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EFFECT OF DIFFERENT LEVELS OF PHYSICAL FATIGUE UPON
MOTOR LEARNING AND SUBSEQUENT
MOTOR PERFORMANCE

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 Education

in

The Department of Health, Physical, and Recreation Education

by
Jerry R. Stockard
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M.Ed., University of Missouri, 1967
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ABSTRACT

The purpose of this study was to determine if physical fatigue introduced prior to practicing a novel gross motor task influenced either the learning resulting from that practice or subsequent performance of the task. Eighty-one male college students, randomly assigned to three groups ($n = 27$), practiced a novel gross motor task under either heavy, moderate or nonfatigue conditions.

The criteria for the fatigue conditions were exercise heart rate levels. The fatigue was induced through work bouts on a bicycle ergometer immediately preceding the trial. The moderate fatigue criterion was 150 beats per minute obtained after a work bout of approximately five minutes. The heavy fatigue criterion was 180 beats per minute obtained after a work bout of five to six minutes. The nonfatigue subjects performed at resting heart rate levels.

The task consisted of running a triangular course while balancing a volleyball on an eight inch tee (badminton shuttlecock container). The course was laid out on one end of a basketball court with each leg of the triangle forty-five feet in length. A performance station was located at each of the first two corners of the triangle. At the first station the subject attempted to kick the ball from the tee into a basketball goal placed two feet above the floor. At the second station the ball was pitched

against a standard basketball goal and the subject attempted to catch the rebounding ball on the tee. One trial consisted of completing five circuits around the course with the score being the number of seconds required to complete the trial. Each subject was given six practice trials, all under a designated level of physical fatigue. These trials were considered the learning phase of the study. The following week each subject performed the same task under each of the three conditions of physical fatigue. These trials were considered the performance phase of the study.

The findings were the following:

1. The learning groups did not differ significantly when total performance mean scores were compared.
2. Performance under moderate fatigue conditions was significantly better than performance under heavy fatigue conditions.
3. A significant interaction found in the performance analysis indicated that learning under a specific condition of fatigue resulted in superior subsequent performance under that same condition of fatigue.
4. No significant differences were found among the learning groups in the rate of learning which resulted from practicing under different levels of physical fatigue.
5. The learning trials differed significantly indicating that learning occurred.
6. The interaction effect of trials and fatigue condition was not significant.

The conclusions were as follows:

1. The specificity of practice and performance conditions found in this study indicated that vigorous sports should be practiced under the same fatigue condition under which they would subsequently be performed.

2. Motor learning, within the context of this study, resulted from practice trials despite the physical fatigue introduced prior to the practice trials.

3. Motor learning, within the context of this study, was not significantly influenced by physical fatigue introduced prior to practice trials.

CHAPTER I

INTRODUCTION

The study of conditions which influence learning has long been of interest to psychologists and educators. Early studies in this area were primarily designed to study the nature of learning verbal materials. Interest has spread into the area of motor learning, that is, learning movement skills involving fine and/or gross movement. A topic which is currently receiving considerable attention deals with the question of whether practice under fatigued conditions results in less efficient learning than practice under rested conditions. It is well known that physical fatigue, i.e., impairment to muscular efficiency resulting from sustained muscular exertion, causes decrements in motor performance; but whether physical fatigue influences motor learning is still open to question. Several recent studies have shown that motor learning is not influenced by physical fatigue introduced either prior to or during the practice of a motor skill.^{1,2,3,4,5} On the other hand, one investigator⁶ has

¹Richard B. Alderman, "Influence of Local Fatigue on Speed and Accuracy in Motor Learning, "Research Quarterly, 36 (May, 1965), 131.

²Albert V. Carron, "Physical Fatigue and Motor Learning, "Research Quarterly, 40 (December, 1969), 682.

found physical fatigue to have a beneficial effect, while other studies^{7,8} have shown a negative influence on learning motor skills. The differences in type and degree of physical fatigue imposed, coupled with the wide variety of tasks employed, make it difficult to draw but the most tentative conclusions about the role of fatigue in motor learning.

Another question arises from the consideration of physical fatigue and its effect upon motor learning. If a motor skill was practiced under a specific level of physical fatigue, would the subsequent performance of that skill be influenced when performed under different levels of fatigue, or no fatigue at all? This question implies a transfer

³Richard Schmidt, "Performance and Learning a Gross Motor Skill Under Conditions of Artificially Induced Fatigue," Research Quarterly, 28 (May, 1957), 47.

⁴Douglas W. Bartz and Leon E. Smith, "Effect of Moderate Exercise on the Performance and Learning of a Gross Motor Skill," Perceptual and Motor Skills, 31 (August, 1970), 187.

⁵William Phillips, "The Effect of Physical Fatigue on Two Motor Learning Tasks," Doctoral Dissertation (Unpublished), University of California, 1962.

⁶David Benson, "Influence of Imposed Fatigue on Learning a Jumping Task and a Juggling Task," Research Quarterly, 39 (May, 1968), 251.

⁷Dereck K. Nunney, "Fatigue Impairment and Psycho-Motor Learning," Perceptual and Motor Skills, 16 (April, 1963), 369.

⁸Margaret A. Godwin and Richard A. Schmidt, "Muscular Fatigue and Learning a Discrete Motor Skill," Research Quarterly, 42 (December, 1971), 374 - 381.

effect from the learning conditions and could possibly be based upon Henry's specificity theory of motor learning. According to Henry, separate neuromotor programs are developed for each of the conditions which influences the practice of a motor task.⁹ Physical fatigue could be one of these influencing conditions. It may be that the fatigue causes the learner to adopt different neuromotor responses during practice of a skill than would be adopted if no fatigue were present. If this is the case, it could be predicted that if a motor skill is learned under fatigued conditions, it would later be performed best under fatigued conditions, or if learned under nonfatigue conditions, the skill would subsequently be performed best under nonfatigue conditions.

Many games and sports such as basketball, soccer, and ice hockey require execution of a variety of motor skills while the players are fatigued. Practical applications may be made by teachers and coaches of knowledge related to fatigue and its role in motor skill acquisition. Length and placement of certain drills within the practice session could possibly be affected. Perhaps practicing skills under both fatigued and nonfatigued conditions could be beneficial.

⁹F. M. Henry, "Specificity Versus Generality in Learning Motor Skills," Proceedings of the College Physical Education Association, 59 (1956), 68 - 75.

At the present time too little is known about physical fatigue as a learning variable to arrive at any firm conclusions. Further research in this area seems to be warranted.

STATEMENT OF THE PROBLEM

The problems of this study were: 1) to determine if practicing a novel gross motor task under a specific level of physical fatigue influenced the subsequent performance of that task when performed under differing levels of physical fatigue, and 2) to determine if different levels of physical fatigue introduced prior to practicing a novel gross motor task, influenced the learning resulting from that practice.

HYPOTHESES

The hypotheses were:

1. A novel gross motor task practiced under a specific level of physical fatigue would subsequently be performed best under that same level of physical fatigue;
2. Motor learning would result from practice regardless of the fatigued condition of the learner;
3. Higher levels of physical fatigue would have a more adverse effect on motor learning than lower levels of physical fatigue.

BASIC ASSUMPTIONS

For the purpose of this study it was assumed that:

1. The novel gross motor task used in this study was unique to each of the subjects;
2. Since the subjects were randomly assigned to groups, the motor ability and general state of training were equal among the groups;
3. Each subject performed to the best of his ability throughout the course of the study;
4. After six practice trials each subject would be approaching or have reached an asymptote position on the learning curve.

DEFINITION OF TERMS

Physical fatigue. Physical fatigue was defined as a state or degree of impairment to muscular efficiency resulting from work bouts on a bicycle ergometer ranging in severity from moderate to heavy and lasting from five to six minutes.

Motor learning. Motor learning was defined as the process of acquiring physical movement skills through repeated practice trials. More specifically, motor learning referred to the improvement in the learning task score measured in a reduction in the number of seconds required to complete one task trial.

Motor Performance. Motor performance was defined as the execution of specific movement patterns stressing rapid bodily movement, accuracy, and balance.

Nonfatigue. Nonfatigue was defined as a state wherein the subject performed no warmup or other specific exercise prior to practice or performance of the novel gross motor learning task.

Moderate fatigue. Moderate fatigue was defined as a condition produced through a work bout on a bicycle ergometer in which a heart rate of 150 beats per minute was reached within a period of four to five minutes.

Heavy fatigue. Heavy fatigue was defined as a condition produced through a work bout on a bicycle ergometer in which a heart rate of 180 beats per minute was reached within three to four minutes and sustained for an additional two minutes.

DELIMITATIONS

The samples were limited to eighty-one male students enrolled at Tulane University during the summer and fall semester, 1971.

The learning phase of the study was limited to six practice trials.

The task score was determined as the amount of time in seconds required to complete a trial. Part of the task procedure included kicking and pitching a ball. No attempt

was made to count the successful or unsuccessful kicking or pitching attempts within a trial.

Only exercise heart rate measures were used to determine the fatigue status of the subject during the work bouts.

LIMITATIONS

It was possible that some recovery from fatigue may have occurred during a trial, especially if the subject performed poorly.

Since the task required rapid and continuous movement, the subjects practicing under the nonfatigue condition may have become fatigued.

A training effect may have accumulated during the course of the study resulting from the bicycle ergometer work and from the task itself, especially among the heavy fatigue group.

The subjects were requested to refrain from any vigorous physical activity during the course of the study, but no further attempt was made to govern the subjects' activity.

Since learning rates among subjects differed, the six practice trials afforded each subject may have resulted in different degrees of learning among the subjects.

SIGNIFICANCE OF THE STUDY

There appears to be both practical and theoretical reasons for studying the influence of physical fatigue. Coaches, for instance, might want specific skills practiced while the players are fatigued, or set up practice sessions as nearly like game situations as possible. If neuromuscular responses altered by fatigue during the learning of skills are later reflected in the skill performance, practice conditions would certainly be important. It may be beneficial for coaches and teachers of movement skills to control fatigue within the learning environment.

Excellence in teaching is based upon firm knowledge of subject matter, good teaching techniques, and an understanding of the learning process. In motor learning, much of what we do in terms of teaching is based on tradition rather than upon evidence gleaned from research. The many theories which explain the processes or mechanisms of motor skill acquisition need to be substantiated or refuted through research. The evidence supplied by this study and other studies of a related nature may be accumulated to build a more scientific basis for motor learning theories.

ORGANIZATION OF THE REMAINDER OF THE THESIS

The remainder of this dissertation was organized to review the literature pertaining to the present study,

to describe the experimental procedures employed in gathering the data, to present an analysis of the data, and to summarize, give conclusions, and recommendations resulting from the data.

CHAPTER II

REVIEW OF RELATED LITERATURE

Motor learning is the term applied to the process of acquiring movement skills. Motor skills are generally classified as either fine movement skills or gross movement skills. A fine motor skill involves intricate movements generally performed with the hands or fingers. A gross motor skill generally involves total body movement.

Physical fatigue, as specifically identified for this study, refers to a state or degree of muscular inefficiency resulting from muscular exertion. The studies reviewed in this chapter in which physical fatigue was a variable, used basically the same definition as the one stated above.

Physical fatigue has been introduced either locally, as in fatiguing the muscles controlling hand or finger movements, or generally, as in fatiguing large muscle groups which control total body movement. A number of studies using different combinations of learning tasks and types of fatigue have been reported. This chapter was organized to present research work related to motor learning and performance under conditions of artificially induced physical fatigue. The studies presented were categorized under the following headings:

- 1) Studies Related to the Influence of Fatigue on Learning Fine Motor Skills;
- 2) Studies Related to the Influence of Fatigue on Learning Gross Motor Skills;
- 3) Studies Related to the Influence of Fatigue on Motor Performance;
- 4) Studies Related to Producing Standard Workloads and Heart Rate Response.

STUDIES RELATED TO THE INFLUENCE OF FATIGUE ON LEARNING FINE MOTOR SKILLS

In the early 1950's attempts to study the effect of fatigue upon motor learning were made by experimental psychologists interested in the controversy between massed versus distributed practice. These studies, notably by Adams¹, Ammons², Archer³, and Digman⁴ dealt with a type

¹Jack A. Adams, "Psycho Motor Performance As A Function of Intertrial Rest Interval," Journal of Experimental Psychology, 48 (1954), 131-133.

²R. B. Ammons and Leslie Willig, "Acquisition of Skill IV Effects of Repeated Periods of Massed Practice," Journal of Experimental Psychology, 51 (1956), 26.

³James E. Archer, "Postrest Performance In Motor Learning As A Function of Prerest Degree of Distribution of Practice," Journal of Experimental Psychology, 47 (1954), 47-51.

⁴John M. Digman, "Performance Under Optimal Practice Conditions Following Three Degrees of Massing of Early Practice," Journal of Experimental Psychology, 52 (1956), 189-193.

of fatigue best described as central in origin as opposed to physical fatigue of the muscle. Their findings concurred that the fatigue resulting from massing practice created a performance decrement but learning was not influenced.

Only recently have attempts been made to discover the effect of physical fatigue, that is, impairing muscular efficiency by imposing work loads, upon learning fine motor tasks.

Alderman⁵ induced severe local physical fatigue halfway through the learning of two fine motor tasks. The fatigue resulted from work performed on an arm ergometer and the tasks employed were the rho learning test, a speed test, and a pursuit rotor learning test, a test of accuracy. Four groups of subjects, each consisting of thirty male college students, learned either the speed task or the accuracy task under either treatment or control conditions. It was found that the treatment groups suffered a forty percent decline in performance but no differences in amount of learning resulted.

Carron⁶ investigated the influence of local muscular fatigue upon learning a motor task when imposed early

⁵Richard B. Alderman, "Influence of Local Fatigue on Speed and Accuracy in Motor Learning," Research Quarterly, 36 (May, 1965), 131.

⁶Albert V. Carron, "Physical Fatigue and Motor Learning," Research Quarterly, 40 (December, 1969), 682.

and late in the learning session. Seventy-five college women were assigned to three groups ($n = 25$ in each group). Each subject performed fifty trials of a pursuit rotor task on the first day. The fatigue, induced by a hand ergometer, was introduced to one group after twenty-five percent of the learning had occurred. The control group experienced no fatigue. Fatigue was introduced to another group after seventy-five percent of the learning had occurred. All three groups performed fifty trials of the same task the following day. It was found that the experimental subjects performed significantly poorer following the fatigue treatments than did the control subjects, but no significant difference in the amount learned resulted.

Nunney⁷ designed a study to investigate the effect of impairment from physical activity upon the subjective feelings of fatigue and upon psycho-motor learning. Eighty college men were assigned to five groups, equated on the basis of one trial of a fine motor learning task. Four work loads and two psycho-motor tests were used. A control group learned both tasks under no fatigue. The four experimental groups learned the first task following four different work loads, two performed on a bicycle ergometer and two on a treadmill, each requiring different

⁷Dereck K. Nunney, "Fatigue Impairment and Psycho-Motor Learning," Perceptual and Motor Skills, 16 (April, 1963), 369.

energy expenditures. The learning task was the Snoddy Stabilimeter test. A score was recorded on each of six practices held on alternate days. Similar comparative data were obtained from a second psycho-motor skill, the Rotary Pursuit meter.

Results of the study revealed that the over-all rate of learning of the control group was significantly higher than that of the experimental groups as shown by level of performance on the final Snoddy Stabilimeter scores. The four groups experienced different levels of energy expenditure, yet there were no significant differences among them in learning rate. No differences were found among the Rotary Pursuit Meter scores.

Godwin and Schmidt⁸ studied fatigue as a learning variable by introducing fatigue prior to the first and between each of twenty trials on a fine motor skill similar to the rho task. Two groups of thirty-two subjects each practiced twenty trials on day one either under fatigued conditions or nonfatigued conditions. An arm ergometer was used to induce the fatigue. On day two both groups performed under nonfatigued conditions. It was found that the fatigue caused small but statistically significant decrements in learning. The authors suggested that the significant finding was the result of the maintenance

⁸Margaret Godwin and Richard Schmidt, "Muscular Fatigue and Learning a Discrete Motor Skill," Research Quarterly, 42 (December, 1971), 374.

of the severe fatigue throughout the practice period.

Contradictory findings have been reported concerning the role of physical fatigue on learning fine motor skills. The findings of Alderman⁹ and Carron¹⁰ suggest that local muscular fatigue, when introduced into a fine motor learning situation, was a performance variable, but not a learning variable. Godwin and Schmidt¹¹ have found localized fatigue causes learning decrements and Nunney¹² found the same result under general fatigue. The conflicting nature of the findings reported to date pertaining to the role of fatigue in motor learning suggests a need for further investigation.

STUDIES RELATED TO THE INFLUENCE OF FATIGUE ON LEARNING GROSS MOTOR SKILLS

Most of the movement skills taught in physical education and related fields, such as recreation and athletic programs, are basically gross motor skills, i.e., skills involving total body movement. Several studies have been reported which explore the influence of physical fatigue upon gross motor learning.

⁹Alderman, loc. cit., p. 131.

¹⁰Carron, loc. cit., p. 682.

¹¹Godwin, loc. cit., p. 374.

¹²Nunney, loc. cit., p. 369.

Benson¹³ conducted a study to determine if practice during a state of fatigue influenced the rate or amount of learning in a jumping task and in a juggling task.

Forty-one male college students were randomly assigned to two groups. Two tasks were learned; a juggling task and a jumping task with both speed and accuracy scores recorded for both tasks. One group practiced the jumping task in a fatigued state, the second group followed the same procedure except the task order was reversed. Fatigue was imposed by regulating resistance on a bicycle ergometer to an intensity which developed a heart rate of 180 beats per minute and sustained this rate for an additional two minutes. Eleven practice sessions were scheduled over a six week period. It was found that 1) learning the speed component of the jumping task was impaired by the fatigue; 2) learning the accuracy component of the jumping task was aided by practice in the fatigued state; and 3) learning to juggle was also enhanced by practice in the fatigued state. The author concluded that fatigue had a differential effect upon motor learning depending upon the nature of the task being learned. Benson suggested that the overall time allotted to learning the task (six weeks) and the nature of the imposed fatigue (heavy general fatigue rather than local)

¹³David W. Benson, "Influence of Imposed Fatigue on Learning A Jumping Task and A Juggling Task," Research Quarterly, 39 (May, 1968), 251.

could have been responsible for the significant results. It was further suggested that because of the fatigue the learner adopted different perceptual and motor responses in order to execute the skill.

Schmidt¹⁴ investigated the influence of two bicycle ergometer work bouts on learning a gross motor balancing skill using the Bachman ladder task. Two experimental groups and a control group practiced the task ten times on the learning day. The trials were spaced by ninety seconds in which either work or rest was introduced. Two days later the groups performed four trials with rest periods in between. The fatigue was shown to have caused a performance decrement on the learning day but no differences in learning resulted when the second day performance scores were analyzed.

Bartz and Smith¹⁵ sought to discover the influence of moderate fatigue upon learning a balancing task performed on a stabilometer. A modification of the Balke Treadmill test was used to induce fatigue. They found that although the exercising subjects had elevated heart rates, the scores did not differ significantly from the scores of the non-exercising subjects. They warned however:

¹⁴Richard A. Schmidt, "Performance and Learning a Gross Motor Skill Under Conditions of Artificially Induced Fatigue," Research Quarterly, 28 (May, 1957), 47.

¹⁵Douglas W. Bartz and Leon E. Smith, "Effect of Moderate Exercise on the Performance and Learning of a Gross Motor Skill," Perceptual and Motor Skills, 31 (August, 1970), 187.

Studies should be evaluated in terms of relative workloads, duration of rest intervals, and type of skill being learned (complexity and duration) before any attempt is made to generalize and derive practical application from these specific research findings.

Phillips¹⁶ used two motor learning tasks and three groups, each experiencing a different level of physical fatigue, to determine if learning was influenced by interpolated physical fatigue. A stabilometer task and a rho task served as the learning tasks. Localized fatigue and heavy general fatigue was introduced prior to practice of both tasks. The control group rested. It was found that physical fatigue had no effect on motor learning for these fatigue levels and learning tasks. The conclusion was made that learning resulted from practice in terms of the number of practice trials rather than from the quality of the performance.

The studies reviewed in this section were in general agreement that fatigue does not influence the learning of gross motor skills. The wide variation in types of learning tasks and methods of inducing fatigue make it difficult to draw definite conclusions about fatigue and motor learning. The differential findings of Benson¹⁷ also add to the uncertainty surrounding the role of fatigue in the learning of gross motor skills.

¹⁶William H. Phillips, "The Effect of Physical Fatigue on Two Motor Learning Tasks," Doctoral Dissertation (Unpublished), University of California, 1962.

¹⁷Benson, loc. cit., p. 251.

STUDIES RELATED TO THE INFLUENCE OF FATIGUE ON MOTOR PERFORMANCE

There has been a great deal of research reported dealing with the effect of physical activity, and its resulting fatigue, on motor performance. Only selected studies have been reviewed to outline the general findings.

Phillips¹⁸ conducted a study for the purpose of determining the effect of severe warm up activities on speed of performance of a standardized limb movement. Three groups (n = 25) were tested under experimental and control conditions. Both a related warm up and an unrelated warm up were used as well as the control condition. Results indicated that the related warm up did not significantly increase the speed of the criterion movement, but that the nonrelated warmup resulted in significantly faster movement times than the control group for all the test periods. Neither warm up influenced reaction time.

An investigation of the influence of warm up on the speed of arm movement was conducted by Lotter.¹⁹ The testing apparatus was a bicycle crank attached to the wall with no resistance applied. The subject turned the crank as fast

¹⁸William H. Phillips, "Influence of Fatiguing Warmup Exercises on Speed of Movement and Reaction Latency," Research Quarterly, 43 (October, 1963), 370.

¹⁹Willard S. Lotter, "Effects of Fatigue and Warmup on Speed of Arm Movements," Research Quarterly, 30 (March, 1959), 57.

as possible for four minutes, either under a control situation or following a warm up exercise. The warm up treatment consisted of stationary running while simultaneously rotating both arms in a complete circle, alternating first forward then backward. It was found that the preliminary exercise had no effect on the speed of the arm cranking test.

Skubic and Hodgkins²⁰ reported a study in which thirty-one women physical education majors, divided into three groups, participated in a series of tests to determine the influence of light physical activity on measures of speed, strength and accuracy. The speed test was a one-tenth mile ride on a bicycle ergometer; strength was measured by the distance a softball could be thrown; and accuracy was measured by the number of successful basketball free throws a subject could score in ten tries.

The measuring tests were performed under conditions of no warmup, a general warmup, and a task related warmup. An analysis of the data showed that there were no significant differences among the three types of warmup procedures on the test performance.

Welch²¹ conducted a study to determine whether

²⁰Vera Skubic and Jean Hodgkins, "Effect of Warmup Activities on Speed, Strength and Accuracy," Research Quarterly, 28 (May, 1957), 147.

²¹Marya Welch, "Specificity of Heavy Work Fatigue: Absence of Transfer from Heavy Leg Work to Coordination Tasks Using the Arms," Research Quarterly 4 (May, 1969), 402.

heavy work fatigue would transfer from the legs to the arms. Leg fatigue was induced through a stepping exercise in which the subject stepped on and off an eighteen inch bench at a rate of sixty mounts per minute. The motor performance tasks used were the rho test (speed) in two forms (easy and difficult), and the pursuit rotor test. It was hypothesized that fatigue would transfer from the leg work to impair the arm performance tasks. No significant differences were found between the exercise groups and the control groups on any of the tasks. In fact, the experimental groups performed slightly but not significantly better than the controls.

A study was designed by Evans²² to examine the effects of heavy physical work and high terrestrial environment upon the motor task of pistol firing. The heavy physical work was undertaken on a treadmill walking as fast as possible at a grade of five percent until work decrement levels of zero percent, ten percent, and thirty percent were achieved. The treadmill speed was regulated by the individual and the work load calculated from feet per minute traveled. Six subjects walked to the four levels of fatigue with instructions for either rapid or accurate firing. Results indicated that accuracy was not

²²W. O. Evans, "Performance of a Skilled Task After Physical Work or in a High Altitude Environment," Perceptual and Motor Skills, 22 (1966), 371.

affected by the fatigue treatments but that an increase in firing latency did result from the treadmill walking.

Witte²³ used junior high school girls as subjects for a study to determine if accuracy measures changed in relationship to the amount and intensity of exercise among skilled and unskilled performers. A skilled and unskilled group performed a task in which a twelve inch softball was thrown at a target twenty-one inches in diameter from a distance of twenty-seven feet. Three levels of exercise, light, moderate, and heavy, were administered as the treatment variables. The levels were determined by monitoring heart rates. It was found that no differences existed among the three levels of treatment on throwing accuracy for either the skilled or unskilled. Unskilled subjects showed greater accuracy following exercise at all three levels of fatigue than they did following no exercise.

Kendrick²⁴ conducted a study to determine the effects of fatigue on performance in selected gross motor skills, and to determine the effects of a five minute recovery period after induced fatigue on subsequent

²³F. Witte, "Effect of Participation in Light, Medium and Heavy Exercise Upon Accuracy in Motor Performance of Junior High School Girls," Research Quarterly, 33 (1962), 308.

²⁴Larry L. Kendrick, "Performance In Selected Gross Motor Skills Before and After Fatiguing Exercise," Doctoral Dissertation (Unpublished), Louisiana State University, 1967.

performance of selected gross motor skills. The fatigue was induced through a bench stepping work bout and the gross motor performance skills included the basketball free throw, basketball jump shot, vertical jump, total body response accuracy, and twenty yard sprint. A pre-fatigue skill test was administered followed by the work bout and the post-fatigue skill test. The post-recovery skill test was administered following a five minute recovery period.

It was concluded that fatigue impaired physical performance that demanded strength, endurance and rapidity of response involving total body movement. It was also concluded that general body fatigue did not influence the fine motor skill components.

Vines²⁵ conducted a study to determine if fatigue influenced factors of motor performance such as accuracy, reaction time, and the combination of the accuracy of response.

Arm fatigue was induced through an all-out work bout on a spring device. The test for accuracy was dart throwing and the reaction time test was movement away from a switch on a sound stimulus. One group took a pre-test on the accuracy test followed by the fatigue inducement and the re-test on the accuracy test. The second group followed the same procedure for the reaction time test,

²⁵Roland H. Vines, "The Effect of Localized Fatigue on Accuracy, Reaction Time, and the Combined Performance of Accuracy and Reaction Time," Master's Thesis (Unpublished), Louisiana State University, 1966.

and a third group was tested in the same manner using both variables. It was found that reaction time was not affected but that accuracy was adversely affected.

Elbel²⁶ studied the effects of various forms of strenuous exercise upon the response of men. Fatigue was induced through stool stepping, push ups and extended athletic activity. The responses tested were; finger response, hand response, and body response. It was found that stool stepping and push ups caused no significant changes in response time, but athletic activity improved response time in each type of response tested. It was suggested, however, that motivational factors may have been responsible for the improved responses.

Van Huss and others²⁷ found that an overload warm-up activity had a significant effect on velocity in baseball throwing. Fifty subjects threw a regulation five ounce baseball ten times measured for velocity and accuracy following a standard warm up. The subjects later repeated the ten throws measured for speed and accuracy following an overload warm up consisting of fifteen throws with an eleven ounce baseball. It was found that the overload warm up

²⁶E. R. Elbel, "A Study of Response Time Before and After Strenuous Exercise," Research Quarterly, 11 (May, 1940), 80 - 95.

²⁷W. D. Van Huss, L. A. Allruct, R. Nelson and R. Hageman, "Effect of Overload Warmup on the Velocity and Accuracy of Throwing," Research Quarterly, 33 (October, 1962), 472-275.

throws were significantly faster than the throws preceded by a standard warm up. Significantly different patterns were found among individuals on successive throws in accuracy response, but no group differences were found.

The studies cited in this section reported a divergence of findings. Due to the differences in type of task and imposed fatigue used no firm conclusions were reached in relation to the influence of fatigue upon performance. In each case where severe or heavy preliminary activity preceded the performance, some type of significant finding resulted.^{28,29,30,31,32}

STUDIES RELATED TO PRODUCING STANDARD WORKLOADS AND HEART RATE RESPONSES

In the realm of fitness testing and sport's medicine it has been necessary to construct standardized workloads capable of producing reliable physiologic responses. The three most common methods of standardizing workloads are bench stepping, as used in the Harvard Step test³³ and its

²⁸Phillips, loc. cit., p. 370

²⁹Kendrick, loc. cit.

³⁰Evans, loc. cit., p. 371

³¹Vines, loc. cit.

³²Van Huss, loc. cit., p. 472.

³³L. Brouha, N. W. Fradd and B. M. Savage, "Studies in Physical Efficiency of College Students," Research Quarterly, 15 (1944), 211.

modifications;^{34,35,36} bicycle ergometer workloads, as used in the Astrand and Rhyning Nomogram;³⁷ and treadmill walking as used in the Balke Treadmill test.³⁸

The most common parameter measured to determine the influence of the work bout is increase in heart rate. Heart rate is easy to monitor and correlates linearly with oxygen uptake which is considered to be the best index of a person's cardiovascular condition.³⁹ For practical purposes, exercise heart rate is the easiest gauge of physiologic adaptation to physical exertion to obtain.

Several studies have been conducted to establish the reliability of heart rate during exercise or physical exertion.

³⁴J. L. Patterson and Associates, "Evaluation and Prediction of Physical Fitness, Utilizing Modified Apparatus of the Harvard Step Test," American Journal of Cardiology, 14 (1964), 811.

³⁵Vera Skubic and Jean Hodgkins, "Cardiovascular Efficiency Test for Girls and Women," Research Quarterly, 35 (1963), 191.

³⁶R. Gallagher and L. Brouha, "A Simple Method of Testing the Physical Fitness of Boys," Research Quarterly, 14 (1943), 23.

³⁷P. O. Astrand and I. Rhyning, "A Nomogram for Calculation of Aerobic Capacity (Physical Fitness) from Pulse Rate During Sub-maximal Work," Journal of Applied Physiology, 7 (1954), 218.

³⁸B. Balke, G. P. Grillo, E. B. Konecci and U. C. Luft, "Work Capacity After Blood Donation," Journal of Applied Physiology, 7 (1954), 231.

³⁹Peter V. Karpovich, Physiology of Muscular Activity (Philadelphia: W. B. Saunders Co., 1966), p. 283.

Alderman⁴⁰ conducted a study to determine test-retest reliability for time scores on the bicycle ergometer for producing heart rates up to 180 beats per minute. Forty male college students pedaled at a rate of 45.45 pedal rpms starting with a resistance of .25 Kgm with 50 Kgm added each minute until the 180 rate was reached. A second bout was held forty-eight hours later. The following correlation coefficients were found at ten heart rate intervals from 150 to 180 beats per minute. (At 140 beats per minute $r = .818$; at 150, $r = .856$; at 160, $r = .894$; at 170, $r = .888$; and at 180, $r = .856$.) The results of this study showed that time scores increased in reliability from 100 to 160 per minute, but that no further increase in reliability occurred from 160 to 180 beats per minute. It may be concluded from this study that an individual when exposed to the same work load on different occasions will respond consistently in terms of heart rate increase.

Interindividual differences in heart rate response was the subject of another study by Alderman⁴¹ in which forty college students were tested on four separate occasions on a bicycle ergometer. The first two bouts consisted of pedaling at a rate of 100 wheel rpms and the second two

⁴⁰Richard B. Alderman, "Reliability of Individual Differences in the 180 Heart Rate Response Test in Bicycle Ergometer Work," Research Quarterly, 37 (1966), 429.

⁴¹Richard B. Alderman, "Interindividual Differences in Heart Rate Response to Bicycle Ergometer Work," Research Quarterly, 38 (1967), 323-329.

consisted of pedaling at a rate of 120 wheel rpms. The frictional resistance was progressively increased by one half kilogram per minute at the end of each minute until a heart rate of 180 was achieved. The scores were time readings taken at each ten beat heart rate level between 100 and 180.

It was found that there were no significant differences between test and retest exercise times at any level of heart rate. A correlation coefficient or $r = .875$ was calculated for the two work loads at the 180 heart rate level. It was concluded that "individual differences in heart rate response at two different workloads within the same task showed high generality."⁴²

Nagle and Bedeck⁴³ investigated heart rate response to treadmill running. Forty-four subjects performed an all-out run on a treadmill with an initial speed of 3.5 miles per hour and a five percent grade. Both speed and grade were gradually increased to 5.6 miles per hour and ten percent respectively. The times for heart rates of 150, 160, 170 and 180 beats per minute were recorded. A correlation of .85 was found at the rate of 180 beats per minute. It was also found that correlations between heart rate times and the all-out run times increased with the

⁴²Ibid.

⁴³Francis Nagle and Thomas Bedeck, "Use of the 180 Heart Rate Response as a Measure of Circulorespiratory Capacity," Research Quarterly, 34 (1963), 361.

heart rate.

The studies reviewed in this section present evidence that individual heart rate response to identical repeated workloads is highly reliable. Partially responsible for this finding is the readily reproducible work loads made possible by the bicycle ergometer and treadmill.

GENERAL SUMMARY

It cannot be stated at this time whether physical fatigue is a significant factor influencing motor learning. There is some evidence that fatigue adversely affects motor learning.^{44,45} One study was reported in which fatigue was found to both enhance and hinder motor learning.⁴⁶ Several studies have found that physical fatigue has no influence on motor learning.^{47,48,49,50} There is also an absence of evidence related to the relationship between learning conditions and performance conditions.

⁴⁴Nunney, loc. cit., 369.

⁴⁵Godwin, loc. cit., p. 374.

⁴⁶Benson, loc. cit., p. 251

⁴⁷Alderman, loc. cit., p. 131.

⁴⁸Carron, loc. cit., p. 682.

⁴⁹Bartz, loc. cit., p. 187.

⁵⁰Phillips, loc. cit., p. 370.

The review of studies related to physical fatigue and task performance revealed that severe fatigue induced prior to performance generally had detrimental effects on the performance scores. It was generally found that in studies where light or moderate fatigue was induced, performance scores were not influenced significantly.

The studies related to producing standard work loads and heart rate responses indicated that standardized workloads tend to produce reliable heart rate responses, particularly in studies where the bicycle ergometer and treadmill were used.

CHAPTER III

EXPERIMENTAL PROCEDURES

OVERVIEW OF PROCEDURE

This study was conducted for the purposes of determining (1) if the effects of practicing a novel gross motor task while in fatigued and nonfatigued conditions, were reflected in subsequent performance of the task, and (2) if practicing while in a fatigued state influenced the learning resulting from that practice. The data for this study were obtained from a learning and a performance phase.

Three groups, each composed of twenty-seven male college students, participated in the study over a two week period of time. During the first week, each group practiced a novel gross motor task under a specific level of physical fatigue. One group (Group H) practiced the task under a condition of heavy fatigue. The second group (Group M) practiced the task under a condition of moderate fatigue. The third group (Group N) practiced the task under no fatigue. Each subject had six practice trials; two trials each day for three days with a forty-eight hour period between practice days. The trials were immediately preceded by either a work bout on a bicycle ergometer, as with Group H and Group M, or by rest, as with Group N. Exercise heart rate was used as the physical fatigue

criterion. The moderate fatigue criterion was set at 150 beats per minute, and the heavy fatigue criterion was set at 180 beats per minute. The moderate fatigue subjects worked at a rate of 600 kilopond meters per minute for approximately five minutes. The heavy fatigue subjects worked at a rate of 900 kilopond meters per minute for five to six minutes. The subjects who practiced the task under no fatigue performed no preliminary ergometer work. The six practice trials will henceforth be referred to as the learning phase of the study.

During second week each subject again performed six trials of the novel gross motor task. The procedures were the same except each of the three days the subject performed two trials under a different fatigue condition. At the end of the week the subject had performed under all three fatigue conditions. These second week trials were considered as performance trials and not as learning trials, since the learning was assumed to have taken place during the first week trials. The second week trials will henceforth be referred to as the performance phase of the study.

The data gathered on each of the eighty-one subjects consisted of six practice trial scores all obtained while the subject was under one specific condition of physical fatigue, and three mean performance trial scores, one for each of the physical fatigue conditions.

The learning and performance phase data were analyzed by analysis of variance techniques.

SUBJECTS

Eighty-one male college students ranging in age from seventeen to twenty-seven years and enrolled at Tulane University, New Orleans, Louisiana, during the summer and fall semesters 1971 served as subjects for this study. The subjects were randomly assigned to three experimental groups, each group composed of twenty-seven subjects.

Each subject was interviewed prior to the beginning of the study to explain the procedures to be followed in collecting the data, describing the responsibilities incumbent upon each participant, and familiarizing the subject with apparatus used in the study. The novel gross motor task used in the study was explained and demonstrated to the subject as part of this orientation.

A subject was dropped from the study if he 1) missed a practice session during the learning phase of the study, or 2) if he missed a performance session during the performance phase which was not made up within twenty-four hours.

DESCRIPTION OF THE TASK

Apparatus and Testing Area. Apparatus used in the task performance included a standard volley ball, an eight inch cylindrical badminton shuttlecock container (which will be referred to as the tee), a standard basketball goal

attached to a backboard and mounted two feet above the floor, a regulation square basketball backboard, and a stop watch.

The task was practiced and performed on one end of a basketball court as seen in Figure 1. A triangular course was laid out on the basketball court, each leg of the course being forty-five feet in length. Each of the legs was divided into three zones fifteen feet in length.

The Task. The task began at one corner of the triangular course with the subject picking up the volleyball balanced on the tee. While balancing the ball on the tee, the subject moved as rapidly as possible along the first leg of the course to the first station, shown in Figure 2. At the first station the subject placed the tee and ball on the floor three feet from the nearest edge of the rim of the low basketball goal. The subject attempted to kick the ball from the tee into the goal as depicted in Figure 3. At this station the subject was required to kick the ball into the goal or to make ten unsuccessful kicking attempts, whichever came first. After fulfilling the requirement at the first station, the subject again picked up the ball, placed it on the tee and moved as rapidly as possible to the next station. At this station the subject was required to pitch the ball from the tee against the standard basketball backboard and attempt to catch the rebounding ball on the tee as viewed in Figure 4. The pitch was made seven feet from the backboard and the subject was allowed to move wherever he wished to control the

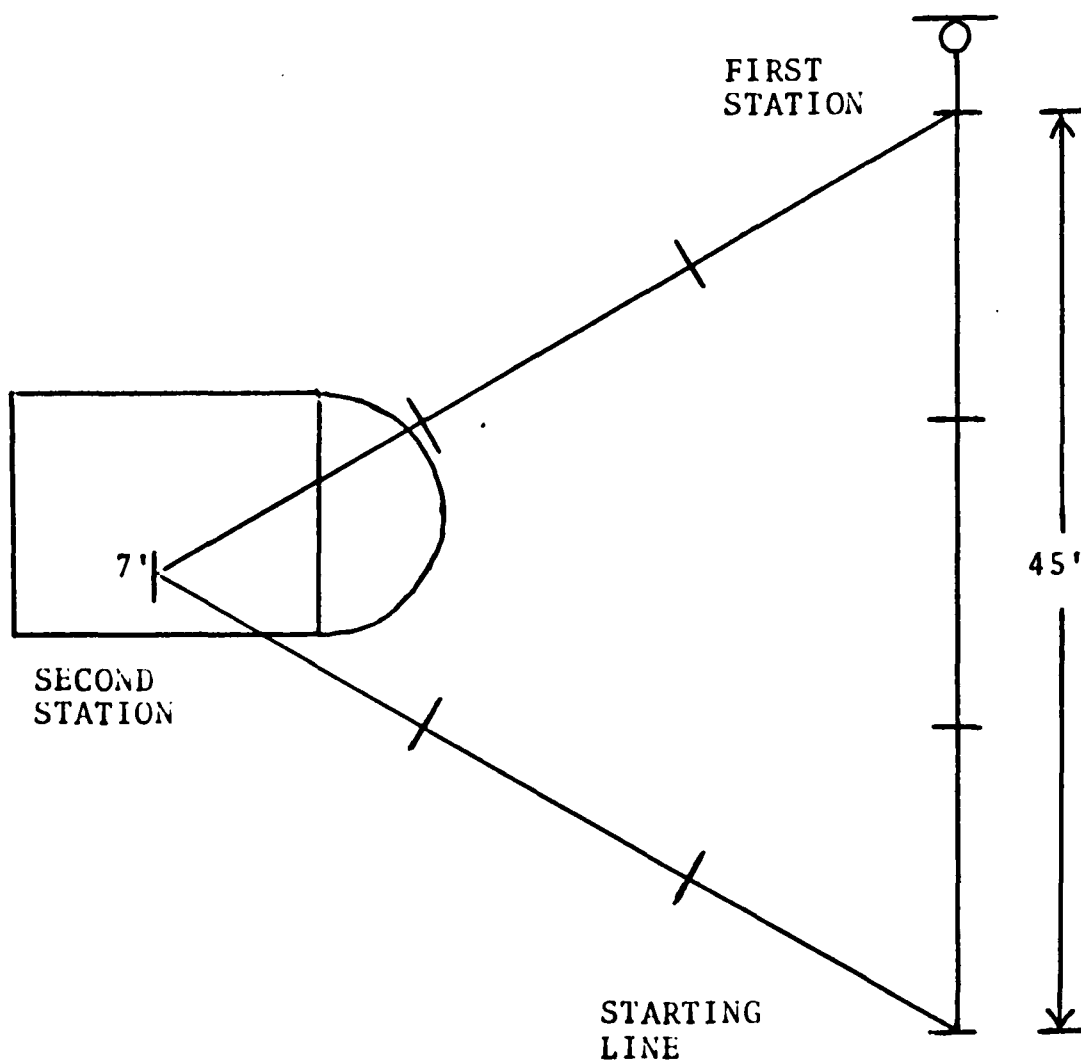


Figure 1
Task Course



Figure 2
Subject Illustrating Run with
Ball Balanced on the Tee



Figure 3
Subject Illustrating Kicking Ball From
Tee Into Low Basketball Goal
At Station One



Figure 4
Subject Illustrating Pitching and
Catching Technique at
Station Two

rebounding ball. Following an unsuccessful pitching attempt, the ball was retrieved and pitched again. The task requirement of the station consisted of either catching the rebounding ball or making ten unsuccessful attempts to catch the rebounding ball, whichever came first. After fulfilling the requirements of this station, the subject returned along the third leg of the triangle to the starting position where the tee and ball were placed on the floor. If during the course of moving from one station to another, control of the ball was lost, or it was dropped, the subject retrieved the ball and returned to the beginning of the zone in which control was lost, before continuing. One trial consisted of covering the triangular course five times. The score, recorded on a stop watch, was the length of time in seconds required to complete the five circuits.

PILOT STUDY

A pilot study was conducted prior to the experiment to determine if the task in question was a learning task. Fourteen male college students practiced the task four times. When the mean of the first two scores was compared with the mean of the last two scores, the t-test for matched groups revealed that the scores differed significantly in favor of trials three and four. It was concluded that learning did take place.

It was noticed that after four practice trials the improvement increments were quite small. It was decided

as a result of this observation that six practice trials would be sufficient for the learning phase of the study. (See Appendix F)

PHYSICAL FATIGUE CRITERIA

Three physical fatigue conditions were used in the study. The conditions were called nonfatigue, moderate fatigue and heavy fatigue. The fatigue conditions were administered to the subject immediately before starting the first trial each day. The criteria established for each condition are described below.

Nonfatigue. The subject's resting heart rate taken after five minutes in a sitting position was considered the criterion for the nonfatigue condition.

Moderate fatigue. The moderate fatigue criterion was an exercise heart rate of 150 beats per minute produced through a work bout on a friction type bicycle ergometer. The work load was 600 kilopond meters per minute sustained for approximately five minutes.

Heavy fatigue. The heavy fatigue criterion was an exercise heart rate of 180 beats per minute produced through a work bout on a friction type bicycle ergometer. The work load was 900 kilopond meters per minute sustained for three to four minutes. After the 180 heart rate was achieved, the work continued an additional two minutes.

PROCEDURES FOR APPLYING FATIGUE TREATMENTS

Two trials were given each day the subjects reported to the testing area for both the learning phase and the performance phase. The following steps were followed in applying the physical fatigue treatments.

1. The subject was asked to report to the test site five minutes early and to wait quietly in an adjacent room.

2. The subject was called to the test area and seated on the bicycle ergometer. A resting heart rate count was taken after five minutes. All heart rate measurements were taken by palpating the radial artery of the subject's left wrist.

3. If the subject was in the nonfatigue group, the first trial began immediately following the resting heart rate count.

4. The moderate fatigue subjects pedaled at a rate of fifty pedal revolutions per minute, which corresponded to a rate of twenty kilometers per hour read from the speedometer. The resistance was set at two kiloponds.

5. The exercise heart rate was monitored the last fifteen seconds of each minute. Slight adjustments in the frictional resistance were made to assure arrival at the 150 beat per minute criterion level at the five minute mark.

6. At the command "stop" the subject dismounted from the ergometer and walked five steps to the task starting point. The task time began as the subject crossed the

starting line and ended when he crossed the finish line.

7. The same procedures were used for the heavy fatigue treatment except the frictional resistance was set at three kiloponds.

8. At the completion of the first trial the heart rate was taken again.

9. The task was inherently fatiguing and the subjects' heart rates were elevated to an average of 160 beats per minute at the completion of the first trial. The non-fatigue group subjects rested in a sitting position until the resting heart rate was restored before starting the second trial.

10. The moderate fatigue group subjects rested in a standing position until the 150 heart rate criterion was attained. Generally, the heart rate level was only elevated a few beats above the criterion level at the end of the first trial, and therefore, the heart rate was monitored continuously until the heart returned to the 150 beat per minute level.

11. The heavy fatigue group subjects' heart rates were monitored at the conclusion of the first trial; if the rate was 180 beats per minute or higher the second trial began immediately. If the heart rate was lower than 180 beats per minute, the subject resumed the ergometer work until the heart rate was again 180 beats per minute. At this point the second trial began.

DATA RECORDING PROCEDURES

1. The study was conducted in three two-week testing periods. In order to eliminate any possible bias, an equal number of subjects from each learning group were tested during each of the three testing periods.
2. The subjects were randomly assigned to learning groups.
3. Subjects were dropped from the study for missing a scheduled learning trial or missing a scheduled performance trial which was not made up within twenty-four hours.
4. Subjects were required to appear for testing at the same time of day each day within a margin of one hour.
5. The subjects were not told the exact nature of the study, only that they were to perform to the best of their ability on each trial.
6. A resting heart rate and final exercise heart rate were taken and recorded for each subject all six days.
(See Appendix G)
7. During the performance phase of the study, the order of the fatigue conditions was counter balanced in order to rule out learning or conditioning gains which might have accrued from the second week trials. The counter balancing was accomplished by assigning a similar number of subjects from each learning group to six subgroups. Each subgroup performed following a different rotation of the fatigue conditions.

8. The task score was considered to be the time in seconds which was required to complete the task.

PERFORMANCE PROCEDURES

1. The stop watch was started when the subject initially touched the tee and volleyball.

2. The subject was allowed to carry the tee in either hand, but was required to grip below the middle of the tee.

3. The subject was instructed to "move as fast as you can" in order to get from one station to the next.

4. If the ball was dropped from the tee, or in the judgement of the experimenter, the subject did not have complete control of the ball, the subject returned to the beginning of the zone through which he was passing before continuing.

5. Both the subject and the experimenter counted the kicking and pitching attempts as well as the number of circuits during the trial.

6. The subject was made aware of the trial score and encouraged to strive to beat that score on the next trial.

7. The subject was required to wear tennis shoes and to dress in gym apparel.

ANALYSIS OF THE DATA

The data gathered on each of the eighty-one subjects consisted of the six practice trial scores, all obtained while the subject was under one specific condition of physical fatigue, and three mean performance trial scores, one under each of the physical fatigue conditions.

The primary problem of the study was to determine if practicing a novel gross motor task under a specific level of physical fatigue influenced the subsequent performance of that task when performed under differing conditions of physical fatigue. The problem was further defined by hypothesis one. A novel gross motor task practiced under a specific level of physical fatigue, would subsequently be performed best under that same level of physical fatigue. To test this hypothesis, the three performance phase scores of the three learning group subjects were compared using a three by three split plot analysis of variance.¹

The second problem was to determine if different levels of physical fatigue introduced prior to practicing a novel gross motor task influenced the learning resulting from that practice. Hypotheses two and three are related to this problem. Hypothesis two stated that motor learning

¹George W. Snedecor, Statistical Methods (Ames, Iowa: Iowa State University Press, 1956), p. 366.

would result from practice regardless of the fatigued condition of the learner and hypothesis three stated that the greater the physical fatigue condition of the learner during practice the less the learning that would result from that practice. To test these hypotheses the six learning phase scores were compared using a three by six split plot analysis of variance.²

²Ibid.

CHAPTER IV

PRESENTATION AND ANALYSIS OF DATA

INTRODUCTION

The data for this study were collected in two phases, a learning phase and a performance phase. The learning phase data consisted of six practice trial scores obtained from eighty-one subjects assigned to one of three groups ($n = 27$). Each group practiced the learning task under a different physical fatigue condition, i.e. heavy fatigue, moderate fatigue or nonfatigue. The performance phase data consisted of three performance trial scores for each of the eighty-one subjects; one under each of the three physical fatigue conditions. The scores are found in Appendixes B through D.

An analysis of variance using a three by three split plot design was utilized for the performance phase scores. This statistical design first determined if significant differences existed among the learning groups in mean performance under the three fatigue conditions. Secondly, the design determined if significant differences existed among the three performance fatigue conditions, that is, the mean performance of all eighty-one subjects under heavy, moderate and nonfatigue conditions. The design also indicated if there was an interaction effect between learning and

performance conditions.

An analysis of variance using a three by six split plot design was employed for the learning phase scores. This statistical design was used to compare scores of the learning groups, the practice trials, and the interaction effect between groups and trials.

ANALYSIS OF THE PERFORMANCE PHASE DATA

Table I presents a summary of the analysis of variance of the performance phase scores. The F-test to determine if the learning groups differed significantly in mean performance under all the physical fatigue conditions was not significant. This comparison indicated that when a learning group's total performance under all fatigue conditions was computed as one mean or average score, the average performances by learning groups were not significantly different. Table 2 shows the learning groups scores under each fatigue condition in rows and the performance condition scores by learning group in columns. The average learning and performance effects, defined as the difference between each row or column mean and the grand mean, are also shown.

The F-test to determine the significance of the differences in the performance conditions was significant, ($F = 4.35$ $P < .05$). This significant result indicated that when the total performance for the three fatigue conditions

Table 1

Analysis of Variance of the Performance Phase Scores
of Eighty-one Subjects Performing Under
Three Physical Fatigue Conditions

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F	P
Learning Groups	2	18071.61	9035.81	.84	N.S.
Subjects/Group	78	835064.96	10705.96		
Performance Conditions	2	8767.34	4383.67	4.35	.05
Learning Group					
Performance Condition	4	10785.99	2696.50	2.67	.05
Residual	156	157367.33	1008.77		
Corrected Total	242				

Table 2

Mean Performance Scores of Eighty-one Subjects Performing
Under Three Conditions of Physical Fatigue Showing
Average Learning Effects and
Performance Effects

	Perf. H	Perf. M	Perf N	Row Means	Average Learning Effect
Learning H	190	183	199	191	-12
Learning M	225	193	203	207	4
Learning N	217	211	202	211	8
Column Means	211	196	202	Grand Mean 203	
Average Perf. Effect	8	-7	-1		

Task Score in Seconds

H = Heavy Fatigue
M = Moderate Fatigue
N = Non fatigue

were compared, they were found to differ significantly.

It was found that performance under moderate fatigue conditions was significantly superior to performance under heavy fatigue conditions as indicated by Table 3.

The third F-test for the interaction between learning condition and performance condition was significant at the .05 level of confidence. This indicated that the combined effects of learning conditions and performance conditions resulted in significant differences in mean group performances. The interaction effect was examined by finding the difference between the grand mean and the mean performance scores by learning groups (average learning effect). Secondly, the difference between the grand mean and the mean performance scores by performance condition (average performance effect) was found. (See Table 2, Page 50) The average learning effect and average performance effect were combined and the sum of the two effects were either added to or subtracted from each learning group's performance scores. Table 4 presents the mean performance scores for the three learning groups performing under the three fatigue conditions adjusted for learning and performance effects. Keeping in mind that the smaller scores are the better scores, it can be seen in Table 4 that the heavy fatigue learning group performed best under the heavy fatigue performance condition; the moderate fatigue learning group performed best under the moderate fatigue performance condition; and the nonfatigue

Table 3

Orthogonal Comparisons Indicating the Significance of the Difference
Among Fatigue Learning Groups Under
Three Performance Conditions

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F	P
Performance Group	(2)	(8767.34)			
Heavy versus Moderate	1	8702.32	8702.32	8.69	.01
Residual Variance	1	65.02	65.02	.064	N.S.
Residual	156	157367.33	1008.77		

Table 4

Adjusted Mean Performance Scores of Eighty-one Subjects
From Three Learning Groups Performing Under
Three Physical Fatigue Conditions

	Perf. H	Perf. M	Perf. N	Row Totals
Learning H	194	202	212	608
Learning M	213	196	200	609
Learning N	201	210	195	606
Column Totals	608	608	607	Grand Mean 203

learning group performed best under the nonfatigue performance condition. This finding substantiated hypothesis 1.

ANALYSIS OF THE LEARNING PHASE DATA

The learning phase data consisted of six practice trial scores obtained from eighty-one subjects divided into three groups ($n = 27$). Each group practiced under a different fatigue condition; heavy fatigue, moderate fatigue or nonfatigue.

Table 5 presents a summary of the analysis of variance of the learning phase data.

The F-test to determine significant differences among the learning groups was not significant, indicating that the physical fatigue conditions introduced prior to practice did not significantly influence the learning of the criterion task.

The F-test to determine significant differences among practice trials, was significant at the .01 level of confidence ($F = 90.39$ $P < .01$). The differences in the mean practice trial scores were attributed to learning since the direction of the differences was toward improved performance as illustrated by Figure 5.

The F-test of the interaction of trials and groups (fatigue condition) was not significant, indicating that the three learning groups tended to parallel each other in learning rate as depicted in Figure 6.

Table 5

Analysis of Variance of Learning Phase Data of Three Groups Of
College Men (n = 81) Practicing A Motor Learning Task
Under Three Conditions of Physical Fatigue

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F	P
Learning Group	2	42692.15	21346.07	.67	N.S.
Subject/Group	78	2465988.78	31615.24		
Trials	5	1236116.75	247223.35	90.39	.01
Groups/Trials	10	33647.45	3364.74		
Residual	390	1062185.96	2723.55	1.85	N.S.
Corrected Total	485				

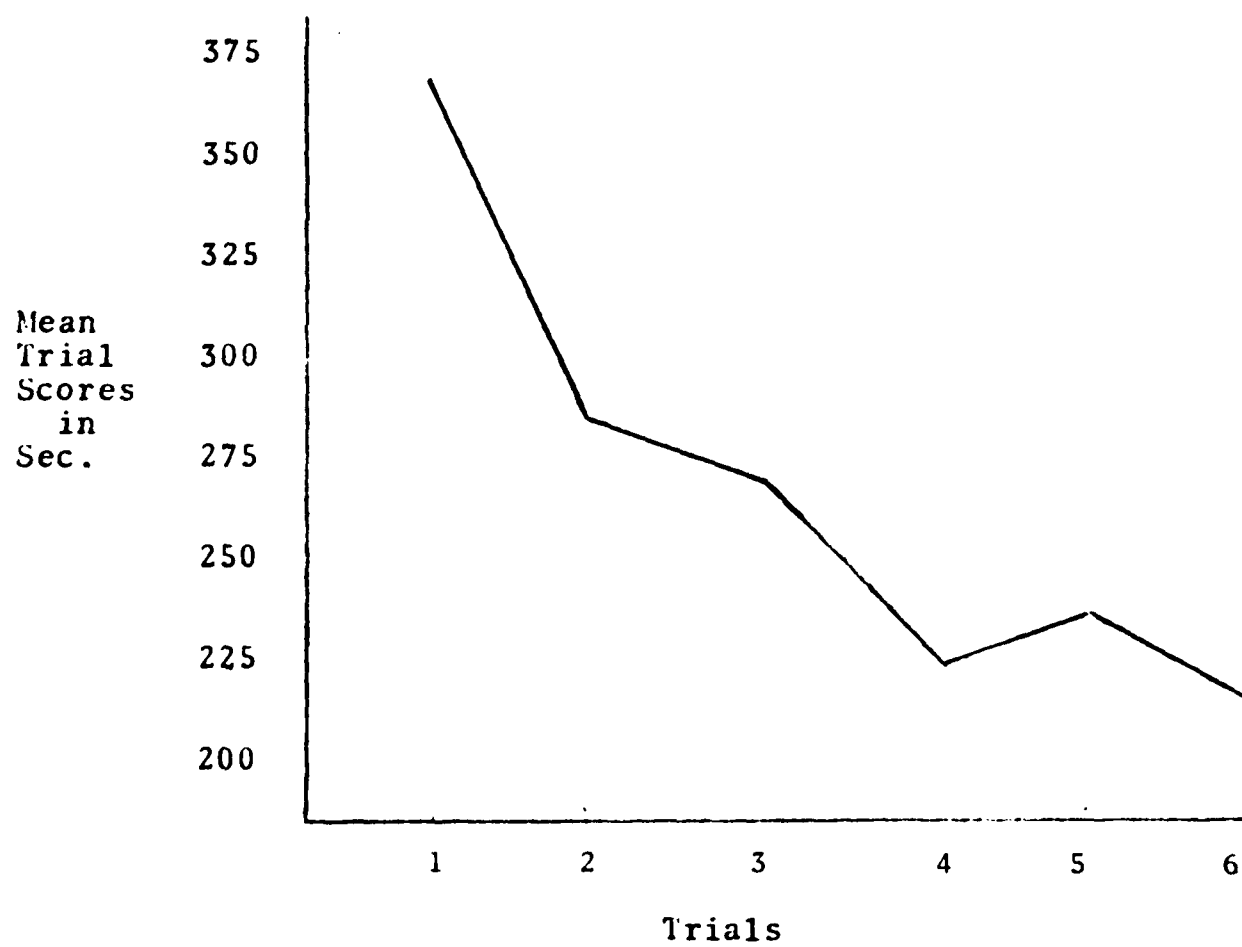


Figure 5

Mean Practice Trials For Eighty-one
Subjects Plotted by Trials

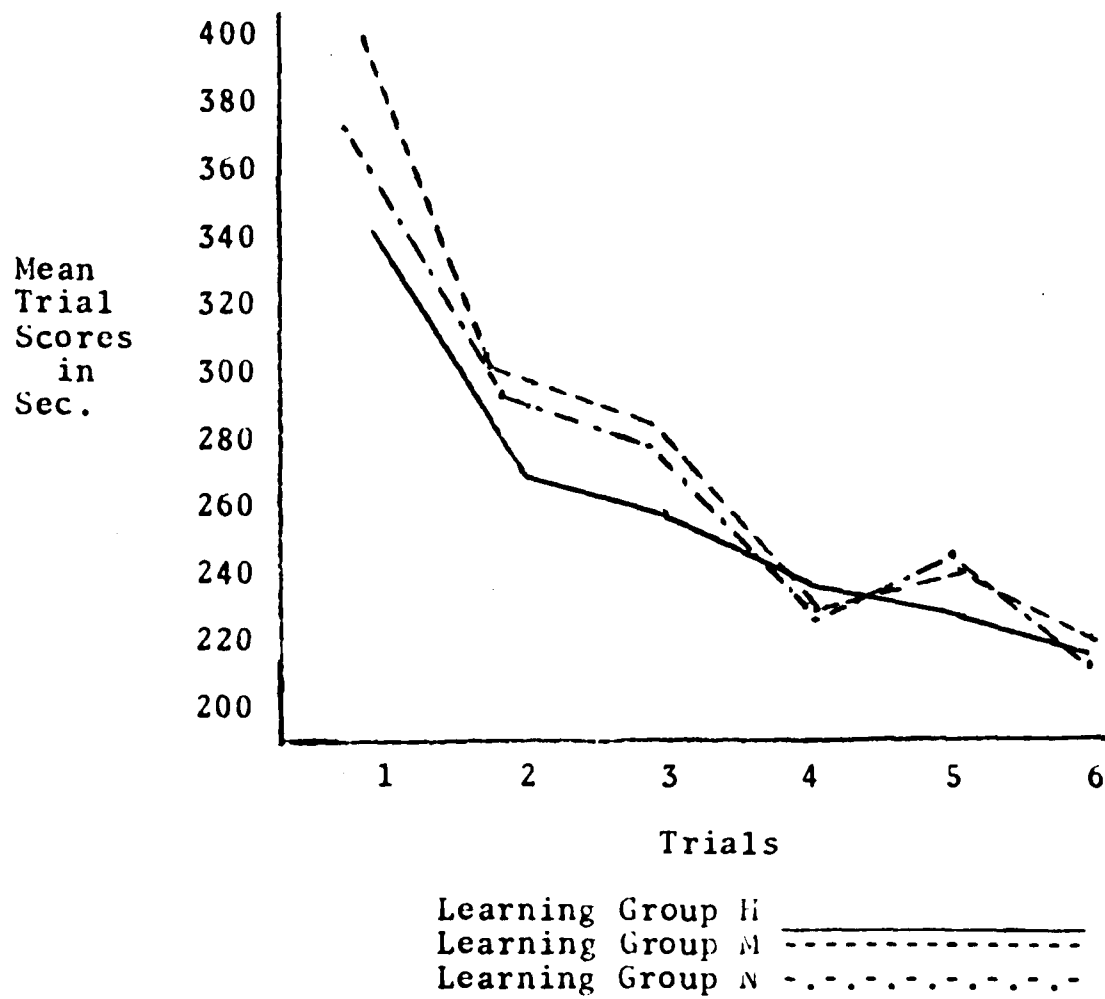


Figure 6

Mean Practice Trial Scores Plotted For
Each Group by Trial

DISCUSSION OF ANALYSIS

Three hypotheses were tested from the data gathered in this study. Hypothesis 1 postulated that a novel gross motor task practiced under a specific level of physical fatigue would subsequently be performed best under that same level of physical fatigue. This hypothesis was substantiated by the significant interaction effect obtained from the analysis of the performance data. This interaction effect was shown by the adjusted cell scores in Table 4. It was found that Group H performed best under Condition H, Group M performed best under Condition M and Group N performed best under Condition N.

Hypothesis 2 postulated that motor learning would result from practice regardless of the level of fatigue of the learner. The analysis revealed that all the groups learned at approximately the same rate as indicated by Figure 6, in spite of the imposed fatigue.

In hypothesis 3 it was stated that higher levels of physical fatigue would have a more adverse effect on motor learning than lower levels of physical fatigue. The failure to find physical fatigue a significant learning variable refuted hypothesis 3.

It has been generally accepted that physical fatigue has a detrimental effect upon performance of motor tasks. The analysis of the performance data revealed a significantly

poorer mean score for performance by the eighty-one subjects under heavy fatigue than under moderate fatigue. The superior moderate fatigue performance may possibly be attributed to a warmup effect.

Analysis of the mean performance scores among the learning groups did not disclose any significant differences. Analysis of the learning phase data revealed that the learning groups did not differ significantly. The mean learning trial scores proved to be significantly different; the differences being attributed to learning. The mean score for learning trial one was 371 seconds. The sixth or final mean learning trial score was 220 seconds, the difference between the two being 151 seconds. Of the 151 seconds difference, eighty-five seconds came from the difference between trials one and two. It may be seen that most of the learning took place during the early trials.

In summary, the physical fatigue introduced prior to practicing a specific novel gross motor task did not significantly influence learning resulting from that practice but subsequent performance of the task under all the fatigue conditions resulted in significantly better performance under the same fatigue condition in which the task was initially learned.

CHAPTER V

SUMMARY, FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

SUMMARY

The problems of this study were 1) to determine if practicing a novel gross motor task under a specific level of physical fatigue influenced the subsequent performance of that task when performed under differing levels of physical fatigue, and 2) to determine if different levels of physical fatigue introduced prior to practicing a novel gross motor task, influenced the learning resulting from that practice.

Eighty-one male college students, randomly assigned to three groups ($n = 27$), practiced and later performed a novel gross motor task under either heavy, moderate or non-fatigue conditions.

The criteria for the fatigue conditions were exercise heart rate levels. The fatigue was induced through work bouts on a bicycle ergometer immediately preceding the trial. The moderate fatigue criterion was 150 beats per minute obtained after a work bout of approximately five minutes. The heavy fatigue criterion was 180 beats per minute obtained after a work bout of five to six minutes. The nonfatigue subjects performed at resting heart rate levels.

The task consisted of running a triangular course

while balancing a volleyball on an eight inch tee (badminton shuttlecock container). The course was laid out on one end of a basketball court with each leg of the triangle being forty-five feet in length. Two performance stations were located at the corners of the triangle. At the first station the subject attempted to kick the ball from the tee into a basketball goal placed two feet above the floor. At the second station the ball was pitched against a standard basketball goal and the subject attempted to catch the rebounding ball on the tee. One trial consisted of completing five circuits around the course. The score was the number of seconds required to complete the trial. Each subject practiced the learning task six times under one of the three levels of physical fatigue. Following the learning phase, the subjects performed the task under all the physical fatigue conditions. This part of the study was called the performance phase.

The study was conducted during the summer and fall semesters of 1971 at Tulane University in New Orleans, Louisiana.

The learning phase data consisted of the six practice trial scores of the eighty-one subjects analyzed by group. A three by six split plot analysis of variance design was used to analyze the learning data. The performance phase data consisted of a performance score for each of the eighty-one subjects under each of the physical

fatigue conditions. A three by three split plot analysis of variance was used to analyze the performance phase data.

The hypotheses tested in this study were:

1. A novel gross motor task practiced under a specific level of physical fatigue would subsequently be performed best under that same level of physical fatigue.

2. Motor learning would result from practicing the learning task regardless of the fatigued condition of the learner.

3. Higher levels of physical fatigue would have a more adverse effect on motor learning than lower levels of physical fatigue.

FINDINGS

The findings of this study were as follows:

1. The learning groups did not differ significantly when total performance mean scores were compared.

2. Performance under moderate fatigue conditions was significantly better than performance under heavy fatigue conditions.

3. A significant interaction found in the performance analysis indicated that learning under a specific condition of fatigue resulted in superior subsequent performance under that same condition of fatigue.

4. No significant differences were found among the learning groups in the rate of learning which resulted from practicing under different levels of physical fatigue.

5. The learning trials differed significantly indicating that learning occurred.

6. The interaction effect of trials and groups (fatigue condition) was not significant.

CONCLUSIONS

The findings from the data provided by this study warranted the following conclusions:

1. The specificity of practice and performance conditions found in this study indicated that vigorous sports should be practiced under the same fatigue condition under which they would subsequently be performed.

2. Motor learning, within the context of this study, resulted from practice trials despite the physical fatigue introduced prior the practice trials.

3. Motor learning, within the context of this study, was not significantly influenced by physical fatigue introduced prior to practice trials.

RECOMMENDATIONS

It was recommended that the following studies be conducted:

1. A study similar in design to this study but using a learning task short enough in terms of practice time to prevent recovery from the induced fatigue.

2. A study similar in design to this study employing a fine motor learning task and local muscular fatigue.

3. A study to investigate the effect of fatigue on motor learning among groups in different stages of physical training.

SELECTED BIBLIOGRAPHY

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A. BOOKS

- Astrand, Per-Olaf, and Kaare Kodahl. Textbook of Work Physiology. New York; McGraw-Hill Book Co., 1970.
- Karpovich, Peter V. Physiology of Muscular Activity. Philadelphia: W. B. Saunders Co., 1966.
- Snedecor, George W. Statistical Methods. Ames, Iowa: Iowa State University Press, 1956.

B. PERIODICALS AND PUBLICATIONS

- Adams, Jack A., "Psycho Motor Performance As A Function of Intertrial Rest Interval," Journal of Experimental Psychology, 48 (1954), 131.
- Alderman, Richard B., "Influence of Local Fatigue on Speed and Accuracy in Motor Learning," Research Quarterly, 36 (May, 1965), 131.
- Alderman, Richard B., "Reliability of Individual Differences in the 180 Heart Rate Response Test in Bicycle Ergometer Work." Research Quarterly, 37 (1966), 429.
- Alderman, Richard B., "Interindividual Differences in Heart Rate Response to Bicycle Ergometer Work," Research Quarterly, 38 (1967), 323.
- Ammons, R. B. and Leslie Willeg, "Acquisition of Skill IV Effects of Repeated Periods of Massed Practice," Journal of Experimental Psychology, 51 (1956), 118.
- Archer, James E., "Postrest Performance in Motor Learning as a Function of Prerest Degree of Distribution of Practice." Journal of Experimental Psychology, 47:2 (1954), 47.
- Astrand, P. O. and I. Rhyning, "A Nomogram for Calculation of Aerobic Capacity (Physical Fitness) from Pulse Rate During Sub-maximal Work," Journal of Applied Physiology, 7 (1954), 218.
- Astrand, P. O., Work Tests with the Bicycle Ergometer. Vargerg, Sweden: Monark-Crescent AB.

- Balke, B. and G. P. Grillo, E. B. Kinecci and U. C. Luft, "Work Capacity After Blood Donation," Journal of Applied Physiology, 7 (1954), 231.
- Balke, Bruno, "Correlation of Static and Physical Endurance: I. A Test of Physical Performance Based on the Cardiovascular and Respiratory Responses to Gradually Increased Work," Randolph AFB, Texas: USAF School of Aviation Medicine, Project No. 21-32-004, Report No. 1, 1952.
- Bartz, Douglas W. and Leo E. Smith, "Effect of Moderate Exercise on the Performance and Learning of a Gross Motor Skill," Perceptual and Motor Skills, 31 (August, 1970), 187.
- Benson, David W., "Influence of Imposed Fatigue on Learning A Jumping Task and A Juggling Task." Research Quarterly, 39 (May, 1968), 251.
- Brouha, L., N. W. Fradd and B. M. Savage, "Studies in Physical Efficiency of College Students," Research Quarterly, 15 (1944), 211.
- Carron, Albert V., "Physical Fatigue and Motor Learning," Research Quarterly, 40 (December, 1969), 682.
- Digman, John M., "Performance Under Optimal Practice Conditions Following Three Degrees of Massing of Early Practice," Journal of Experimental Psychology, 52:3 (1956), 189.
- Elbel, E. R., "A Study of Response Time Before and After Strenuous Exercise," Research Quarterly, 11 (May, 1940), 80.
- Evans, W. O., "Performance of a Skilled Task After Physical Work or in a High Altitude Environment," Perceptual and Motor Skills, 22 (1966), 371.
- Gallagher, Roswell J. and Lucien Brouha, "A Simple Method of Testing the Physical Fitness of Boys," Research Quarterly, 14 (1943), 23.
- Godwin, Margaret A. and Richard A. Schmidt, "Muscular Fatigue and Learning a Discrete Motor Skill," Research Quarterly, 42 (December, 1971), 374.
- Henry, F. M., "Specificity Versus Generality in Learning Motor Skill," Proceedings of the College Physical Education Association, 59 (1956), 68.

- Lotter, Willard S., "Effects of Fatigue and Warmup on Speed of Arm Movements," Research Quarterly, 30 (March, 1959), 57.
- Nagle, Francis J. and Thomas G. Bedeck, "Use of the 180 Heart Rate Response as a Measure of Circulo-respiratory Capacity," Research Quarterly, 34 (1963), 361.
- Nunney, Dereck K., "Fatigue Impairment and Psycho-Motor Learning," Perceptual and Motor Skills, 16 (April, 1963), 369.
- Patterson, John L. and Associates, "Evaluation and Prediction of Physical Fitness Utilizing Modified Apparatus of the Harvard Step Test," American Journal of Cardiology, 41 (1954), 811.
- Phillips, William H., "Influence of Fatiguing Warmup Exercises on Speed of Movement and Reaction Latency," Research Quarterly, 43 (October, 1963), 370.
- Schmidt, Richard A., "Performance and Learning a Gross Motor Skill Under Conditions of Artificially Induced Fatigue," Research Quarterly, 28 (May, 1957), 147.
- Skubic, Vera and Jean Hodgkins, "Effects of Warmup Activities on Speed, Strength and Accuracy," Research Quarterly, 28 (May, 1957), 147.
- Skubic, Vera and Jean Hodgkins, "Cardiovascular Efficiency Test for Girls and Women," Research Quarterly, 35 (1963), 191.
- Van Huss, W. D., L. A. Allruct, R. Nelson and R. Hagerman, "Effect of Overload Warmup on the Velocity and Accuracy of Throwing," Research Quarterly, 33 (October, 1962), 472.
- Welch, Marya, "Specificity of Heavy Work Fatigue: Absence of Transfer from Heavy Leg Work to Coordination Tasks Using the Arms," Research Quarterly, 4 (May, 1969), 402.
- Witte, F., "Effect of Participation in Light, Medium and Heavy Exercise Upon Accuracy in Motor Performance of Junior High School Girls," Research Quarterly, 33 (1962), 308.

C. UNPUBLISHED MATERIALS

Kendrick, Larry L., "Performance in Selected Gross Motor Skills Before and After Fatiguing Exercise," Doctoral Dissertation (Unpublished), Louisiana State University, 1967.

Phillips, William H., "The Effect of Physical Fatigue on Two Motor Learning Tasks," Doctoral Dissertation (Unpublished), University of California, 1962.

Vines, Rolard H., "The Effect of Localized Fatigue on Accuracy, Reaction Time and Combined Performance of Accuracy and Reaction Time," Master's Thesis (Unpublished), Louisiana State University, 1966.

APPENDIXES

APPENDIX A

DATA SHEET

CLASS _____ NAME _____ AGE _____ WT. _____ HT. _____

GROUP _____

LEARNING SCORES	Resting Heart Rate	Final Heart Rate
Initial Trial Score _____		
Second Trial Score _____	_____	_____
Third Trial Score _____		
Fourth Trial Score _____	_____	_____
Fifth Trial Score _____	_____	_____
Sixth Trial Score _____	_____	_____
PERFORMANCE SCORES		
Non-fatigue Score _____	_____	_____
Mild Fatigue Score _____	_____	_____
Heavy Fatigue Score _____	_____	_____

APPENDIX B

AGE, HEIGHT, WEIGHT, CLASS, LEARNING SCORES ONE THROUGH SIX
PERFORMANCE SCORES FOR HEAVY, MODERATE AND NON FATIGUE
FOR GROUP H

Subj.	Age	Ht.	Wt.	Cl.	Learning Score						Perf. Score		
					1	2	3	4	5	6	1	2	3
1	21	71"	165	Jr.	274	232	163	197	182	165	145	183	181
2	21	72"	215	Jr.	341	269	218	185	173	189	202	179	184
3	18	71"	140	Fr.	320	183	197	160	177	131	186	130	124
4	21	72"	180	So.	253	217	214	161	162	123	140	148	170
5	23	73"	160	Sr.	264	183	170	190	168	177	168	161	156
6	20	70"	180	Jr.	324	261	205	186	178	224	166	193	193
7	20	71"	160	So.	384	316	286	241	210	211	187	190	250
8	17	69"	140	Fr.	316	223	267	229	245	261	234	138	195
9	19	63"	115	So.	327	291	263	240	188	135	182	165	167
10	18	67"	135	Fr.	377	256	383	405	315	258	187	171	185
11	20	75"	200	So.	440	295	292	249	234	187	189	172	158
12	19	75"	160	So.	268	255	277	199	219	184	138	172	173
13	19	66"	125	So.	174	155	158	215	178	195	127	169	144
14	20	75"	185	So.	400	306	261	281	240	210	215	163	185
15	18	70"	165	Fr.	286	245	214	201	163	179	201	138	155
16	17	68"	125	Fr.	268	288	175	176	214	195	164	160	189
17	18	66"	130	Fr.	564	443	448	508	534	433	347	432	328
18	17	69"	145	Fr.	398	240	414	282	151	229	188	141	162
19	17	71"	165	Fr.	430	245	349	315	300	340	276	278	313
20	18	71"	155	Fr.	306	223	250	195	290	249	149	162	164
21	18	70"	130	Fr.	346	450	346	207	255	302	206	163	237
22	18	75"	210	Fr.	302	201	244	194	195	145	139	149	139
23	18	69"	140	Fr.	534	487	237	297	227	204	184	188	200
24	18	73"	145	Fr.	577	351	289	382	369	421	326	320	442
25	18	73"	155	Fr.	288	266	195	185	215	217	177	151	188
26	17	74"	185	Fr.	254	163	180	145	161	152	120	170	155
27	17	71"	160	Fr.	295	156	196	232	202	226	189	164	239

Learning and Performance Scores recorded in seconds
Weight recorded in pounds

APPENDIX C

AGE, HEIGHT, WEIGHT, CLASS, LEARNING SCORES ONE THROUGH SIX
PERFORMANCE SCORES FOR HEAVY, MODERATE AND NON FATIGUE
FOR GROUP M

Subj.	Age	Ht.	Wt.	Cl.	Learning Score						Perf. Score		
					1	2	3	4	5	6	1	2	3
1	18	73"	175	Fr.	396	181	218	179	200	137	169	167	183
2	26	68"	165	So.	442	281	255	251	258	188	186	189	177
3	23	70"	155	Sr.	295	262	233	210	198	187	181	187	162
4	22	71"	195	Sr.	488	257	408	290	310	356	322	251	343
5	17	70"	160	Fr.	240	186	260	187	154	126	159	127	147
6	19	74"	185	Jr.	345	223	265	217	278	156	144	151	162
7	19	72"	155	So.	402	405	243	199	220	196	232	163	162
8	22	75"	270	Jr.	371	190	217	237	189	219	160	123	231
9	19	72"	170	So.	516	510	457	354	417	378	285	347	228
10	18	69"	155	Fr.	293	190	239	147	247	315	210	193	172
11	18	64"	135	Fr.	441	396	347	308	357	380	241	203	223
12	18	70"	165	Fr.	245	205	174	220	192	181	131	149	150
13	19	70"	175	So.	305	259	184	138	149	117	189	139	145
14	19	69"	145	So.	376	306	284	157	256	281	190	136	173
15	18	72"	160	So.	266	161	222	154	140	156	199	138	125
16	18	67"	125	Fr.	576	575	295	223	283	296	266	227	232
17	21	72"	150	Sr.	283	199	245	178	199	213	238	165	188
18	16	68"	140	Fr.	436	491	584	366	383	188	201	220	213
19	17	68"	155	Fr.	583	335	250	239	206	186	242	224	205
20	19	70"	135	So.	493	302	336	249	208	332	321	256	225
21	27	72"	230	Sr.	493	447	381	306	473	300	455	366	315
22	21	67"	150	Sr.	421	347	241	208	250	282	244	193	200
23	18	70"	145	Fr.	397	238	253	309	211	245	228	193	186
24	18	70"	150	Fr.	302	236	324	150	194	150	215	167	173
25	18	71"	160	Fr.	409	365	360	206	245	170	233	148	228
26	17	76"	155	Fr.	425	250	302	272	244	255	234	208	276
27	18	70"	160	Fr.	382	368	303	297	226	195	197	186	262

Learning and Performance Scores recorded in seconds
Weight recorded in pounds

APPENDIX D

AGE, HEIGHT, WEIGHT, CLASS, LEARNING SCORES ONE THROUGH SIX
PERFORMANCE SCORES FOR HEAVY, MODERATE AND NON FATIGUE
FOR GROUP N

Subj.	Age	ht.	Wt.	Cl.	Learning Score						Perf. Score		
					1	2	3	4	5	6	1	2	3
1	17	73"	180	Fr.	251	130	132	129	152	101	129	118	131
2	18	73"	136	So.	307	235	268	192	202	209	222	144	168
3	23	72"	180	Sr.	224	214	197	188	167	160	176	155	195
4	18	77"	185	So.	563	346	331	223	317	279	280	304	233
5	18	68"	135	So.	498	500	457	304	327	248	307	281	241
6	23	72"	170	Sr.	428	304	241	184	193	169	204	214	187
7	22	70"	175	Sr.	437	306	256	131	214	156	166	196	193
8	20	72"	180	Sr.	364	215	237	240	209	193	145	172	163
9	19	75"	175	So.	370	325	194	162	184	229	193	204	198
10	17	66"	115	Fr.	221	224	160	179	166	232	167	174	141
11	19	72"	150	So.	281	224	194	174	183	192	256	152	211
12	17	68"	170	Fr.	388	265	190	150	220	192	163	185	178
13	18	69"	210	Fr.	370	397	429	252	381	349	206	277	177
14	19	74"	155	So.	506	249	177	206	244	218	181	204	191
15	21	71"	160	Sr.	343	217	231	201	150	197	158	138	181
16	17	66"	125	Fr.	632	629	480	382	463	468	568	387	501
17	18	71"	145	Fr.	482	326	425	401	304	292	191	189	236
18	18	74"	160	Fr.	263	190	214	185	243	175	216	238	186
19	20	73"	145	Jr.	446	418	379	329	354	212	272	258	333
20	18	69"	170	Fr.	399	297	278	246	216	151	160	247	180
21	18	71"	140	Fr.	321	245	298	229	213	187	145	237	163
22	19	69"	165	So.	419	344	289	277	302	239	216	184	218
23	18	72"	175	So.	306	238	352	217	162	234	233	259	240
24	18	66"	140	Fr.	214	147	178	137	135	143	168	146	166
25	19	73"	180	Jr.	279	179	277	226	390	242	226	180	145
26	18	72"	150	Fr.	363	265	304	352	281	170	190	226	175
27	18	68"	125	Fr.	418	382	316	214	242	292	316	230	184

Learning and Performance Scores recorded in seconds
Weight recorded in pounds

APPENDIX E

MEAN RESTING HEART RATES AND MEAN FINAL HEART RATES
FOR SUBJECTS IN GROUPS H, M, AND N

Subj.	Group H MRHR*	FHR*	Subj.	Group M MRHR	FHR	Subj.	Group N MRHR	FHR
1	19	45	1	18	41	1	19	43
2	21	45	2	19	44	2	26	42
3	21	46	3	20	40	3	21	44
4	19	44	4	19	43	4	18	44
5	18	46	5	22	45	5	22	42
6	25	46	6	18	44	6	18	37
7	22	47	7	19	43	7	20	43
8	20	45	8	23	44	8	18	39
9	17	51	9	24	44	9	27	46
10	20	44	10	16	43	10	27	47
11	20	37	11	23	46	11	22	44
12	27	48	12	28	46	12	22	48
13	22	49	13	23	43	13	26	48
14	20	42	14	21	43	14	19	40
15	23	46	15	23	46	15	20	46
16	19	43	16	21	46	16	26	41
17	23	38	17	23	40	17	20	42
18	24	43	18	23	43	18	23	44
19	20	40	19	21	45	19	22	43
20	22	46	20	20	47	20	23	45
21	24	46	21	23	36	21	28	48
22	25	50	22	24	43	22	22	47
23	20	45	23	24	46	23	22	44
24	25	43	24	21	44	24	20	46
25	23	49	25	15	42	25	22	43
26	25	45	26	24	47	26	24	39
27	17	38	27	20	43	27	22	38
574		1107	578		1166	599		1173
M=21.26		M=44.33	M=21.41		M=43.18	M=22.22		M=43.48

*MRHR - Mean Resting Heart Rates *FHR - Final heart Rate
Heart Rate count taken for 15 seconds

APPENDIX F

PILOT STUDY DATA

Subject	Combined Time Trials 1 and 2	Combined Time Trials 3 and 4
1	708	349
2	612	475
3	606	349
4	583	362
5	495	317
6	494	412
7	791	465
8	426	340
9	867	497
10	674	441
11	437	396
12	472	409
13	585	380
14	437	436
Total Mean	8187 584.39	Total 5628 Mean 402.00

Score in seconds

VITA

The author was born in Creston, Iowa, February 24, 1939. He attended public school in Houston, Missouri and graduated from Houston High School in 1957. He then attended Southwest Missouri State College in Springfield, Missouri majoring in history and physical education. The Bachelor of Science degree in education was awarded in 1961. He taught and coached one year in the Mountain View, Missouri public school system. The author taught social studies and coached basketball in the Nixa, Missouri public school system for five years. He received a Master of Education degree from the University of Missouri in 1967. After serving two years as Intramural Director at Kansas State Teachers College, Emporia, Kansas he accepted a graduate teaching assistantship at Louisiana State University while working toward a Doctor of Education degree with a major in physical education and a minor in education. In 1970 he accepted a teaching position in the Physical Education Department at Tulane University, New Orleans, Louisiana.

He was married to the former Miss Mary Catherine Hoberock in 1966 and they have three children.

EXAMINATION AND THESIS REPORT

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Major Field: Physical Education

Title of Thesis: Effect of Different Levels of Physical Fatigue Upon
Motor Learning and Subsequent Motor Performance

Approved:

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