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The effects of physical education upon cognitive functioning

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THE EFFECTS OF
PHYSICAL EDUCATION
UPON COGNITIVE FUNCTIONING

by

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An Abstract

of a thesis submitted in partial fulfillment

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ABSTRACT

The effects of exercise obtained in a physical education class upon cognitive functioning were examined. Fourth- and fifth-grade students ($N = 124$) from three Ithaca area elementary schools were randomly assigned by class into either an active group or a control group. The cognitive functioning of both groups was assessed through measures of short-term memory (STM) and creativity. Subjects in the active group were tested within 15 min following completion of their physical education class, and subjects in the control group were tested on a school day when physical education class was not scheduled. During the testing period, each student completed two standardized tests, the Benton Visual Retention Test to measure STM and the Torrance Test of Creative Thinking to measure creative ability. One-tailed t tests for the differences between means of two independent groups were performed to determine if any significant differences existed between the active group and the control group for either STM or creativity. A statistically significant difference ($t[122] = 1.76$, $p < .05$) was found between the active and the control groups for STM. A statistically significant difference was also demonstrated between

the means of the two groups for one measure of creativity (i.e., flexibility) but not another (i.e., fluency) ($t[120] = 2.27$ and 0.83, respectively). To conclude, it is possible that the exercise obtained in the physical education classroom was able to enhance the students' STM, when measured by the Benton Visual Retention Test, and one measure of their creativity (i.e., flexibility), when measured by the Torrance Test of Creative Thinking. However, the students who participated in physical education class obtained scores that were not statistically different from the control subjects' scores on fluency, a second measure of creativity also measured by the Torrance Test of Creative Thinking.

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Requirements for the Degree
Master of Science

by
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Ithaca College
Division of Health, Physical Education, and Recreation
Ithaca, New York

CERTIFICATE OF APPROVAL

MASTER OF SCIENCE THESIS

This is to certify that the Master of Science Thesis of

Susan Galloway Gray

submitted in partial fulfillment of the requirements for the degree of Master of Science in the Division of Health, Physical Education, and Recreation at Ithaca College has been approved.

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DEDICATION

This thesis is dedicated to my husband, Doug, and to my parents for having the patience to see this project through to the finish and for always believing in me.

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Chapter 1

INTRODUCTION

When considering the fields of general education and physical education, much controversy arises over the place and importance of programs for exercise and physical fitness in the total education of our youth. Based on the axiom, "A sound mind in a sound body," Ted Grenda, the director of general education for the New York State Education Department, said that physical education is "the most important subject in our school system" (Kirshenbaum & Sullivan, 1983). In fact, research has been conducted that supports the notion that physical fitness and exercise can have a positive influence on a child's academic achievement and cognitive functioning (Christie & Saccone, 1985; Gabbard, 1978).

One of the first attempts to examine the relationship between students' physical and intellectual activities was conducted in Vanves, France in 1951 (cited in Keller, 1982). Academic instruction was reduced from 23.5 hours to 15 hours per week, and physical education was increased from 2 hours to 8 hours per week in the experimental schools. The researchers compared academic achievement, social well-being, and physical well-being between the experimental schools and control schools. By 1960, the results showed that experimental groups were superior to control groups in health, fitness, discipline, and attitude. In addition, the experimental groups performed better academically. This study provided impetus for other similar investigations of the interrelationship of physical fitness and academic performance.

Several studies that followed also found this positive connection between activity and cognitive functioning. Each study examined the relationship in a slightly different manner. For example, a study conducted in Russia in 1981 examined the effects of exercise during the lunch hour on the students' alertness, rate of learning, and overall classroom grades (cited in Power, 1986). The effects of a program of aerobic exercise on fourth- and fifth-grade students' academic achievement, cardiovascular fitness, respiratory efficiency, and self-esteem were examined in 1984-1985 by Christie and Saccone. Young (1979) examined the effects of regular exercise on cognitive functioning and personality, more specifically intelligence, brain function, speed of performance, memory, learning, and anxiety, in adults. Davey (1973) examined the effects of submaximal exercise on short-term memory in adults. As previously stated, researchers in each of the above studies found a positive connection between physical activity and cognitive functioning, in that an increase in activity was linked to an increase in cognitive functioning.

The studies that have examined the effects of exercise on scholastic achievement have utilized exercise training programs. That is, they have examined the effects of improved physical fitness levels upon academic achievement. Few studies have examined the acute effects of exercise on academic performance. The primary purpose of this study was to describe the relationship between a single bout of exercise and subsequent cognitive functioning in the classroom.

Unfortunately, in recent years, elementary school systems have reduced physical education funding, thus producing a decrease in the quantity and quality of physical education that children are receiving (Butts, 1985; Kirshenbaum & Sullivan, 1983; Martin, 1986). In a study conducted in 1977 (cited in Martin, 1986), researchers found that the pulse rates of the students in most physical education classes range between 102 and 125 beats per min. They also found that in the average physical education class, the children increase their heart rates to aerobic fitness levels (i.e., 170 beats per min) for only 1 out of every 45 min of class time, with the remaining time engaged in stop-and-go activities. In addition, research has shown that these children are spending less time engaged in physical activity outside the classroom (Croce & Lavay, 1985). Cole (1970) found that 85% of the children in the United States between the ages of 6 and 11 years watch television each day, and 98% watch television each week, with a weekly average of 26 hours. These figures are supported by a recent statement from the American Academy of Pediatrics, stating that children between the ages of 2 and 5 years currently watch approximately 25 hours of television per week and those between 6 and 11 years average more than 22 hours per week (Shearer, 1990). When you consider the time allotted to sleeping, eating, and school, the number of hours available for activity is substantially decreased. The total decrease in the activity level of today's youth has led to a decrease in standardized physical fitness test scores (Croce & Lavay, 1985). Essentially, the age of television, computers, and video games is producing children who are soft and sedentary (Martin, 1986).

Exercise and physical fitness are documented to have a positive effect on students' cognitive functioning and academic achievement. Thus, it is the purpose of this study to examine whether or not the physical activity found in a typical physical education class has any immediate effects on the students' cognitive functioning, specifically, the students' short-term memory (STM) and creativity.

Scope of the Problem

The study was conducted to determine the effects of physical activity found in an average elementary school physical education class on the students' short-term memory and creativity skills. The subjects were 124 fourth- and fifth-grade children from elementary schools in the Ithaca, NY area. Two standardized tests were administered in a group setting to each subject. The Benton Visual Retention Test (Benton, 1974) measured the students' STM, and the Torrance Test of Creative Thinking (Torrance, 1966) measured creative ability. Classes from each school were to be tested either directly following their physical education class (active group) or on a school day when they did not have physical education (control group).

Statement of the Problem

The purpose of this study was to examine the effects of a bout of physical activity performed in a typical physical education class on STM and creativity in elementary school students.

Null Hypothesis

There will be no significant difference in STM or creativity between students who had just participated in a physical education class and students who remained sedentary prior to testing.

Assumptions of the Study

The following assumptions were made concerning this study:

1. The fourth- and fifth-grade students in the Ithaca area were representative of the average fourth- and fifth-grade population.

2. The activity level in the physical education class was typical of the average physical education class.

3. The two groups of students had similar fitness levels and engaged in similar levels of activity outside the classroom on the day of testing.

4. The two groups of students had similar STM and creative ability prior to the experimental treatment.

5. The active group was truly active prior to the administration of the tests.

6. The control group was truly nonactive prior to the administration of the tests.

7. The order in which the tests were administered had no effect on the students' scores.

8. The Benton Visual Retention Test is a valid tool for measuring STM.

9. The Torrance Test of Creative Thinking is a valid tool for measuring creativity.

Definition of Terms

The following terms were operationally defined for the purpose of this study:

1. Short-term memory (STM) is the ability to recall a figure or group of figures after a 10-s period.

2. Creativity is the ability to make objects or pictures from sets of circles by using the imagination.

Delimitations of the Study

The following were the delimitations of this study:

1. The subjects were 124 fourth- and fifth-grade elementary school children from the Ithaca, NY area.

2. The students were tested in groups as opposed to being tested individually.

3. Only the Benton Visual Retention Test was used to assess STM.

4. Only the Torrance Test of Creativity was used to assess creative ability.

5. STM and creativity were the only aspects of cognitive functioning that were assessed.

Limitations of the Study

The following were the limitations of the study:

1. The findings may not be generalized beyond fourth- and fifth-grade students.

2. The findings may only be valid for comparison when testing is conducted in a group format.

3. Comparisons of the effect of exercise on cognitive function may only be valid when STM, as measured by the Benton Visual Retention Test, and creativity, as measured by the Torrance Test of Creativity, are utilized.

Chapter 2

REVIEW OF RELATED LITERATURE

The review of literature relevant to this study focuses on the following areas: (a) the relationship between physical activity and general cognitive well-being, (b) the relationship between physical activity and intellectual performance, (c) selected physiological responses to exercise, (d) the physiological mechanisms of memory, (e) the physical fitness level of today's youth and the role of the physical education class, and (f) summary.

The Relationship Between Physical Activity and General Cognitive Functioning

In past years, many people conducted their lives under the philosophy that a healthy body leads to a healthy mind without any real data to substantiate their belief. "Orandum est ut sit mens sana in corpore sano," in translation, means that you should pray to have a sound mind in a sound body. People's feelings of alertness, arousal, released anxiety, unending energy, and euphoria, among others, following periods of exercise have compelled researchers to investigate a possible relationship between the functions of the body and mind. As a result of these initial investigations, beneficial relationships are believed to exist between physical exercise and psychological functioning. This implies that exercise may enhance mental processes and/or personality traits (Blumenthal, Needles, Williams, & Wallace, 1981; Davey, 1973; Folkins, Lynch, & Gardner, 1972; Gutin & DiGennaro, 1968; Powell & Pohndorf, 1971; Young, 1979). On the other hand, data have also been produced that failed to uncover this positive connection between exercise and the processes of the brain (Buccola & Stone, 1975; Morgan, Roberts, & Feinerman, 1971). Based on these contradictions, further research needs to be conducted to confirm whether or not the feelings of alertness, arousal, and euphoria following periods of exercise are connected to physiological changes occurring as a result of this activity.

Folkins et al. (1972) investigated the relationship between physical fitness levels and general psychological well-being. The subjects were 84 junior college students. Half of these subjects, whom they referred to as the experimental group, were enrolled in a one-semester jogging course, and the other half, comprising their control group, were enrolled in either an archery or a golf activity course. Measures of fitness levels and psychological well-being were taken prior to the start of the courses and after their completion. Improvements in the physical fitness levels of the experimental group were significantly correlated with improvements in psychological fitness, in contrast to the control group, which did not experience an improvement in either variable. Therefore, these researchers concluded that increases in physical fitness levels achieved through a program of aerobic conditioning can have positive effects on psychological fitness levels.

In addition to Folkins et al. (1972), three studies investigated the influence of aerobic activity and physical fitness upon cognitive functioning and personality traits. These studies supported the theory that increased fitness levels can have beneficial effects on subjects' cognitive ability and personality (Blumenthal et al., 1981; Powell & Pohndorf, 1971; Young, 1979).

Blumenthal et al. (1981) found that as a result of a 10-week running program, subjects in the experimental group demonstrated improvements in certain aspects of their personality that were not seen in the control group. A positive relationship between regular exercise habits and intelligence in 71 adult men was reported by Powell and Pohndorf in 1971. They measured "fluid intelligence," which was operationally defined as intelligence that decreases as one's age increases. Powell and Pohndorf discovered that with regular exercise, the decrease in fluid intelligence was not as great as the decrease in intelligence in the men who did not exercise. They concluded that fitness obtained from regular exercise helps to maintain fluid intelligence levels. The third study supporting the notion that improved physical fitness levels enhance cognitive performance and personality traits was conducted by Young (1979). Following a 10-week program of aerobic conditioning, significant improvements were demonstrated in specific areas of intelligence. In addition, subjects' morale improved, and their anxiety levels decreased.

In all of the previously discussed articles, the effects of improved physical fitness on mental functions were examined. The acute effects of exercise, that is, the immediate effects of a single bout of exercise upon cognitive functioning, have also been investigated (Davey, 1973; Gutin & DiGennaro, 1968).

The effects of a single bout of exercise on the ability to perform simple addition was investigated by Gutin and DiGennaro (1968). The subjects (N = 23) were divided into three groups. All groups were administered tests of simple addition prior to and immediately following either a period of rest, 1 min of exercise, or 5 min of exercise. The group that exercised for 5 min performed significantly better than the group at rest. Davey (1973) also found that submaximal exercise enhanced STM. Three groups were formed from the 30 subjects. Between periods of testing that relied heavily on STM, subjects in Group 1 rested. Subjects in Group 2 performed a tapping test that required little physical activity, and subjects in the third group exercised at submaximal levels on a cycle ergometer. The results demonstrated a significant enhancement in STM with the exercise group when it was compared to the other two groups. No other differences were found. Both of these studies examined the acute effects of exercise upon cognitive functioning, and both concluded that submaximal exercise tended to enhance certain aspects of cognitive functioning, specifically simple addition and STM.

As stated earlier, not all research has concluded that exercise is beneficial to the functioning of the mind. Two studies that examined the relationship between exercise and cognitive functioning failed to find a positive connection (Buccola & Stone, 1975; Morgan et al., 1971).

Morgan et al. (1971) failed to find any relationship between acute physical activity and psychological depression or anxiety. Measures of depression and anxiety levels were taken prior to and following exercise periods in 120 men participating in a faculty fitness program. These exercise periods elevated the subject's heart rates to 150, 160, 170, or 180 beats per minute. No significant differences were found between the pre-exercise and the post-exercise measurements of depression and anxiety. However, the subjects reported that the exercise bouts were exhilerating and that they felt better following the exercise period. Thus, although no significant changes were seen in the psychological variables measured, the researchers suggested that other personality variables might have changed as a result of the exercise. It should also be noted that the psychological variables (i.e., depression and anxiety) measured in this study represent different forms of cognitive functioning than those previously reviewed.

The effects of increased physical fitness levels upon personality traits in elderly men were investigated by Buccola and Stone (1975). They failed to find a positive connection between improved physical fitness and certain measures of personality. Following a 14-week program of walking/jogging or cycling, significant improvements in several measures of fitness levels were reported. However, no significant differences were found following the 14-week program for any of the personality variables for the cycling group. The only significant changes appeared in the walking/jogging group. These subjects were less surgent and more self-sufficient at the end of the program than at the beginning of the program. The researchers concluded that few personality changes resulted from increased levels of fitness. It was also suggested that a longer program of exercise, coupled with measurement of different personality traits, might lead to different results. Reliability coefficients for the testing devices were not provided in the studies that failed to find a connection between increased fitness and changes in personality traits. If this information had been provided, a stronger conclusion addressing the objectivity of the measures could be made.

In summary, the notion that psychological well-being, intelligence, and short-term memory can be enhanced through improvements in physical fitness levels or single bouts of exercise is well supported. Data suggesting that there is no connection between the functions of the body and the well-being of the mind appear when more subjective traits, such as selected factors of personality, are measured. When traits that can be measured objectively are monitored, the theory that a positive relationship exists between physical activity and cognitive functioning is upheld.

The Relationship Between Physical Activity and Intellectual Performance

It is evident from the previously outlined studies that a relationship between physical activity and mental ability is suggested and, in most cases, supported. Based on this suggestion, the importance of physical activity to the total education of children, especially that activity found in the physical education classroom, should be examined. Several studies investigated the connection between physical activity or physical fitness levels and the academic performance of students. The results from these studies provide conflicting data regarding the theory that physical activity or fitness tends to increase the academic performance of students.

In 1951, a study was conducted in Vanves, France that examined the interrrelationship between physical fitness and academic achievement (cited in Keller, 1982). In addition to studying the relationship between fitness and academic status, these researchers examined the effects of physical fitness on social and psychological well-being. In order to investigate these relationships, the physical education class time in the experimental schools was increased from 2 to 8 hours per week, and at the same time the academic instruction time (non-physical education instruction) was decreased from 23.5 to 15 hours per week. The class schedule of the control schools remained unaltered, with 2 hours of physical education time and 23.5 hours of non-physical education instruction. When the researchers compared the academic achievement, social well-being, psychological well-being, and physical fitness levels of the two groups, they found beneficial results from the scheduling changes in the experimental group. By 1960, the children who had more physical education class time were superior in health, fitness, discipline, and attitude. In addition, these children performed better academically than the children from the control schools. This study was the first to examine the effects of physical fitness on social well-being, psychological well-being, and in particular, academic performance, and it also provided the impetus for related studies. One must question, however, whether or not simply labeling the school as "experimental" would be enough to incite excellence because of the additional attention given to these children. In other words, an experimental bias (i.e., Hawthorne effect) may be inherent in this design. There was not a control school in which scheduling was altered to provide a facade of experimental treatment without increasing the amount of physical education class time.

Hart and Shay (1964) examined the correlations between physical fitness and various academic achievement variables. The subjects were 60 sophomore women from Springfield College. The criteria for academic achievement were the students' SAT scores and cumulative grade point averages (GPAs). A significant correlation ($p < .05$) was found between physical fitness and students' cumulative GPAs. Correlations between physical fitness levels and verbal scores, as well as between physical fitness levels and mathematical scores, were not significant. These researchers concluded that even though physical fitness is not a strong predictor of academic success, there is a strong enough correlation for fitness to be considered a necessary factor for improvement in academic performance, and therefore, a necessary factor for the improvement in the general education of the college student.

Ismail and Gruber (1967) examined the effects of an organized physical education program on the intellectual performance of fifth- and sixth-grade students. The organized physical education program was designed to accomplish the following three objectives: (a) organic development was to be attained by developing muscular strength, muscular endurance, and cardiovascular endurance; (b) neuromuscular development was to be attained by developing coordination, balance, rhythm, and kinesthesis; and (c) personal-social interaction was to be improved by including activities requiring cooperative efforts in order to achieve success. This program was implemented for 1 year, after which the I. Q. and academic achievement of the students participating in this program were compared with those of students who participated in an existing physical education program. Although the results indicated no significant differences between the two groups of students on I. Q. scores, academic achievement scores were higher for students in the experimental program. Ismail and Gruber concluded that physical education centering around organic, neuromuscular, and personal-social development can have positive effects on students' academic achievement.

In an additional study conducted by Gabbard (1978), a positive relationship between acute physical exertion and classroom performance was found. Gabbard focused on the duration of the exercise period, examining how long the students needed to exercise in order for the bout to improve their academic performance. He noted, "elementary physical education class durations are usually based on effective scheduling or board recommendations, but few are based on researched information pertaining to student capabilities and later classroom performance" (Gabbard, 1978, p 13). Second-grade students (N = 166) were given mathematical computation tests under five different experimental conditions while in their physical education class. Each class was tested five separate times, once with no prior physical exertion (control), and then following 20-, 30-, 40-, and 50-min periods of organized exercise. The exercise consisted of ball relay games. There were no significant differences between the control test scores and the test scores after the 20-, 30-, and 40-min exercise periods. However, the results demonstrated that following the 50-min exercise period, students scored significantly higher on the math tests than they had under the control situation. The researcher concluded that a certain level of physical exertion must be obtained in order to influence mental performance on the mathematical test, and this level was only obtained in the 50-min exercise bout. The heart rates of the students during the exercise periods were not examined. It would be interesting to know at what level these students were exercising and then compare this level to those of other physical education classes. For example, in relay contests, teammates tend to stand for varying periods of time waiting for their turn to compete. During these periods, the participants would rest, thus lowering their heart rates.

Therefore, it is improbable that these students were able to maintain heart rates close enough to the target levels necessary to trigger aerobic benefits during these relay games. Based on this finding, a longer period of activity may be needed in order to achieve the same results as a 20-to-30-min period with constant aerobic acitivity, such as running or cycling. If an activity that is capable of sustaining elevated heart rates had been utilized during the exercise period, significant results may have been obtained for the shorter exercise periods. On the other hand, if this exercise is typical of elementary level physical education programs, the length of the class may need to be increased in order to improve academic performance through exercise. This study by Gabbard, however, was one of the few studies to document changes in cognitive function immediately following a period of exercise.

An experimentally sound study was conducted by Christie and Saccone in 1984-1985. The fitness, academics, and self-esteem training program (FAST) was designed for the purpose of assessing the effects of aerobic exercise on the fitness, academic performance, and self-esteem of elementary school children. A program of aerobic exercise focusing on running was incorporated into an elementary school, replacing the normal physical education curriculum. The subjects for this study were fourth- and fifth-grade students from a randomly selected school. A comparison group from a separate school participated in the normal physical education activities for fourth- and fifth-grade students. After a year of participating in the specified physical education program, both groups were tested. Fitness was measured by assessing changes in each student's weight, systolic blood pressure, diastolic blood pressure, maximum oxygen consumption, body fat, and resting heart rate. Academic achievement was measured at the beginning of the year using the total battery on the Comprehensive Test of Basic Skills (CTBS). This battery predicts student achievement for the upcoming year. These test scores were compared to their actual performance at the year's end. Self-esteem was measured through the Dimensions of Self Concept Scale, which was administered in the fall and then again in the spring.

The students who participated in the FAST program improved their cardiovascular fitness and respiratory efficiency. These students also had higher academic achievement levels in math, reading, and language than those students who participated in normal physical education activities. There were no significant differences in the self-esteem levels between the two groups. The researcher suggested that perhaps the modality utilized to measure self-concept was not appropriate and that a broader measure including such areas as behavior, physical appearance, anxiety, popularity, and happiness might produce different results. To conclude, this was a very thorough study that again supports the concept that improvements in fitness levels may lead to improvements in academic performance. As with the study conducted in Vanves, France, one must question the potential bias of these results based on the fact that only the experimental school's schedule was changed and they might have fallen subject to the "Hawthorne effect." That is, these students may have improved in the measured factors simply because they were the experimental school and improvements were expected. If the control school's schedule had also been modified and the study had been truly a blind study (neither group knowing which they were), the results may have differed.

As previously stated, not all of the studies indicated a positive connection between physical activity and academic performance. O'Connor (1969) investigated the effects of a program of physical activity upon motor performance, perceptual performance, and academic achievement. First-grade elementary school children (N = 123) were randomly assigned to either an experimental or a control group. The experimental group participated in a program of physical activity focusing on gross motor activities, such as strength, balance, and coordination, that replaced their regular physical education curriculum. The control group participated in their normal physical education class. Both groups were tested on several measures of motor ability, perceptual performance, and academic achievement. After a period of 6 months, significant differences were found between the two groups on measures of motor ability and on lateral awareness, one specific measure of perceptual performance. No significant differences were found on the remainder of the perceptual performance measures or on the tests of academic achievement. The researcher concluded that the changes in gross motor ability do not necessarily affect changes in perceptual performance or academic achievement.

While contradictory data have been presented, in only one study did the researchers fail to find a positive connection between physical activity and academic performance. This suggests that the theory that physical activity can enhance academic performance is supported. In addition, when comparing the latter study to the previous studies that found positive results, a difference in the type of activity specified in the experimental groups is found. In studies that tended to show significant differences in academic performance as a result of physical activity, the focus of the implemented programs was more on strenuous levels of activity and increases in fitness levels than on coordination or gross motor activities. Perhaps the higher level of exertion is needed to elicit responses in the body that in turn may affect a student's awareness or mental ability.

A second study that failed to find a positive relationship between fitness and cognitive performance was conducted by Powell (1984). He investigated the possibility that aerobic fitness achieved by improvements in the distance covered during a 12-min run would influence students' academic achievement. The students' GPAs were used to measure academic achievement for 284 university students. After a 12-week training period, significant improvements were reported for the distance covered during a 12-min run, demonstrating improvements in aerobic fitness. However, this improvement in fitness was not accompanied by improvements in academic performance. Powell based this conclusion on the fact that the students' actual GPA was not significantly higher than their estimated GPA after the 12-week period. With a different measure of academic achievement or a longer experimental period, allowing for changes in GPA, the results obtained from improved physical fitness upon academic performance may have been different. For example, if mathematical problem solving or reading comprehension tests had been used to measure academic achievement, a positive relationship may have resulted.

This study differs from the other studies with respect to the age group tested. One must wonder whether it is easier to affect younger students with regard to academic standings. The college-age students who have settled into a pattern, good or bad, might not reflect a change in academic ability as readily as an elementary school child.

Physiological Responses to Exercise

The responses of the human body to various degrees of exercise intensity have been investigated and well documented (Lamb, 1984). In the discussion that follows, the adaptations of hormones and those substances connected to hormonal functions from improved fitness or single bouts of exercise and their potential link to improvements in cognitive function are examined.

An organ of the endocrine system is an organ that secretes a molecule, most commonly referred to as a hormone, into the bloodstream (Vander, Sherman, & Luciano, 1980). Once the hormone is in the bloodstream, it travels throughout the body to specific target areas. Once the hormone reaches its target area, it is absorbed by the tissue and serves to influence a specific biological process. While it is being carried in the blood to its target area, the hormone may also affect other tissues. Because these effects are not the primary functions of the hormone, they are referred to as secondary functions. Below is a discussion of the hormones whose primary function may be linked to improvements in mental functioning and the effect of exercise upon the secretion of these hormones.

The human brain uses glucose as its main energy source. Any hormone that influences the mobilization of fat, and therefore the availability of glucose, will have pronounced effects on the functioning of the brain. With increased fat mobilization, plasma glucose levels increase (Lamb, 1984). Four hormones that directly enhance the mobilization of fatty acids are adrenocorticotropin hormone (ACTH), cortisol, epinephrine, and norepinephrine. Each of these hormones is secreted from a different area of the body, but all result in increased plasma glucose levels.

ACTH is secreted from the pituitary and directly acts upon the adrenal cortex as a releasing factor, controlling the release of certain hormones from the adrenal cortex. Increased blood concentrations of ACTH have been reported following marathon running and cycling, and the blood concentration levels increase as the intensity levels of the exercise increase (Lamb, 1984). In addition, reports of greater increases as a result of overall improved physical fitness levels are documented (Lamb, 1984). It is not known, however, whether these increased ACTH levels are a result of training or simply a result of the ability of the athlete to perform at higher intensities of exercise (Lamb, 1984). These studies suggest that exercise of moderate intensity levels for longer durations is needed to influence the plasma levels of ACTH. The half life of ACTH, defined by Lamb as the period of time it takes for one half of a given amount of hormone to be destroyed by the body, is 4 to 18 min. The length of time a hormone is present in the body is essential in the discussion of its secondary functions. One needs to know how long the levels remain elevated in order to connect its presence with alterations in function.

As previously stated, the adrenal cortex is stimulated by ACTH and releases two hormones, cortisol and aldosterone (Vander et al., 1980). Much controversy exists concerning the response of cortisol to single bouts of light to moderate exercise (Lamb, 1984). The concentration of this hormone in the blood has been documented to increase, decrease, or remain unchanged in response to exercise (Lamb, 1984). However, it is agreed that heavy exercise (whose parameters were not given) results in an increased concentration of blood cortisol (Lamb, 1984). No firm data have been documented regarding training effects upon the release of cortisol. Research suggests that the secretion of cortisol and aldosterone is generally not enhanced through exercise, however, it may be possible to increase plasma levels of these hormones through intense exercise.

The sympathoadrenal hormones, epinephrine and norepinephrine, are secreted from the endings of sympathetic nerves. These well-studied hormones are the main hormones involved in the "fight or flight" response triggered in most animals as a result of a stressful situation. Once released, these hormones act to increase awareness and alertness (Vander et al., 1980). They are quickly destroyed by the body, thus eliminating the possibility for prolonged secondary effects. Plasma levels will return to normal within 6 min of the completion of a bout of exercise (Lamb, 1984). Periods of exercise of moderate intensity may not affect plasma levels of these hormones (Lamb, 1984). However, with exercise that is 60% or greater than the maximum oxygen uptake (mVO2) there is a significant rise in blood levels of both hormones. As the intensity of the exercise increases, so does the plasma concentration of the hormones. It has also been stated by Lamb that these increases may be a result of the increased psychological stress accompanying the higher intensities of the exercise.

Endorphins are a group of hormones secreted from the pituitary that may also influence the functioning of the brain. These hormones may act very similarly to morphine, thus being referred to as endogenous pain killers. The endorphins with the most potent documented effects are beta-endorphin and dynorphin (Vander et al., 1980). Based on the facts that there is still much to be learned concerning the processes in the brain and that the primary target for these hormones is in the brain, researchers are investigating any possible secondary functions of these hormones related to cognitive function. Recent research has found that with a single strenuous bout of exercise the concentrations of beta-endorphin and beta-lipotropin increase (Lamb, 1984). There has also been documentation of training effects resulting in increased blood levels following a period of exercise, although it was suggested that these increases may be a result of the increased intensity levels, not solely training effects (Lamb, 1984).

In addition to the hormones discussed above, research suggests that another substance known as cyclic adenosine monophosphate (cAMP) influences processes of the mind, and the secretion of this substance is also influenced by exercise. This molecule is produced when the enzyme adenylate cyclase is activated and is able to catalyze a reaction which produces cAMP from adenosine triphosphate (ATP). Once created, cAMP acts as a second messenger, triggering various intracellular responses (Vander et al., 1980). In fact, cAMP is a second messenger for epinephrine, a hormone that stimulates the production of glucose from glycogen in the liver. Epinephrine stimulates the production of glucose by first activating adenylate cyclase, which will control the production of cAMP. Once produced, cAMP triggers the activation of a chain of enzymes that ultimately activates the catabolism of glycogen to glucose (Vander et al., 1980). Because the production of cAMP is dependent upon the presence of other substances, the response of the production of this molecule to exercise depends on the responses of the other substances. For example, it has previously been stated that the secretion of epinephrine is enhanced by exercise. If the level of circulating epinephrine is increased, more cAMP will also be produced, increasing its concentration in the body.

Research supports the ideas that exercise increases the secretion of certain hormones and that different hormones respond to different exercise intensities. If the level of the hormone is increased, the processes that the hormone influences will be enhanced. The following section presents research providing evidence for the involvement of several substances in the process of memory. If the theories that certain hormones enhance the process of memory and that the circulating level of these hormones can be increased through varying intensities of exercise are valid, one might speculate that the process of memory can be enhanced through specific types of exercise by the involvement of specific hormonal channels.

The Physiological Mechanisms of Memory

The processes of the mind have presented a challenging topic of research for scientists. It was not until 1950 that memory was thought to consist of two separate processes. The first process, short-term memory (STM), was thought to be transient, lasting from seconds to minutes, and the second, long-term memory (LTM), was permanent, lasting days to years (Baddeley, 1986). The original investigators of STM were cognitive psychologists, and as a result, the original models that provided an explanation for the process did not incorporate specific neural pathways and specific neurochemicals. The first model to provide an explanation for how these two seemingly separate processes (LTM and STM) could work together was proposed by Atkinson and Shiffrin in 1968 and then later named by Murdock as "the modal model" (cited in Baddeley, 1986). This model suggested that memory consisted of three stages. The first stage comprised a bank of sensory buffer stores that could accept and temporarily store information. These buffers then fed into the second stage, a limited capacity short-term storage, which in turn fed the information into the final stage, the long-term storage. In addition to feeding information into the long-term storage, the second component could also retrieve information from the long-term storage.

The modal model was formulated in the late 1960s, but it has not been until recently that neurophysiological information that provides more precise biochemical mechanisms has been gathered. Some explanations for the length of time between the formulation of the first models in the 1950s and the more precise biochemical models are based on the difficulties involved with investigating the functions of the human brain. One strategy for examining human memory, reductionism, refers to the study of a specific process in lower order species, such as the invertebrates. Reductionists believe that pertinent information can be obtained through studying parallel processes in lower order species. Reductionist strategies have successfully provided explanations for such mechanisms as muscle contractions, protein synthesis, membrane excitability, electrical and chemical transmission between nerve cells, and the genetic code (Kandel & Schwartz, 1985). However, some researchers do not accept reductionism because they believe that the processes underlying human learning are much too complex to be explained through the data gathered from investigating the same process in an invertebrate. Thus, the opponents argue that the information gathered concerning the mechanism of learning in a lower order species can not be generalized to the parallel mechanism in a human.

Another problem with research in this field is that of precision. For example, if a study determined that through introducing a certain chemical into the circulatory system of a human the memory of subjects could be enhanced, then the results could be interpreted as either a direct or an indirect consequence of the chemical treatment. For instance, researchers have determined that ACTH affects the consolidation of certain material into memory. These researchers, however, cannot determine if ACTH is directly influencing the memory trace, or if it is affecting some other function, such as attention or arousal, which in turn would enhance the memory process. Because researchers are unable to directly measure the levels of chemicals, such as ACTH, inside the human brain, concrete conclusions have yet to be determined with regard to the precise mechanisms of the process of human memory.

The distinction between STM and LTM as two separate processes remains well accepted by researchers. STM is viewed as a transient process involving the alteration of the synaptic potential, which leads to an increase in the level of the neurotransmitters released, but the process of LTM relies on the formation of new proteins and is a more permanent process (Deutsch & Deutsch, 1975). Because these two processes are believed to operate under separate mechanisms, the following explanations will center only on the process of STM. The more widely accepted theories of STM include models suggesting the involvement of a) cAMP, b) norepinephrine, c) ACTH, and d) several stress hormones and opioids. The next several paragraphs describe the specific mechanisms underlying each of these theories in varying detail.

A sound explanation of the first theory was presented in a review article by Kandel and Schwartz (1985) and also in an article written by Kennedy (1987). In both articles, the research examined the sensitization of the defensive withdrawal reflex of the external organs to stimulation by touch in the invertebrate, Aplasia. Kandel and Schwartz defined sensitization as being "an elementary form of nonassociative learning in which an animal learns to strengthen its defense reflexes and to respond vigorously to previously neutral or indifferent stimuli after it has been exposed to a potentially threatening or noxious stimulus" (Kandel & Schwartz, 1985, p. 383). Thus, sensitization is considered a form of STM and is controlled by neurotransmitter release into the sensory synapses that contact the retracting external organs (Kennedy, 1987). Kandel and Schwartz suggested that protein phosphorylation of cAMP ultimately brings about a prolonged stimulation of the synapse leading to an increased level of transmitter release into the synaptic junction. This increased concentration of neurotransmitter causes the desired behavioral pattern of learning. The increase in neurotransmitter release is triggered by an increase in the amount of cAMP at the synaptic junction. As long as the level of cAMP remains elevated, the short-term sensitization will last. An increase in cAMP can be brought about by many factors, one of them being the presence of the hormone serotonin (Kandel & Schwartz, 1985). Exposure to serotonin stimulates synthesis of cAMP through the phosphorylation of the protein, adenylate cyclase. The activation of cAMP may be the key to this process (Kandel & Schwartz, 1985). As long as levels of cAMP remain elevated, a prolonged stimulation of the synapse occurs. The cAMP causes the dissociation of a regulatory subunit from a cAMP-dependent protein kinase in the terminals of the neurons. The separate catalytic subunit can then phosphorylate a protein that is incorporated in a specific type of K+ channel, the S-channel. This phosphorylation inactivates the K+ channel and therefore slows down the repolarization of the membrane. This slower repolarization allows more Ca++ to flow into the terminal. The fact that intracranial injections of a certain substance that disturbs the ion transport across the membrane in the synaptic regions, leads to impaired acquisition of information supports this theory (Tsukada, 1988). Ca++ is responsible for controlling the binding of vesicles to the discharge sites, which in turn controls the amount of neurotransmitter released from the terminal. Lynch and Baudry (1985) also found that increased Ca++ levels in the synaptic junction enhanced the STM in rats. Therefore, with increased levels of Ca++ flowing into the neuron, more synaptic vesicles will bind to the release sites, leading to more transmitters being released, thereby enhancing the memory process.

In 1970, Kety suggested that the neurotransmitter, norepinephrine, could act to selectively enhance cell firing in neurons receiving environmental stimulus and it could also induce a persistent facilitation of the inputs that would lead to increased neurotransmitter release thus promoting memory (cited in Harley, 1987). Norepinephrine, due to its ability to inhibit neuronal cell firing, is classified as a CNS-inhibitory neurotransmitter

(Vander et al., 1980). However, it is now known that norepinephrine does not act soley as an inhibitor but also has the ability to enhance neural inputs (Harley, 1987). Anatomically, there is a group of axons that originate from the locus coeruleus (LC), which is located in the dorsal pons of the human brain, and which innervates several areas of the brain associated with memory (e.g., the neocortex, hippocampus, and cerebellum). All of these axons release norepinephrine as a neurotransmitter. In one study in which the firing of these LC neurons was monitored, researchers discovered a correlation between the firing and the level of arousal in rats (cited in Harley, 1987). As the firing of the neurons increased, so did the arousal of the animals. Therefore, the researchers concluded that LC firing is a direct function of arousal (Harley, 1987). From this conclusion, it was suggested that stimulation of these axons would lead to the enhancement of memory through an improved state of arousal. However, with continued research, it was found that norepinephrine reduced the rate of repolarization of the membranes that it innervated. As in the cyclic AMP mechanism discussed earlier, a slower repolarization can lead to an increased Ca^{++} flux into the membrane, causing a higher level of vesicle binding and ultimately a higher amount of neurotransmitter release. These findings support Kety's original hypothesis, that norepinephrine can enhance the firing of LC neurons and, ultimately, enhance memory.

In the past several years, researchers have discovered that several of the peripheral hormones are partially responsible for the modulation of certain memory processes. Among these hormones is ACTH. ACTH is a chemical that is secreted from the anterior lobe of the hypophysis of the pituitary and has its main effects on the adrenal cortex, where it triggers the release of cortisol, aldosterone, and other hormones (Vander et al., 1980). In the late 1970s, researchers discovered that hypophysectomized animals experienced impaired acquisition of a number of different behavioral patterns, such as active avoidance, visually discriminated escape, and a water maze (Rigter & van Riezen, 1978). Further examination demonstrated that the anterior lobe of the pituitary was necessary to cause this impairment and that injections of ACTH reversed this condition (Zornetzer, 1978). Zornetzer concluded that ACTH contributes to the modulation of the consolidation of new material. It has not yet been determined exactly how this peptide affects the acquisition of the new material, but two main theories have been proposed. The first hypothesis describes how ACTH could have a direct effect on the memory process, and the second describes an indirect method.

As previously stated, ACTH controls the release of cortisol from the adrenal cortex. Cortisol is a neuromodulator that influences the activity of norepinephrine. Cortisol, once through the blood-brain barrier, alters the rate-limiting enzyme that controls the synthesis of norepinephrine. Therefore, as levels of ACTH increase, greater amounts of cortisol are released, and this hormone then controls the amount of norepinephrine being released into the brain. Based on the Kety hypothesis (cited in Harley, 1987) concerning the involvement of norepinephrine with the memory process, this notion that ACTH may enhance STM through the synthesis of norepinephrine appears plausible.

Miller, Kastin, Sandman, Fink, and Van Veen (1974) examined the connection between ACTH and memory, specifically short-term visual memory. After discovering that injections of ACTH enhanced performance on the Benton Visual Retention Test, along with other measurements of cognitive functioning, the researchers concluded that ACTH appeared to activate specific regions of the brain through an unspecified pathway. The explanation Miller et al. provided is that ACTH enhanced the subjects' attention with consequent enhancement of STM. In fact, the subjects reported being more relaxed, alert, and resistant to attentional fatigue and boredom.

In addition to ACTH, certain stress hormones and opioids may also be linked to the enhancement of learning and memory. These hormones include epinephrine, peripheral norepinephrine, beta endorphin, and certain enkephalins (Martinez, Weinberger, & Schulteis, 1988). These researchers suggested that the hormones have their effect in the periphery of the body and need not travel through the blood brain barrier to enhance learning. Enkephalins injected peripherally into mice, rats, and monkeys influenced the acquisition of certain responses (Martinez et al., 1988). These researchers provided no precise mechanism for the results, however, others have suggested that the hormones enhance attention rather than directly affecting the cognitive process of memory (Tsukada, 1988).

In summary, the research investigating specific neurochemical processes that provide an explanation for the functions of the mind has led to the development of several models. Memory can be enhanced either directly through a slower repolarization of the neural membranes, thus allowing greater synaptic response, or indirectly through the enhancement of attention and/or arousal.

The Physical Fitness Levels of Today's Youth and the Role of Physical Education

Exercise can be beneficial. Not only does regular exercise improve fitness but, according to much of the literature reviewed in this chapter, it may also enhance cognitive ability. Unfortunately, the fitness levels of America's young are lower than the fitness levels of previous generations. A survey of 20,000 elementary children from across the country found that the fitness levels of the children were significantly lower than the fitness levels from previous years (Power, 1986). One of the tests in this survey measured the ability of a child to run 1 mile in 10 minutes. Only one-half of the girls were able to cover the required distance, and only one-third of the boys were able to complete the task. In addition, the number of children unable to cover 1 mile in 10 minutes was greater than numbers from previous years.

Three federally funded studies have examined the condition of public school children over the past quarter of a century (Kirshenbaum & Sullivan, 1983). Results showed that gains in fitness were evident between the first study in 1957 and the second in 1965. However, a comparison of the results of the 1965 study and the third study in 1975 failed to demonstrate improvements. In fact, in 1975, 57% of the students failed to achieve standards considered "average" for a healthy child. In an additional study conducted in 1979, evidence of one or more of the common risk factors for heart disease (e.g., high blood cholesterol, high blood pressure, obesity, and low cardiovascular fitness) was found to be present in 50% of the children examined (Kirshenbaum & Sullivan, 1983). Weight problems clearly plague today's young, and 15% to 20% of children are already obese, potentially due to a lack of activity (Croce & Lavay, 1985). One study that monitored daily heart rates of children reported that during the summer months, a child's most active time, boys sustained a heart rate of 160 beats per minute for an average of 20 min per day, but girls only sustained the same heart rate for 9 minutes per day (Gilliam, MacConnie, Geenen, Pels, & Freedeson, 1982).

The National Children and Youth Fitness Study was a 2-year survey of children between the ages of 10 and 17 years (Martin, 1986). These researchers suggested that children are not developing the exercise and fitness skills that will help them maintain good health as they become adults, and more importantly, they suggest that the children are not getting enough exercise to develop healthy cardiorespiratory systems. Two elementary physical education instructors realized the seriousness of the conclusions noted by this survey. Beth and Charlie Kuntzleman decided to improve the awareness and fitness of their students through what they referred to as the "Feelin' Good Program" (Martin, 1986). This program consisted of a 30-min aerobic workout and a health education program targeted to enable the students to assume greater responsibility for their own health. Prior to and after participation in this program, students' fitness levels were assessed. The Kuntzlemans expected the students' physical fitness to improve as a result of the program, and in fact, that is what occurred. What surprised the instructors was the additional improvements in self-esteem and the reports from teachers of improved academic performance.

Although these studies suggest that America's children are less educated with regard to controlling their own health and that they are less fit, a means for improving the children's knowledge and fitness has been provided. A strong physical education program can nurture the mental development, the personal-social effectiveness, and the physical fitness of the student (Clarke, 1982). Unfortunately, cost-conscious school systems are decreasing the funding to the education curricula. The programs that are hardest hit by these budget cuts are music and physical education (Kirshenbaum & Sullivan, 1983; Martin, 1986). Because physical education programs are losing funding, the schools are forced to decrease both the quantity and quality of the exercise in the class. As a result of these cuts, there are fewer classes per week, larger classes, and unqualified instructors (Kirshenbaum & Sullivan, 1983). It is not surprising that today's youth are less fit than previous years when both recreation programs and physical education funding are being reduced.

G. R. Cumming (1976), a cardiologist in a children's hospital, defined several reasons for sound physical education programs in the schools:

1. Physical exercise is important during childhood for the proper development of the functional capacity of the heart and lungs and the strength of the bones and muscles.
2. Continued physical exercise is important in later life for the prevention of heart disease.
3. Physical exercise can contribute toward the mental health of children and adults.
4. Physical exercise is important for weight control in childhood as well as in the adult years.
5. Physical conditioning has a role in the prevention of many diseases. Physical fitness increases the body's resistance against general stress and illness throughout life.
6. The basic orientation toward adult participation in physical activity is developed at a very early age, developing sound health habits and worthwhile use of

leisure time.

7. Classroom learning may be enhanced and supported via physical activity, as well as providing opportunity for creativity and expression.
8. Physical activity can increase self-concept and overall body image.

As it stands, with the present level of funding, the majority of the school systems will not be able to provide the amount of activity that is necessary to accomplish many of the above goals. In addition, the children are exercising less during their extra time, devoting most of it to stationary activities (e.g., television and video games).

Although physical education may be one of the most important parts of children's education, they are not receiving an adequate level of exercise during or after school. Further, they are lacking in information pertinent to maintaining good health. Therefore, these children are not receiving the possible benefits of good physical fitness. Today's youth are not as fit as they once were, and are probably not as mentally aware as they could be.

Summary

It is generally accepted that regular exercise has many physiological benefits. Recently, research has suggested that improved fitness levels and single bouts of exercise may also improve mental functions. For example, Folkins et al. (1972) found that improved fitness levels were positively correlated with improvements in psychological fitness. Other studies (Blumenthal et al., 1981; Powell & Pohndorf, 1971; Young, 1979) found improvements in personality traits, fluid intelligence, and morale as a result of improved fitness levels.

Additional data support the theory that single exercise sessions may improve cognitive funtioning. Gutin and DiGennaro (1968) found that after exercising for 5 min, the experimental group performed significantly better on a simple addition test. In addition, Davey (1973) found improvements in STM as a result of exercise on a cycle ergometer. When more subjective traits were examined (e.g., depression, anxiety, and selected personality traits) improvements in cognitive functioning as a result of exercise did not occur (Buccola & Stone, 1975; Morgan et al., 1971).

The relationship between improved fitness or single periods of exercise and classroom performance has also been investigated. By increasing the amount of time spent in physical education class and decreasing the amount of academic instruction time, students improved their physical fitness levels, social well-being, psychological well-being, and academic achievement in comparison to students who participated in the normal class schedule (cited in Keller, 1982). In addition, several studies found improvements in classroom performance as a result of regular exercise (Christie & Saccone, 1985; Gabbard, 1978; Hart & Shay, 1964; Ismail & Gruber, 1967), although two studies failed to find such a relationship (O'Connor, 1969; Powell, 1984).

If physical fitness or single periods of activity do positively influence the functioning of the brain, there has to be some physiological connection between the adaptations from exercise and the mental processes being utilized. Periods of exercise tend to influence the circulating levels of ACTH, epinephrine, norepinephrine, cAMP, and beta-endorphins. In connection, theories have been postulated for the involvement of ACTH, cAMP, norepinephrine, several stress hormones, and opioids in the memory process. If exercise can influence the levels of the chemicals involved in mental processes, exercise may very well be able to improve academic performance through enhanced cognitive functioning. It is also possible that exercise can improve alertness, attention, and arousal through the increased levels of the stress hormones and thereby improve cognitive functioning.

Unfortunately, today's youth are more overweight and less fit than children of previous generations. If the theories that exercise can enhance the functioning of the brain through alterations in specific neurochemicals, or that exercise can indirectly enhance mental processes through improved attention or arousal are true, the amount of exercise children obtain must be carefully examined. Children may be spending less free time being physically active. Therefore, the majority of the exercise these children are receiving is during the physical education class time. If this information is valid, the role of the physical education curriculum in our school systems must be reevaluated. As it stands, the exercise children are obtaining in the physical education classroom is decreasing both in quantity and quality because of decreased funding. Because physical education and physical activity may be a significant part of a child's education, it is necessary to re-examine the importance that is placed on their physical education class and their daytime activities. Assuming that exercise and physical fitness are beneficial to the well-being of the individual and that they may enhance cognitive functioning, children must become more active and physically fit.

Chapter 3

METHODS AND PROCEDURES

This chapter defines (a) the selection of subjects, (b) the treatment of subjects, and (c) the testing instruments. It also details the general procedures utilized in this study: (a) the method of data collection, (b) the scoring of the data, and (c) the treatment of the data.

Selection of Subjects

The subjects were 124 fourth- and fifth-grade students from selected Ithaca area elementary schools. A phone call was made to the principal of each elementary school in the area explaining the purpose and procedure of the study and requesting participation. Once the principal had given permission, the teachers of all the fourth- and fifth-grade classes were briefed on the purpose and procedures, and their permission was obtained. Following this, each student was given a permission slip that his/her parent or guardian completed, allowing the son or daughter to participate in the study (See Appendix A). It was explained throughout this procedure that the identity, age, gender, grade, and school of individual students would remain confidential. Once permission was obtained, the investigator randomly assigned classes to be tested immediately after physical education class (the active group) or to be tested on a day when they are not scheduled to participate in physical education class (the control group). At least one active group and one control group was selected from each school.

Treatment of Subjects

Each subject was administered two standardized tests in a group setting. The Benton Visual Retention Test measured the student's short-term memory, and the Torrance Test of Creative Thinking measured the student's creative ability. The active group was tested within 15 min following the completion of their physical education class. The control group was administered the same tests, however, these subjects had not participated in any physical activity the day of the testing prior to the testing.

Testing Instruments

The Benton Visual Retention Test (see Appendix B) was the first test administered to the subjects. It consisted of 10 pictures of a figure or several figures. These figures ranged from single circles, squares, triangles, or oddly shaped figures to combinations of the same in various sizes. Each picture was placed on an overhead projector and cast onto a screen that every subject could see clearly. After the subjects viewed the picture for 10 s, the overhead projector was turned off, and the students were told to draw exactly what they had seen on the screen in the answer booklet provided. This test measures the subjects' ability to recall figures from their short-term memory. The reliability coefficient for the scoring of this test is .95 (Benton, 1974).

One of the four batteries of the Torrance Test of Creative Thinking was the second test administered (see Appendix C). The battery selected for the purpose of this study was a figural test, entitled the task of repeated figures. This activity was designed to measure the fluency and flexibility of the subjects. Fluency is the subject's ability to make as many relevant answers as possible in the time allotted, and flexibility is the subject's ability to make as many different pictures or objects in the same time frame. In an alternative-form test-retest reliability study conducted by Mackler, reliability coefficients of .61 and .60 were obtained for fluency and flexibility, respectively (cited in Torrance, 1966).

Procedures

The two tests were administered in a group setting to a total of six classes, one active class and one control class from each of three Ithaca area elementary schools. The total time for test administration in each class was 30 min. It should be noted that prior to the administration of the tests, in order to alleviate any unnecessary pressure, the students were told that these activities were not tests, that there were no correct responses, and that the results from these activities would not influence their grades in school. It was stressed that these activities were merely for fun.

The first test administered was the Benton Visual Retention Test. A picture of a figure, usually squares, circles, triangles, or a combination of these figures, was placed on an overhead projector and cast onto a screen. After the subjects had viewed the picture for a period of 10 s, the projector was turned off and the subjects immediately drew what they had seen in the answer booklet provided.

The Torrance Test of Creative Thinking was then administered. This activity, the figural test of repeated figures, consisted of 36 empty circles. The subjects were instructed to see how many objects or pictures they could make from the circles provided, testing their fluency. They were then told that the circles should be the main part of what they drew, and to make as many different pictures or objects as possible, testing their flexibility. A time limit of 10 min was placed on the subjects, after which the answer booklets were collected.

Scoring the Tests

The data collected from both tests were scored blindly; that is, the scorer did not know whether a test was from the active group or the control group. The data from the Benton Visual Retention Test were scored based upon how many correct replications were produced out of 10 pictures.

The data collected from the Torrance Test of Creative Thinking was scored on fluency and flexibility. The fluency was measured by the number of responses that accurately incorporated the circle into the figure drawn minus the number of duplications and irrelevant responses. The flexibility was measured by counting the number of different categories into which a subject's responses were classified. These categories were derived from an analysis of 588 subjects from kindergarten through the college years (Torrance, 1966). New categories were created when a response did not fall under one of the established categories.

Treatment of Data

One-tailed t tests for the difference between two independent means were performed to determine whether any differences existed between the active group and the control group for memory and creativity. For all tests the .05 level of significance was set prior to data collection.

Summary

The subjects for this study were 124 fourth- and fifth-grade students from Ithaca, New York area elementary schools. All subjects were administered two standardized tests in a group setting, the Benton Visual Retention Test and the Torrance Test of Creative Thinking.

The students were randomly assigned by class to either the active group or the control group. The active group was administered the tests on a school day when they had participated in physical education, taking the tests 15 min after the completion of the class. The control group was administered the same tests on a school day when they did not have physical education class, therefore remaining sedentary immediately prior to testing.

The *t* test for the difference between two independent means was utilized to determine whether significant differences existed between the active and control groups for STM and creativity. The .05 level of significance was set prior to the collection of the data.

Chapter 4

ANALYSIS OF DATA

This chapter presents the results obtained from a comparison between subjects in the treatment and control groups for memory and creativity. The Benton Visual Retention Test was used to measure the subjects' short-term memory (STM) and the Torrance Test of Creative Thinking was utilized to measure the subjects' creativity. This chapter is divided into the analysis of data and a chapter summary.

Analysis of Data

A one-tailed $\underline{t}$ test for the difference between the means of two independent groups was performed on each test of cognitive functioning. The group means and the respective $\underline{t}$ values are presented in Table 1. The statistical analysis between the active and control group on STM produced a $\underline{t}$ value of 1.76, statistically significant at the .05 level. Therefore, the null hypothesis, which stated that there will be no difference between the subjects who were administered the Benton Visual Retention Test following a period of physical education and the subjects who took the same test after being inactive, was rejected. In other words, subjects who had just

Table 1

Descriptive Statistics by Group

Dependent Measures	Active M	Active SD	Control M	Control SD	t
Benton Visual Retention Test	(n = 60)		(n = 64)		
STM	6.97	1.39	4.97	2.00	1.76*
Torrance Test of Creative Thinking	(n = 58)		(n = 64)		
Fluency	17.76	9.46	17.03	10.30	0.83
Flexibility					
Raw data	5.67	3.64	4.30	2.33	2.51*
Square root Transform	2.27	0.74	2.00	0.55	2.27*

*$p < .05$.

participated in physical activity were able to perform significantly better on the Benton Visual Retention Test, which assesses the subjects' STM, than subjects who were inactive prior to testing.

When the *t* tests were performed on the creativity variables measured by the Torrance Test of Creative Thinking, a statistically significant difference was obtained for flexibility (t[120] = 2.51, $p < .05$), but not for fluency (t[120] = 0.83, $p < .05$). Thus, the null hypothesis, which stated there will be no significant difference between the active group and the control group on measures of creativity, was rejected. The subjects who participated in physical education prior to testing obtained scores that were significantly greater than those scores of the control subjects on one aspect of creativity, flexibility, but not on the other, fluency.

The flexibility data did not meet the assumption of homogeneity of variance (Bartlett-Box F[63, 57] = 11.64, $p < .001$). Therefore, a square root transformation was completed, and the resulting data did meet the homogeneity of variance assumption. In addition, the difference between the means of the transformed data was significant (see Table 1, t[120]

= 2.27, $p < .05$), meaning that the subjects who were active prior to testing performed significantly better on measures of creative thinking than the control subjects.

Summary

A one-tailed t test for the difference between the means of two independent groups was performed on each variable to determine if any statistically significant differences existed between the active group and the control group on memory and creativity. The results from this analysis demonstrated a statistically significant difference between the groups on measures of STM. The active group performed significantly better ($p < .05$) than the control group on the Benton Visual Retention Test.

The analysis for the Torrance Test of Creative Thinking resulted in a significant difference between the means of the groups for flexibility but not for fluency. Therefore, the subjects that participated in physical education prior to taking the Torrance Test of Creative Thinking obtained significantly higher scores when compared to the control subjects on one measure of creativity, flexibility. The scores for fluency, a second measure of creativity were not statistically different.

Chapter 5

DISCUSSION OF RESULTS

When people are asked why they exercise, the most common answers include such reasons as improving their cardiovascular health, improving their muscle tone, gaining strength, and managing stress. A new reason may be added to this list, that is, improving their cognitive functioning. In fact, many scientists have begun to investigate the effects of physical exercise upon cognitive functioning. As described in Chapter 2, several studies have examined the relationship between improved physical fitness and academic performance, and others have examined the connection between single periods of physical activity and cognitive functioning. However, few studies have examined the acute effects of exercise upon cognitive functioning in an academic setting. The present study examined the immediate effects of the activity obtained in a typical physical education session upon the short-term memory (STM) and creativity of fourth- and fifth-grade students. The results demonstrated that the students who participated in physical education class prior to testing performed significantly better on a test of

STM than those students who remained sedentary. In addition, the active group obtained a significantly higher score than the control group on a measure of creativity (i.e., flexibility), although, there was no difference between the two groups on another measure of creativity (i.e., fluency). This chapter will present a discussion of how the results obtained from this study relate to previous work and to research in the fields of exercise physiology and neuropsychology.

Submaximal Exercise and Academic Performance

French researchers (cited in Keller, 1982) were among the first to study the relationship between improved physical fitness and classroom performance and to find that improved fitness led to improved classroom performance. These researchers altered the structure of the academic day to increase the time children spent exercising. They found that students who exercised more during the academic day were superior in health, fitness, discipline, and attitude. These students also performed at significantly higher academic levels. Additional studies supporting the theory that improved fitness can enhance classroom performance were conducted by

Ismail and Gruber (1967) and Christie and Saccone (1985).

Other studies have investigated the immediate effects of submaximal exercise upon academic performance (Davey, 1973; Gabbard, 1978; Gutin & DiGennaro, 1968). Two studies, one conducted by Gutin and DiGennaro and another conducted by Davey, found that submaximal exercise enhanced subjects' cognitive functioning. Gutin and DiGennaro found improved performances on tests measuring simple mathematical ability, and Davey found that exercise enhanced STM. In fact, the study conducted by Davey utilized the Benton Visual Retention Test to measure the students' STM, as did the current study.

Gabbard (1978) also investigated the effects of submaximal exercise upon cognitive functioning. His study was oriented toward discovering how long students needed to exercise to enhance their classroom performance. Gabbard found that 50 min of physical education class time was necessary to cause a significant improvement on a mathematical computation test, supporting the theory that exercise can have immediate effects upon classroom performance.

In the current study, the immediate effects of the exercise obtained in the typical physical education class upon STM and creativity were examined. Neither the type of exercise in the physical education class nor the students' levels of exertion were measured directly in this study. Therefore, it was assumed that the activity level was submaximal and that the students remained active throughout the class period. All three of the above studies found that submaximal exercise can enhance classroom performance, however, there were no measures of the level of exertion (i.e., the intensity that the students exercised). In order for more valid conclusions to be made concerning the level of exertion that a student needs to obtain beneficial results on academic performance, specific measurement of the activity level (e.g., percentage of VO2 max) should be obtained. Regardless, all four of the above studies found that submaximal exercise can improve students' classroom performance, more specifically, their mathematical computation ability or their STM.

Possible Mechanisms Explaining How Exercise May Effect STM

As stated earlier, studies have supported the theory that exercise can enhance cognitive functioning, but these studies have failed to provide an explanation for how exercise may bring about these improvements. The discussion that follows will focus on two areas: (a) the known physiological effects of submaximal exercise and (b) the theories of the control of STM. These two areas will be combined to formulate a theory for how submaximal exercise may enhance such cognitive processes.

The concepts that provide the connection between the physiological effects of submaximal exercise and the control of STM include the involvement of (a) cAMP, (b) epinephrine, (c) norepinephrine, (d) ACTH, and (e) other hormones that may influence attention and arousal (Baddeley, 1986; Harley, 1987; Kandel & Schwartz, 1985; Kennedy, 1987; Martinez et al., 1988; Miller et al., 1974). Each of these possible relationships is examined in the following paragraphs.

During periods of exercise, the entire body relies on glucose as its main energy source (Lamb, 1984). Once circulating levels of glucose are lowered, the body relies on the breakdown of glycogen in the liver for glucose. Two enzymes, glycogen phosphorylase and phosphofructokinase, control the rate of glycogen breakdown, and therefore the amount of circulating glucose. In addition, glucose is produced from the breakdown of triglycerides in the adipose tissue (Lamb, 1984). A chemical that can control the activation of these two hormones and the breakdown of the triglycerides is cAMP, which is produced through the activation of adenylate cyclase. Because cAMP is responsible for controlling the levels of circulating glucose, and because glucose is the major energy source utilized during submaximal exercise, the production of cAMP is sensitive to exercise (Lamb, 1984). The amount of cAMP produced increases during periods of exercise, and as the exercise intensity increases, the circulating level of this compound increases. Accordingly, as the body creates more cAMP, more glycogen is broken down, more fat is mobilized, and more glucose is produced to provide the energy needed for the continuation of exercise (Lamb, 1984).

Kandel and Schwartz (1985) suggested that cAMP may be responsible, in part, for controlling STM. The cAMP is thought to slow the repolarization of the neural membrane, allowing more Ca++ to flow into the membrane. This allows more vesicles that contain specific neurotransmitters to bind to the membrane and ultimately increases the amount of neurotransmitters released. When the level of neurotransmitters is increased, mental functions are enhanced. Therefore, cAMP may improve STM through increased levels of neurotransmitters.

The hormone epinephrine also influences circulating levels of plasma glucose and is sensitive to exercise (Lamb, 1984). This hormone controls glycogenolysis, the production of glucose from glycogen, through the action of cAMP. In response to exercise, the adrenal medulla secretes greater amounts of epinephrine, and as a result of the increased levels, more glucose circulates in the blood. Because this mechanism involves increases in cAMP, a rise in epinephrine may also lead indirectly to improved STM through the pathway previously described. In addition, epinephrine is secreted along with other stress hormones as a part of the "fight or flight" response to stress (Vander et al., 1980). During this stress response, the body prepares itself by becoming more aroused and alert. As a result, the mind may be able to function more accurately and quickly. Thus, epinephrine may effect STM through the enhancement of attention or arousal.

The secretion of norepinephrine is increased as a result of exercise, and as the exercise intensity increases, the amount of norepinephrine secreted also increases. Two mechanisms have been suggested to explain how norepinephrine might enhance STM following a period of submaximal exercise (Harley, 1987). The first mechanism is through improving an individual's attention or arousal. Norepinephrine is also a stress hormone, so during a stressful situation, greater amounts of this hormone are secreted and are responsible for the improved attention and arousal characteristic of this stress response described above. Therefore, norepinephrine may contribute to improved STM through the enhancement of an individual's attention, similar to the pathway described for epinephrine.

The second mechanism involves the stimulation of locus coeruleus (LC) neurons, which are neurons that emanate from the dorsal pons and innervate areas of the brain associated with memory. The LC neurons are responsible for controlling the release of norepinephrine from neural cells. This hormone may enhance STM by slowing the repolarization of the membrane, leading eventually to increased neurotransmitter release. Documentation of the effects of exercise upon the firing of LC neurons has not yet been produced, so no conclusive statements can be made as to the involvement of norepinephrine as a neurotransmitter in enhancing the student's STM.

The presence of the stress hormone ACTH may improve STM (Miller et al., 1974; Rigter & van Riezen, 1978; Zornetzer, 1978). ACTH is secreted from the pituitary and is responsible for controlling the release of cortisol from the hypothalamus. Cortisol, in turn, is responsible for controlling the release of norepinephrine. Increased levels of circulating norepinephrine enhance cognitive functioning by the two mechanisms described above. ACTH has also been connected to alterations in the state of arousal (Miller et al., 1974). That is, as the circulating level of ACTH increases, so does the level of arousal. Because exercise increases the level of ACTH circulating in the body (Lamb, 1984), it is plausible that exercise may enhance STM through increased levels of ACTH either by influencing the levels of norepinephrine in the brain and the activity of the LC neurons or indirectly by improving the attention and arousal.

The fact that circulating levels of beta-endorphin increase as a result of exercise may also explain the improvement of the subject's STM (Martinez et al., 1988). However, the studies examining how beta-endorphin may enhance cognitive functioning, more specifically STM, are inconclusive. Beta-endorphin may affect the periphery, possibly enhancing arousal and attention in a manner similar to the way the hormones discussed earlier affect the body. Although it is possible that increased levels of beta-endorphin may have contributed to enhancement of STM, no conclusions regarding its involvement can be made until further research is conducted.

Possible Mechanisms Explaining How Exercise May Effect Creativity

Although a substantial amount of research has been conducted to investigate the neurophysiological control of STM, similar research has yet to be performed on creativity. In fact, this author is unaware of any known neurophysiological explanations for creativity. In this next section, possible explanations for the link between submaximal exercise and creativity will be presented.

Any substance that improves attention or arousal may indirectly improve creativity. As discussed above, the circulating levels of the catecholamines, epinephrine and norepinephrine, increase following periods of exercise. These hormones increase attention, arousal, and alertness in order to prepare the body for the "fight or flight" response to stress. Therefore, if an improved state of arousal leads to improved creativity, creativity may be enhanced following periods of activity through the action of catecholamines.

Increased levels of ACTH and beta-endorphin have also been connected with improved attention. In addition, these substances are sensitive to varying degrees of activity, so that as a person exercises, the circulating level of these hormones increases. If the activity that the subjects obtained in the physical education class was able to produce a significant increase in any one of these hormones, their attention and arousal may have been enhanced. As a result of this improved state, the subjects may have been able to perform significantly better than the control subjects on measures of flexibility.

However, if improvements in attention and arousal were responsible for the significant difference in the scores of flexibility, one would also expect to see improvements in the scores of fluency. This was not the case. One reason that only one measure of creativity was significantly different between the groups may be the low reliability coefficients for fluency and flexibility (.61 and .60, respectively) on the Torrance Test of Creativity as reported by Paul Torrance (1966). Low reliability coefficients can be attributed, in part, to the fact that this test was not easily scored. Before any concrete conclusions are made regarding the effects of exercise upon creativity, further research should be conducted using a more reliable testing instrument.

Summary

In several studies, researchers have found a positive relationship between physical fitness levels or single bouts of submaximal exercise and students' classroom performance (Christie & Saccone, 1985; Davey, 1973; Gabbard, 1978; Gutin & DiGennaro, 1968; Ismail & Gruber, 1967; Keller, 1982). The findings from three of these studies (Davey, 1973; Gabbard, 1978; Gutin & DiGennaro, 1968) support more specifically the findings of the current study, that a person's cognitive functioning may be enhanced following a single period of submaximal exercise.

In the current study, students' STM was increased following a single bout of exercise performed in a physical education class. Although the theory that improved STM may follow exercise has been supported, the precise mechanism by which this occurs has not been determined. Several mechanisms were presented that suggest how a period of exercise may lead to the enhancement of STM. First, it is plausible that increases in circulating cAMP may have improved STM through increasing the level of neurotransmitters released in the brain. Second, increases in circulating levels of epinephrine may enhance STM by either increasing cAMP secretion or by increasing attention or arousal. In addition, norepinephrine, ACTH, and beta-endorphin may also contribute to the enhancement of STM through improving the subjects' attention and arousal. These theories concerning the possible mechanisms explaining the improvement in STM are not directly supported with measurements of circulating hormones or neurotransmitter activity following exercise in this study, however, the mechanisms are well supported through other research.

There was also a significant difference between the two groups on one measure of creativity, flexibility. As previously stated, there are several hormones that are released in greater amounts as a result of exercise that may act to improve attention and arousal. The improvement of the subjects' attention and arousal may have been responsible for the difference in flexibility seen in this study.

Although the mechanisms proposed above appears plausible, their validity has yet to be experimentally confirmed. Nonetheless, the current study concludes that participation in a single physical education class may have beneficial effects on certain measures of cognitive functioning and, as a result, should prove beneficial in the academic setting.

Chapter 6

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to examine the effects of physical activity, as found in the average physical education class, on students' cognitive functioning. The variables selected to measure cognitive function were short-term memory (STM) and creativity. Fourth- and fifth- grade elementary school students (N = 124) from three Ithaca area elementary schools served as the subjects for the study. Each subject completed two standardized tests, the Benton Visual Retention Test to measure STM and the Torrance Test of Creative Thinking to measure creative ability.

Classes were randomly assigned either to the active group or to the control group, so that there was one active group and one control group from each of the three schools. The active group was tested for cognitive functioning within 15 min following completion of their physical education class. The control group was tested on a school day when they did not have physical education class.

One-tailed t tests for the differences between means of two independent groups were performed to determine if any significant differences existed between the active group and the control group for either STM or creativity. The .05 level of significance was set prior to the data collection for each analysis.

Examination of the data revealed a statistically significant difference ($t[122] = 1.76$, $p < .05$) between the active and the control groups for STM. Subjects who had participated in physical education prior to taking the Benton Visual Retention Test tended to score higher than subjects who were inactive prior to testing.

Analysis of the data gathered from the Torrance Test of Creative Thinking demonstrated a significant difference between the means of the two groups for flexibility, but not for fluency ($t[120] =$ 2.27 and 0.83, respectively). Therefore, subjects who participated in physical education prior to taking the Torrance Test of Creative Thinking obtained higher scores for one measure of creativity, flexibility, but not for the other, fluency.

Conclusions

The results of the study led to the following conclusions regarding the effects of exercise upon students' STM and creativity.

1. The fourth- and fifth-grade students who participated in a physical education class obtained significantly higher scores on the Benton Visual Retention Test than the students who remained inactive prior to testing.

2. The students who participated in physical education class obtained significantly higher scores than the control subjects on one measure of creativity, flexibility, as measured by the Torrance Test of Creative Thinking.

3. The students who participated in physical education class obtained scores that were not statistically different from the control subjects' scores on fluency, a second measure of creativity as measured by the Torrance Test of Creative Thinking.

Recommendations for Further Study

The following recommendations are suggested for further study in this area:

1. Using a similar procedure, examine the acute effects of activity upon cognitive functioning. However, monitor the level of activity in order to

determine how much exercise the students receive prior to testing. This could be further controlled by implementing predetermined physical education classes. These classes would be designed so that a specific level of physical exertion is attained by the students.

2. Implement baseline testing to determine the differences between the groups prior to the experiment allowing the results obtained to be more directly attributed to the experimental treatment.

3. Utilize different instruments for the analysis of cognitive functioning. For each of these instruments, the scoring should be as objective as possible, so that it has a relatively high reliability coefficient.

4. Long-term memory could be tested using information the student would receive in a normal class day. For example, a study could be conducted to measure the student's ability to retain information given in a math or science lecture (one with objective information) over a quarter or a semester.

5. Select a different age level for the analysis, investigating possible differences in the effects of exercise upon older and younger groups.

6. Separate the data for male and female students, examining the possibility of gender differences.

7. Test at different times in the day, investigating the possibility that exercise in the morning may produce different results than exercise in the afternoon or evening.

Appendix A

INFORMED CONSENT FORM

1. <u>Purpose and Benefits</u>

The purpose of this study will be to measure creativity and memory in elementary school children in the Ithaca area using two standardized activities. From these activities, we may learn something about children's memory and creativity in school.

2. <u>Methods</u>

Your child will be asked to participate in two standardized design, copying, and drawing activities (the Benton Visual Retention Test that assesses the ability to memorize and the Torrance Test that measures creativity). This will take place during a regularly scheduled class period. Your child's teacher will be present and will help administer these activities in cooperation with Susan Galloway, a graduate student from Ithaca College. Total time, including preparation and administration, should be about 30 minutes. If you choose not to let your child participate in the activities, his/her teacher will provide suitable reading to occupy the time period.

3. <u>Potential Risks</u>

There are no foreseeable physical, social, or psychological risks involved with participation in these activities. The only problem that might arise is some frustration from the inability to recall the memorized material. To alleviate any frustration, your child should understand that these are not tests related to his/her grades and are actually fun exercises. There will be no pressure placed on your child to perform at a level above that which he/she is naturally capable of achieving.

4. <u>Additional Information</u>

Any questions or concerns related to your child's participation in this study are welcomed and encouraged. Please contact either Susan Galloway at 273-1751 or Dr. Gary Sforzo at 274-3359 at Ithaca College with your inquiries.

Initials______

5. Withdrawal from the Study

Your child is free to withdraw from participation in this study at any time, and no penalty of any kind will occur as a result of his/her lack of participation in this study. However, once the data have been collected and subsequently analyzed, it will become impossible to separate your child's responses from the group.

6. Confidentiality

All information resulting from this study will be presented only in group form. Your child's activity results will never be identified to anyone, and only the experimenters (Susan Galloway and Gary Sforzo) will have access to your child's completed materials.

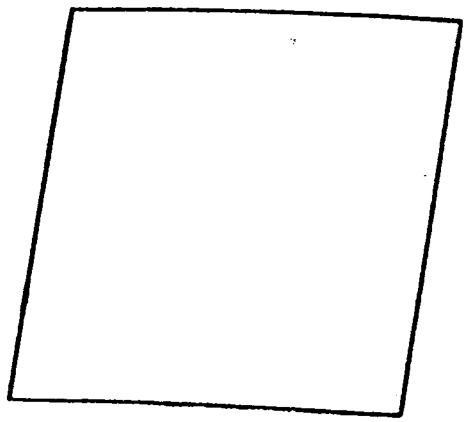
I have read the above and I understand its content. I agree to allow my child ______________________________ to participatein this study. I acknowledge that I am 18 years of age or older.

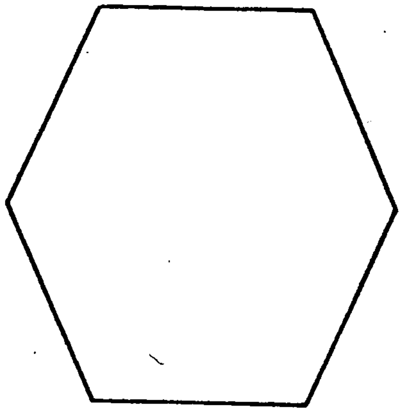
______________________________ ____________

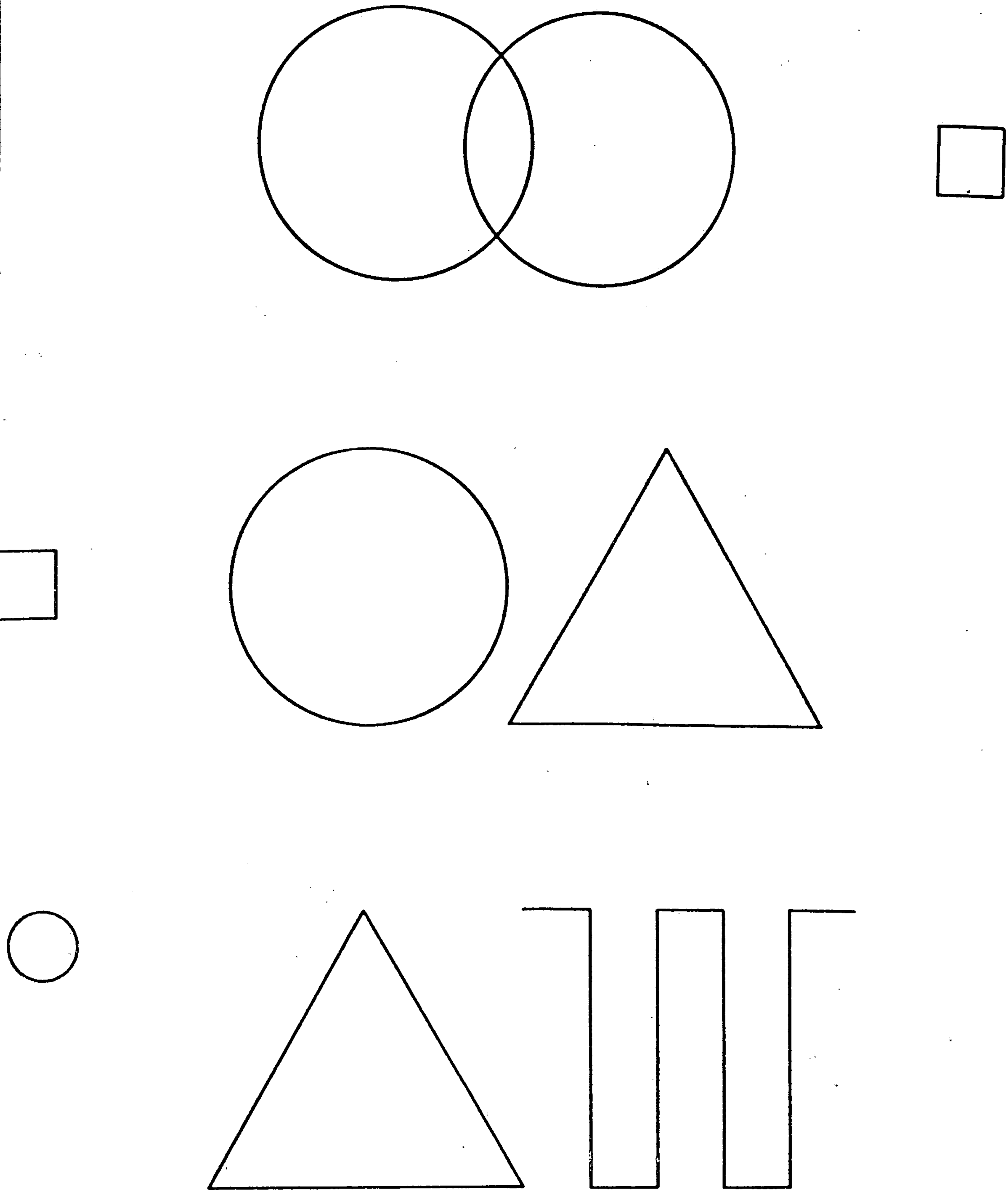
Signature of Parent or Guardian Date

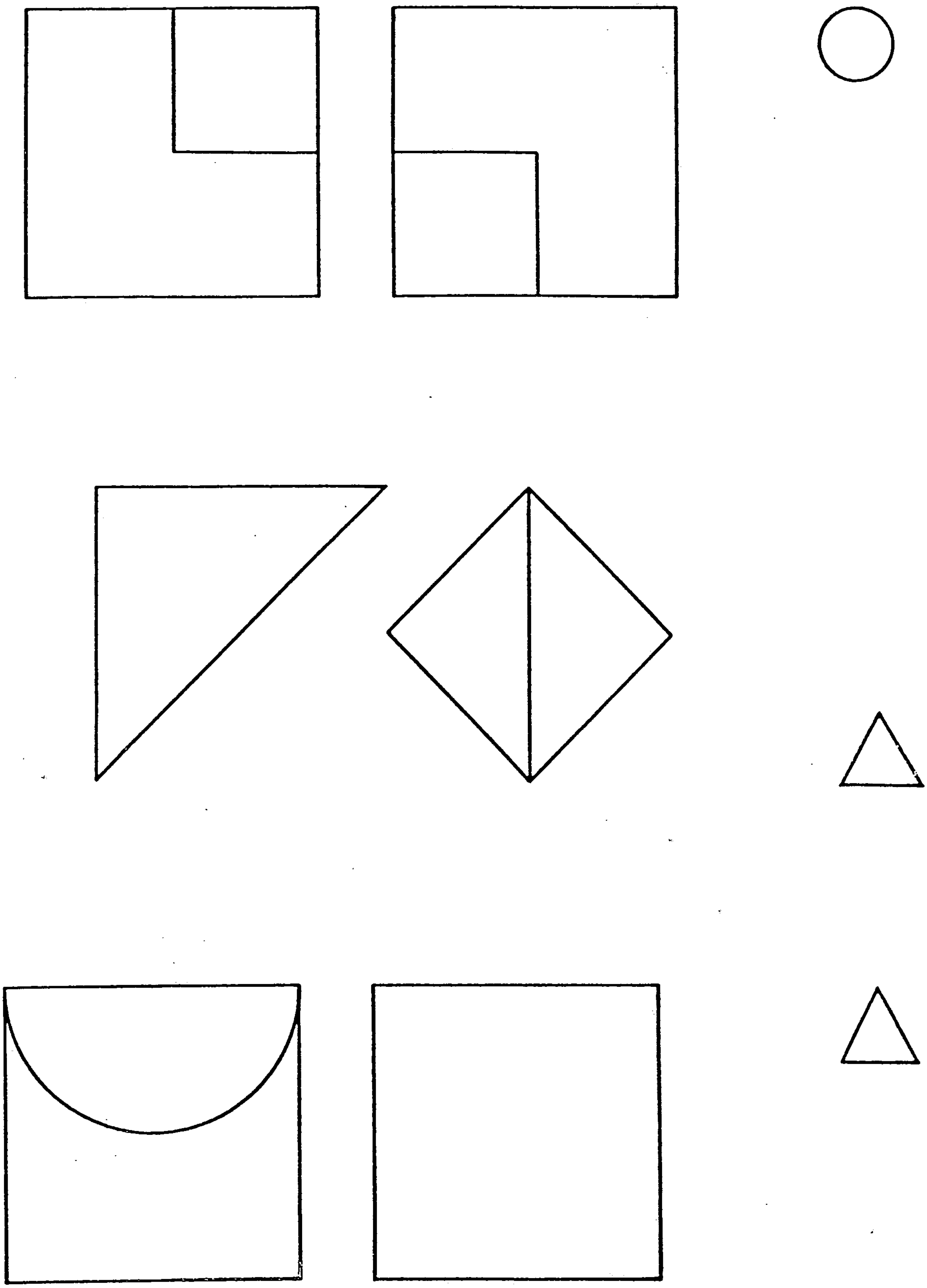
Appendix B

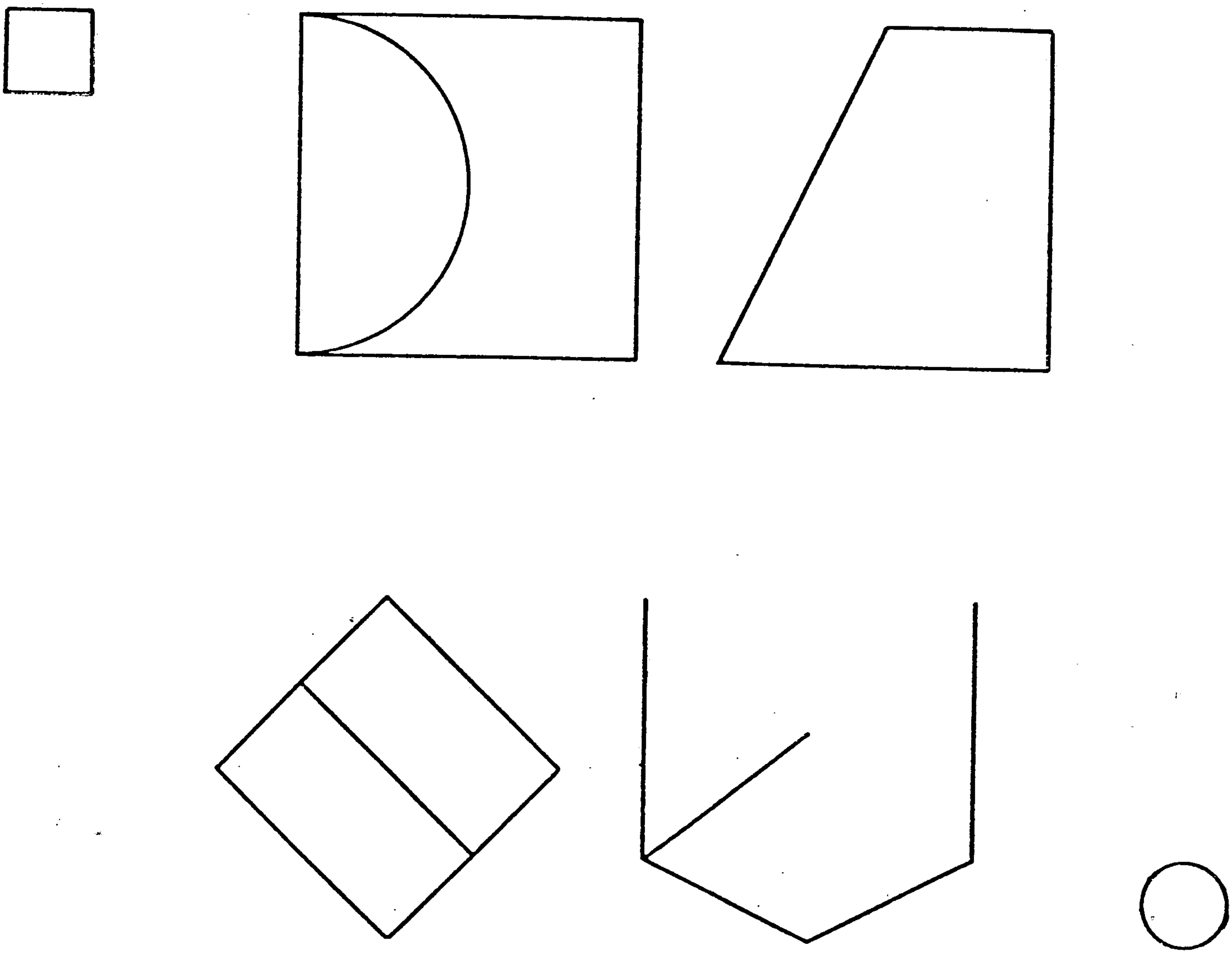
FIGURES USED IN THE BENTON VISUAL RETINETION TEST





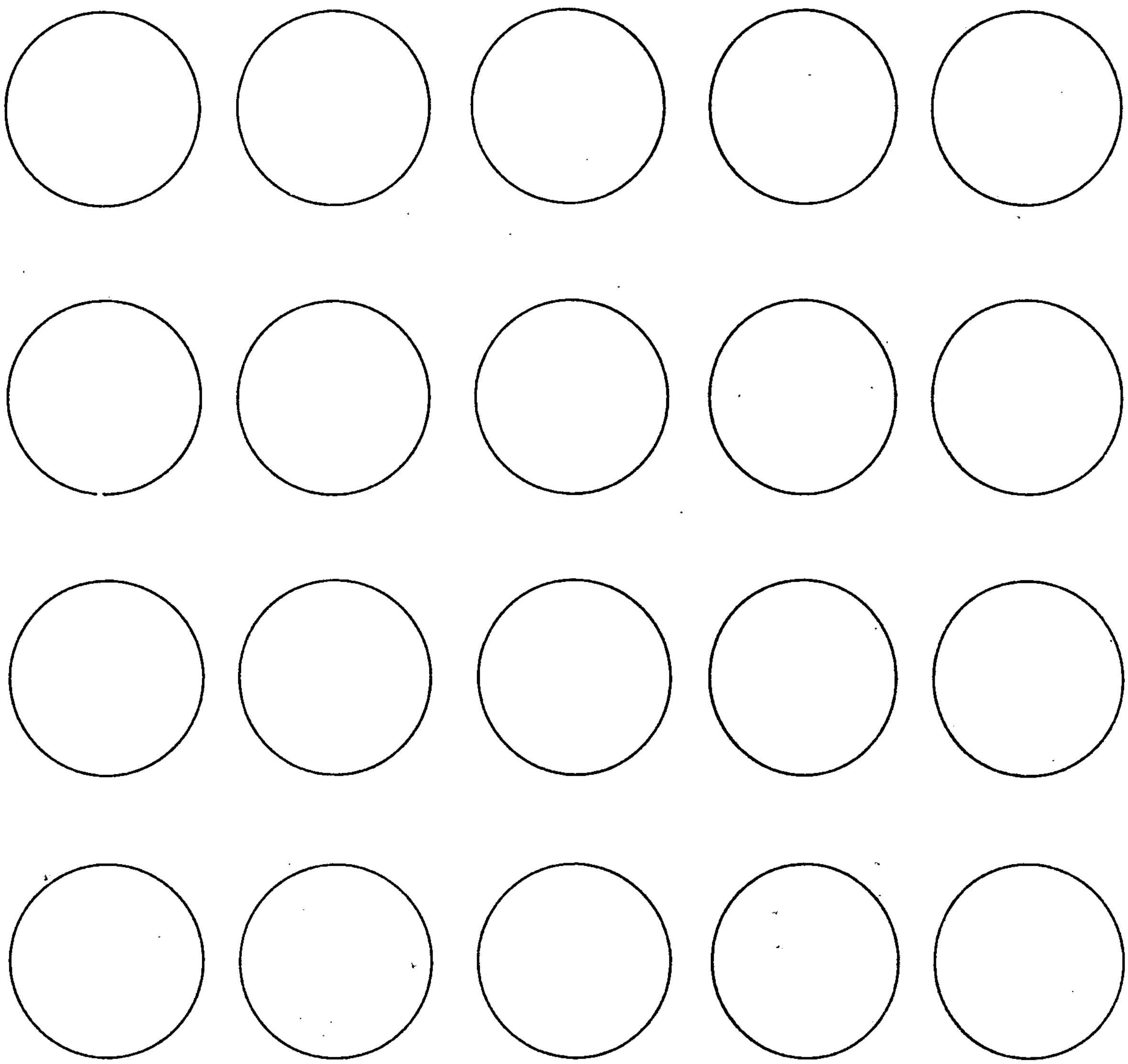






Appendix C

FIGURES USED IN THE TORRANCE TEST OF CREATIVE THINKING



REFERENCES

Baddeley, A. (1986). Working memory. Oxford: Clarendon Press.

Benton, A. L. (1974). Revised Visual Retention Test. New York: The Psychological Corporation.

Blumenthal, J. A., Needles, T., Williams, R. S., & Wallace, A. G. (1981). Psychological changes accompanying physical exercise: A controlled study (Abstract). Medicine and Science in Sports and Exercise, 13, 74.

Buccola, V. A., & Stone, W. J. (1975). Effects of jogging and cycling programs on physiological and personality variables in aged men. Research Quarterly, 46, 134-139.

Butts, N. K. (February/March, 1985). Don't assume play and physical education are enough for fit children, study warns. Cardiogram, 11, 1, 6-7.

Christie, S. H., & Saccone, P. P. (December, 1985). An evaluation of the fitness, academics, and self-esteem training program at Meridian School, 1984-1985. El Cajon, CA: Cajon Valley School District. (ERIC Document Reproduction Service No. ED 267 053)

Clarke, H. H. (April, 1982). Responsibilities of physical education to the total person: The Alliance Scholar Lecture, 1982. Eugene, OR: University of Oregon. (ERIC Document Reproduction Service No. ED 230 554)

Cole, B. D. (1970). Television. New York: Free Press.

Croce, R., & Lavay, B. (Spring, 1985). Now more than ever: Physical education for the elementary school-aged child. Physical Educator, 42(2), 52-58.

Cumming. G. R. (1976). The child in sport and physical activity: Medical comment. In J. G. Albinson & G. M. Andrew (Eds.), Child in Sport and Physical Activity. Baltimore: University Park Press.

Davey, C. P. (1973). Physical exertion and mental performance. Ergonomics, 16, 595-599.

Deutsch, D., & Deutsch, J. A. (1975). Short term memory. New York: Academic Press.

Folkins, C. H., Lynch, S., & Gardner, M. M. (1972). Psychological fitness as a function of physical fitness. Archives of Physical Medicine and Rehabilitation, 53, 503-508.

Gabbard, C. (1978). Physical exertion and immediate classroom mental performance among elementary school children. College Station, TX: Texas A & M University. (ERIC Document Reproduction Servive No. ED 156 329).

Gilliam, T. B., MacConnie, S. I., Geenen, D. L., Pels, A. E., & Freedson, P. S. (1982). Exercise programs for children: A way to prevent heart disease. The Physician and Sportsmedicine, 10(9), 96-108.

Gutin, B., & DiGennaro, J. (1968). Effect of one-minute and five-minute step-ups on performance of simple addition. Research Quarterly, 39, 81-85.

Harley, C. W. (1987). A role for norepinephrine in arousal, emotion, and learning?: Limbic modulation by norepinephrine and the Kety hypothesis. Progressive Neuro-psychopharmacological and Biological Psychiatry, 11, 419-458.

Hart, M. E., & Shay, C. T. (1964). Relationship between physical fitness and academic success. Research Quarterly, 35, 443-445.

Ismail, A. H., & Gruber, J. J. (1967). Motor aptitude and intellectual performance. Columbus, OH: Merrill.

Kandel, E. R., & Schwartz, J. H. (1985). Molecular biology of learning: Modulation of transmitter release. In P. H. Abelson, E. Butz, & S. H. Snyder (Eds.), Neuroscience (pp. 381-402). Washington, DC: American Association for the Advancement of Science.

Keller, S. (November/December, 1982). An historical review. Journal of Physical Education, Recreation, and Dance, pp. 26-28.

Kennedy, M. B. (September, 1987). Molecules underlying memory. Nature, 329, 15-16.

Kirshenbaum, J., & Sullivan, R. (February 7, 1983). Hold on there, America. Sports Illustrated, pp. 62-74.

Lamb, D. R. (1984). Physiology of exercise: Responses and adaptations. New York: Macmillan.

Lynch, G., & Baudry, M. (1985). The biochemistry of memory: A new and specific hypothesis. In P. H. Abelson, E. Butz, & S. H. Snyder (Eds.), Neuroscience (pp. 403-417). Washington, DC: American Association for the Advancement of Science.

Martin, K. (May 11, 1986). Couple is shaping up physically unfit children. Syracuse Herald American, p. BB2.

Martinez, J. L., Weinberger, S. B., & Schulteis, G. (1988). Enkephalins and learning and memory: A review of evidence for a site of action outside the blood-brain barrier. <u>Behavioral and Neural Biology</u>, <u>49</u>, 192-221.

Miller, L. H., Kastin, A. J., Sandman, C. A., Fink, M., & Van Veen, W. J. (1974). Polypeptide influences on attention, memory and anxiety in man. <u>Pharmacology Biochemistry and Behavior</u>, <u>2</u>, 663-668.

Morgan, W. P., Roberts, J. A., & Feinerman, A. D. (1971). Psychologic effect of acute physical activity. <u>Archives of Physical Medicine and Rehabilitation</u>, <u>52</u>, 422-425.

O'Connor, C. (1969). Effects of selected physical activities upon motor performance, perceptual performance, and academic achievement of first graders. <u>Perceptual and Motor Skills</u>, <u>29</u>, 703-709.

Powell, J. M. (1984). Cognitive and physical relationships in college women and men. Greenville, SC: Furman University. (ERIC Document Reproduction Service No. ED 244 938)

Powell, R. P., & Pohndorf, R. H. (1971). Comparison of adult exercisers and nonexercisers on fluid intelligence and selected physiological variables. <u>Research Quarterly</u>, <u>42</u>, 70-77.

Power, L. (November 9, 1986). American kids still less fit, survey says. Syracuse Herald American, p. BB2.

Rigter, H., & van Riezen, H. (1978). Hormones and memory. In M. A. Lipton, A. DiMascio, & K. F. Killam (Eds.), Psychopharmacology: A generation of progress (pp. 677-681). New York: Raven Press.

Shearer, L. (May 27, 1990). Too much television = too much fat. Parade Magazine, p. 13.

Torrance, E. P. (1966). Torrance Test of Creative Thinking. Princeton, NJ: Personnel Press.

Tsukada, Y. (1988). Molecular approaches to learning and memory. Japanese Journal of Physiology, 38, 115-132.

Vander, A. J., Sherman, J. H., & Luciano, D. S. (1980). Human physiology: The mechanisms of body function. New York: McGraw-Hill.

Young, R. J. (1979). The effect of regular exercise on cognitive functioning and personality. British Journal of Sports Medicine, 13, 110-117.

Zornetzer, S. F. (1978). Neurotransmitter modulation and memory: A new neuropharmacological phrenology. In M. A. Lipton, A. DiMascio, & K. F. Killam (Eds.),

Psychopharmacology: A generation of progress
(pp. 681-694). New York: Raven Press.