minutes 1-7 were 58.28, 58.25, 58.20, 57.80, 57.02, 56.40, and
55.68 rpm's, respectively. There was no significant Treatment X Time
interaction. A significant interaction of this type would be ev­
dence that the pedaling did cause a diversion of attention from the
recognition task. It was shown that the pedal rates for both treat­
ments significantly decreased the longer the subjects pedaled but they
decreased at the same rate. Since this interaction did not occur, it
was assumed that any decrease in pedal rate could be attributed to
fatigue.
CHAPTER IV

DISCUSSION

Effect of Fatigue on Recognition

The results indicate that fatigue of the type and intensity employed in this study does not significantly affect overall visual recognition time. An alternate explanation might be that the level of fatigue was not high enough. Allocation theory (Kahneman, 1973) states that man has only so much attention capacity available to meet demands. The available attention is allocated as required by certain situations. When an individual is performing a task, performance will not decrease as long as the available attention is not exceeded. An individual performing two concurrent tasks will be able to work at optimum level so long as the attentional demands of one or the other of the tasks do not increase significantly. A significant increase is attentional demands of one task can only happen with a reduction of attention to the other task; thus, leading to a decrement in performance on the task with the decrease in attention. It is conceivable that the mental task and the physical task employed in the present study did not sufficiently overload the system and cause a drop in performance. The design of this study was such so as to closely approximate the type of fatigue experienced by individuals participating in a number of athletic endeavors. It can be stated that exercising at such a level
is not sufficient to affect overall response time in recognition memory. Although no overall effects in recognition time performance were noted, differences were revealed when response time was broken down into component parts. Sternberg (1969) stated that when response times are regressed across memory set size that the resultant slope of this regression represents the increase in response time as the memory set size increases, and that the resultant intercept represents the total time for all activities which occur just once in the memory process. Activities which occur just once in the memory process are the encoding of the stimulus and the organization and execution of the motor response. Sternberg (1969) stated that the slope of the regression line represents only the comparison process of memory and that the slope increases as each new item is added to the memory set. Individual regression analyses for each fatigue level suggest that arousal may exist in the comparison stage of memory. The slope for the intermediate fatigue group was considerably less than for either the low fatigue group or the high fatigue group. When the differences for time of comparison were obtained for each fatigue level an inverted U (Hebb, 1949) was demonstrated. These data indicate that is an aroused state, such as that induced by the subject's pedaling at 80% of their PWC, less time is spent in the comparison stage of memory. Thus, time of comparison may be enhanced by arousal in the form of physical work.

The same arousal phenomenon was not exhibited in the intercepts of the three fatigue treatments in the present study. As stated previously these intercepts contain activities in the memory process.
other than the comparison of items, i.e., encoding and organization and execution of a motor response. It is noted that the low fatigue group had the lowest intercept, the high fatigue group had the next lowest, and the intermediate fatigue group had the highest.

The comparison of the intercepts to the slopes for each fatigue treatment is both interesting and suggestive. Numerous researchers as early as Donders have supported the notion that the time between the onset of the stimulus and the response is occupied by various stages. Stages such as encoding, comparison, and the execution of response are basic to this notion. Modern day information processing theories also follow this line of thought. Assuming that Sternberg's (1969) argument concerning the properties of the intercepts and slopes of the regression line is valid, it is possible to investigate the effects of arousal on the various stages of memory. If arousal affected all stages in memory the same way then one may expect to find the slopes corresponding to the intercepts at each individual fatigue treatment, i.e., the fatigue treatment with the lowest intercept would have the least amount of slope. This was not the case as no relationship of this type was noted. The fact that no such relationship existed could be taken as evidence that arousal by physical work affects the different stages in information processing in different ways. Sternberg (1969) states that the slope of the regression line represents the comparison stage of memory while the intercept represents more than one stage of the memory process. Therefore, based on present results, it can be stated only that arousal in the form of physical fatigue affects the comparison stage of memory differently than it affects the sum total of the other
processes. Since the sum total of the other processes, which is represented by the intercept of the regression line, cannot be separated, it cannot be speculated as to how arousal in the form of physical fatigue influences the individual processes that make up the intercept. It is quite possible that one or more of the components of the intercept, i.e., encoding, selection, or execution of motor responses may have exhibited the same effect (arousal) as did the slope. It is conceivable that one or more of the components of the intercept may have exhibited an arousal effect.

Previous research (Burgess & Hokanson, 1964; Stennett, 1957) suggests that a performance curve in the form of an inverted U (Hebb, 1949) should have occurred. The fact that this phenomenon was not evidenced here may be due to a masking effect. Although the arousal curve was evidenced in the comparison stage of memory (slope), this same effect was not evidenced in those stages which only occur once (intercept). It appears as though an intermediate level hinders certain stages in the recognition process. It is conceivable that the effects of fatigue on the intercept may have overshadowed the effects of fatigue on the slope thus negating the arousal effect.

**Effect of Item Type on Response Time**

A significant difference in response time between types of items presented was to be expected. The differences existed between the two targets, the two lures, and the targets and the lures. The differences were due to the varying complexity of the mental task at hand; i.e., Type 1 (target of high goodness) was more quickly recognized than Type
2 (target of low goodness). This is in support of previous findings (Checkosky & Whitlock, 1973; Garner, 1974; Garner & Clement, 1963).

A graph of the Fatigue x Type interaction (see Figure 6, p. 36) illustrates the effects of fatigue on the different stimulus items. This interaction offers support to the premise that certain mental processes may be affected by various complexities of mental tasks during an aroused state.

The significant interaction between the types of items and the number of items in memory is in support of previous research (Checkosky & Whitlock, 1973). This interaction may be viewed as evidence that the goodness of the item presented may influence the stage involved in the processing of memory set items. It is suggested that pattern goodness affects the time needed to process information.

**Effect of Set Size on Response Time**

As expected, a significant difference was found between the two item group and the six item group in mean response time with the six item group having the longer response time. Sternberg (1969) concluded that additional time was needed for the comparison process as additional items were added to the memory set. The present study utilized memory set sizes of two and six. Checkosky and Whitlock (1973), using two different set sizes, noted the same phenomenon.

**Summary**

The results indicate that fatigue of the type and intensity employed does not significantly affect overall recognition time. Allocation theory (Kahenman, 1973) postulates that performance will decrease
when the total amount of attention available is exceeded. This phenomenon did not occur. Possibly the physical task employed was not sufficient to produce enough diversion of attention away from the recognition task. The physical task employed was designed to resemble the type of fatigue experienced by individuals participating in athletic endeavors. It may be that fatigue of the type experienced by participants in athletic endeavors is not sufficient to significantly hinder recognition time performance.

The recognition of various dot patterns may be considered representative of mental tasks that are confronted in other situations. Some of these mental tasks are simple and some are quite complex. Therefore, the effects of fatigue on the recognition of dot patterns may be indicative of fatigue effects on other mental tasks which confront an individual in everyday occurrences.

It was suggested that physical fatigue may affect the comparison stage of memory in such a way as to exhibit an arousal effect in the form of an inverted U. Those stages in memory which just occur once did not exhibit the same phenomenon. Thus, it is conceivable that a masking effect occurred and an overall arousal effect which may have been noted was negated.

The present study supported the following hypotheses.

1. There was no significant decrease in correctness of response as a result of fatigue.

2. There was a significant difference in target response time with the target pattern classified as "good" showing the better response
3. There was a significant difference in response time of the target pattern lures with the lure which is highly dissimilar having the faster response time.

4. There was a significant difference in the overall response time with regard to number of items in memory with the two item group showing the faster response time than the six item group.
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TWO ITEMS IN MEMORY

1 target item of high goodness

\[ \times 12 = 12 \]

1 target item of low goodness

\[ \times 12 = 12 \]

2 lures of low similarity to both targets

\[ \times 3 \text{ ea.} = 6 \]

3 lures of high similarity to high goodness target

\[ \times 3 \text{ ea.} = 9 \]

3 lures of high similarity to low goodness target

\[ \times 3 \text{ ea.} = 9 \]

TOTAL 48 items
SIX ITEMS IN MEMORY

3 target items of high goodness X 4 ea. = 12

3 target items of low goodness X 4 ea. = 12

2 lures of low similarity to all targets X 3 ea. = 6

1 lure of high similarity to each target item X 3 ea. = 18

TOTAL 48 items
The PWC$_{170}$ Test of Physical Working Capacity

**Procedure**

1. Have the subjects pedal a cycle ergometer at rate of 60 rpm's for six minutes at a workload estimated to produce a heart rate of 120-140. Record the heart rate during the sixth minute as the first data point on the graph below.

2. At the end of the first six minute work bout, and without stopping increase the load to one estimated to elicit a heart rate of 150-170. Record the heart rate during the sixth minute as the second data point on the graph below.

3. Plot the straight line through the points plotted in items 1 and 2 above.

4. Drop a perpendicular from the intersection of the plotted line with the 170 heart rate line; this will represent the workload estimated to produce a heart rate of 170 or the PWC-170.
<table>
<thead>
<tr>
<th>Correctness*</th>
<th>Frequency</th>
<th>Percent</th>
<th>Cumulative %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4161</td>
<td>88.9</td>
<td>88.9</td>
</tr>
<tr>
<td>2</td>
<td>518</td>
<td>11.1</td>
<td>100.0</td>
</tr>
</tbody>
</table>

*1 = correct  
2 = incorrect
### TABLE C2
MEANS AND STANDARD DEVIATIONS ACROSS ALL FATIGUE LEVELS

<table>
<thead>
<tr>
<th>Fatigue Level</th>
<th>N</th>
<th>Response Time Mean</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>1536</td>
<td>.72</td>
<td>.23</td>
</tr>
<tr>
<td>Intermediate</td>
<td>1532</td>
<td>.72</td>
<td>.25</td>
</tr>
<tr>
<td>High</td>
<td>1518</td>
<td>.78</td>
<td>.30</td>
</tr>
</tbody>
</table>
### TABLE C3

**MEANS AND STANDARD DEVIATIONS BY TYPE FOR RESPONSE TIME**

<table>
<thead>
<tr>
<th>Type</th>
<th>N</th>
<th>Mean</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1173</td>
<td>.65</td>
<td>.22</td>
</tr>
<tr>
<td>2</td>
<td>1124</td>
<td>.78</td>
<td>.28</td>
</tr>
<tr>
<td>3</td>
<td>578</td>
<td>.67</td>
<td>.16</td>
</tr>
<tr>
<td>4</td>
<td>855</td>
<td>.77</td>
<td>.25</td>
</tr>
<tr>
<td>5</td>
<td>856</td>
<td>.82</td>
<td>.28</td>
</tr>
</tbody>
</table>
TABLE C4
MEANS AND STANDARD DEVIATIONS BY ITEM TYPE
FOR LOW FATIGUE GROUP

<table>
<thead>
<tr>
<th>Type</th>
<th>N</th>
<th>Response Time (sec)</th>
<th>Mean</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>402</td>
<td></td>
<td>.65</td>
<td>.22</td>
</tr>
<tr>
<td>2</td>
<td>368</td>
<td></td>
<td>.76</td>
<td>.25</td>
</tr>
<tr>
<td>3</td>
<td>192</td>
<td></td>
<td>.68</td>
<td>.16</td>
</tr>
<tr>
<td>4</td>
<td>287</td>
<td></td>
<td>.77</td>
<td>.23</td>
</tr>
<tr>
<td>5</td>
<td>287</td>
<td></td>
<td>.78</td>
<td>.22</td>
</tr>
</tbody>
</table>

62
<table>
<thead>
<tr>
<th>Type</th>
<th>N</th>
<th>Response Time (sec)</th>
<th>Mean</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>388</td>
<td></td>
<td>.63</td>
<td>.20</td>
</tr>
<tr>
<td>2</td>
<td>373</td>
<td></td>
<td>.75</td>
<td>.26</td>
</tr>
<tr>
<td>3</td>
<td>191</td>
<td></td>
<td>.65</td>
<td>.15</td>
</tr>
<tr>
<td>4</td>
<td>293</td>
<td></td>
<td>.75</td>
<td>.22</td>
</tr>
<tr>
<td>5</td>
<td>287</td>
<td></td>
<td>.82</td>
<td>.25</td>
</tr>
<tr>
<td>Type</td>
<td>N</td>
<td>Response Time (sec)</td>
<td>Mean</td>
<td>S.D.</td>
</tr>
<tr>
<td>------</td>
<td>----</td>
<td>---------------------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>1</td>
<td>383</td>
<td></td>
<td>.68</td>
<td>.24</td>
</tr>
<tr>
<td>2</td>
<td>383</td>
<td></td>
<td>.84</td>
<td>.32</td>
</tr>
<tr>
<td>3</td>
<td>195</td>
<td></td>
<td>.69</td>
<td>.16</td>
</tr>
<tr>
<td>4</td>
<td>275</td>
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<td>.79</td>
<td>.29</td>
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<tr>
<td>5</td>
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<td></td>
<td>.87</td>
<td>.32</td>
</tr>
<tr>
<td>Fatigue Level</td>
<td>Frequency</td>
<td>Percent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>-----------</td>
<td>---------</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Correct</td>
<td>Incorrect</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>1376</td>
<td>160</td>
<td>90</td>
<td>10</td>
</tr>
<tr>
<td>Intermediate</td>
<td>1362</td>
<td>170</td>
<td>89</td>
<td>11</td>
</tr>
<tr>
<td>High</td>
<td>1338</td>
<td>176</td>
<td>88</td>
<td>12</td>
</tr>
</tbody>
</table>
TABLE D1
SUMMARY OF ANALYSIS OF VARIANCE FOR THE
DEPENDENT VARIABLE PEDAL RATE

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (A)</td>
<td>1</td>
<td>192.86</td>
<td>27.32**</td>
</tr>
<tr>
<td>Time (B)</td>
<td>7</td>
<td>35.49</td>
<td>5.03**</td>
</tr>
<tr>
<td>A x B</td>
<td>7</td>
<td>1.88</td>
<td>.27</td>
</tr>
<tr>
<td>Error</td>
<td>344</td>
<td>7.06</td>
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</table>

** P \leq .01
### TABLE D2

**SUMMARY OF ANALYSIS OF REGRESSION FOR LOW FATIGUE GROUP**

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>1</td>
<td>.89</td>
<td>52.3*</td>
</tr>
<tr>
<td>Error</td>
<td>178</td>
<td>.02</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>179</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* P < .05

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>.584</td>
<td>26.88**</td>
</tr>
<tr>
<td>Group</td>
<td>.035</td>
<td>7.24**</td>
</tr>
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</table>

** P < .01

STANDARD ERROR = .022
TABLE D3
SUMMARY OF ANALYSIS OF REGRESSION FOR
INTERMEDIATE FATIGUE GROUP

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>MS</th>
<th>F</th>
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</thead>
<tbody>
<tr>
<td>Group</td>
<td>1</td>
<td>.208</td>
<td>8.67*</td>
</tr>
<tr>
<td>Error</td>
<td>178</td>
<td>.024</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>179</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p ≤ .05

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>.712</td>
<td>27.63*</td>
</tr>
<tr>
<td>Group</td>
<td>.002</td>
<td>11.26*</td>
</tr>
</tbody>
</table>

* p ≤ .05

STANDARD ERROR = .026
TABLE D4
SUMMARY OF ANALYSIS OF REGRESSION FOR
HIGH FATIGUE GROUP

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>1</td>
<td>.354</td>
<td>9.45*</td>
</tr>
<tr>
<td>Error</td>
<td>178</td>
<td>.037</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>179</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p ≤ .05

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>.684</td>
<td>21.19</td>
</tr>
<tr>
<td>Group</td>
<td>.022</td>
<td>3.07</td>
</tr>
</tbody>
</table>

* p ≤ .05

STANDARD ERROR = .032
VITA

Robert Lewis Johnson was born on January 23, 1951 in Charlotte, North Carolina. He graduated from East Mecklenburg High School in Charlotte in 1969. He attended East Carolina University, Greenville, North Carolina, from 1969 to 1970 and then transferred to Lenoir Rhyne College, Hickory, North Carolina, where he graduated with a Bachelor of Arts Degree in Health and Physical Education in 1973. At both institutions, Dr. Johnson was a scholarship athlete participating in football.

Following graduation from Lenoir Rhyne College, Dr. Johnson accepted a graduate assistantship at the University of South Carolina, Columbia, South Carolina, and began working toward a Master of Arts in Teaching Degree. With the completion of this degree in 1974, Dr. Johnson accepted a position at Lower Richland High School, Hopkins, South Carolina. During his two year tenure at Lower Richland, Dr. Johnson was physical education instructor, assistant football coach, and also baseball coach for the school.

Dr. Johnson enrolled in the Doctor of Philosophy Degree program offered by the Health, Physical, and Recreation Education Department at Louisiana State University. The Doctor of Philosophy Degree was awarded in the major area of Physical Education the Fall semester of 1979.

Dr. Johnson is married to the former Vicki Elizabeth Hyatt.