THE IMMEDIATE EFFECTS OF AN ACUTE BOUT OF MODERATE PHYSICAL ACTIVITY ON COGNITIVE PROCESSING IN CHILDREN

by

Gary Edward Clark

Bachelor of Science, Lock Haven University, 1988

Master of Science, Western Kentucky University, 1990

Submitted to the Graduate Faculty of

School of Education in partial fulfillment

of the requirements for the degree of

Doctor of Philosophy

University of Pittsburgh

2008

UNIVERSITY OF PITTSBURGH

SCHOOL OF EDUCATION

This dissertation was presented

by

Gary Edward Clark

It was defended on

April 3, 2008

and approved by

Mary Duquin Ph.D., Associate Professor, Department of Health and Physical Activity

Carl Johnson Ph.D., Associate Professor, Department of Psychology in Education

Robert Robertson Ph.D., Professor, Department of Health and Physical Activity

Dissertation Advisor: Jere Gallagher Ph.D., Associate Professor/Associate Dean, Department of Health and Physical Activity/Dean's Office

THE IMMEDIATE EFFECTS OF AN ACUTE BOUT OF MODERATE PHYSICAL ACTIVITY ON COGNITIVE PROCESSING IN CHILDREN

Gary Edward Clark

University of Pittsburgh, 2008

This study examined the effect of acute physical activity on cognitive tasks of 37, 7th and 8th grade females. Subjects' cognitive performance following acute physical activity was hypothesized to be significantly better on five tasks (choice reaction time, probed memory, dual task, vigilance, executive function) used in the study, with no significant difference in performance hypothesized for the sixth (simple reaction time).

The study assessed cognitive tasks twice, following a 30 minute sedentary period and 30 minutes of physical activity. The within subject design compared the independent variable of physical activity level (activity or none) on the dependent variables simple reaction time, choice reaction time, dual task-tracking and simple reaction time, vigilance, probed memory, and executive function.

Results indicated that for the simple reaction time task subjects demonstrated significantly faster (reaction and movement) times following acute physical activity. For choice reaction time the percent of correct responses was significantly higher following sedentary behavior, while for choice reaction and movement time, subjects were significantly faster following acute physical activity. Analysis of probed memory reported no significance between the scores following the two activity sessions. Analysis of dual task reported no significance for two subcomponents, however a significant difference was reported for the third subcomponent.

Analysis of vigilance reported subjects demonstrated significantly improved performance on two subcomponents following physical activity. Analysis of the third subcomponent did not report significance. Performance on the executive function task was mixed with no significance reported for subjects between the following physical activity and following sedentary behavior scores, while significance was reported with regard to time to complete the task.

Levels of significance were not reached for every task, however there was a trend consistent with expectations for those that did not reach significance (With the exception of choice reaction time percentage of correct responses.), following physical activity, performance was better.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PREFACE

Famous outdoor writer Hal Borland stated; “knowing trees, I understand the meaning of patience, knowing grass, I can appreciate persistence”. Thank you to everyone who has traveled in part or whole with me on this tree lined and grass covered long and winding path.

Special thanks to committee members Dr. Robert Robertson, Dr. Mary Duquin, and Dr. Carl Johnson. Thank your for your service on my committee but also for the role you played in my education. Whether sitting in a classroom, talking in the hallway, or simply your leading by example, you broadened my horizons in ways you many not recognize, and prodded me to explore avenues where I otherwise would not have ventured.

To friend and colleague Allen Wagner, words are not able to express my appreciation. To Dr. Jere Gallagher saying thanks for all that you have done for me seems hollow and insufficient, but please realize it is a sincere thank you from the bottom of my heart and the depth of my soul, so thank you.

For my family, especially my mother and father, you were always there for me. I hope you understand how much I appreciate that simple fact. You also instilled in me the work ethic to keep going. As for my wife Nicole and sons Edy and James this is not time to take pause. Good fortune is ours and new adventures await, I look forward to a lifetime of adventures as a family.

1.0 INTRODUCTION

Physical activity will not turn a child into a gifted musician or suddenly raise their IQ. Achieving your fullest potential is due to multiple factors, innate ability, motivation, practice, etc. (Larson & Zaichkowky, 1995). So what effect does physical activity have? Is there a link between acute physical activity and cognitive function? The literature indicates that improvements in cognitive function due to acute physical activity for adults are not due to chance (Spirduso & Asplund, 1995). Studies by Dwyer, Sallis, Blizzard, Lazarus, and Dean (2001), Linder (2002), Tremblay, Inman and Willms (2000) support the idea that children who are physically active have academic performance standards exceeding those of their sedentary peers. The literature, however, demonstrates that a robust relationship is not consistently reported specifically as related to the effects of acute physical activity on children. Current evidence continues to support the premise that physical activity enhances early brain development and maintains cognitive function (Jable, 1998), but whether acute physical activity translates into a measurable improvement in cognitive function is a new area of inquiry with limited research available (Schuler, Chodzko-Zajko, & Tomporowski, 1993).

The study of physical activity, its effects on the human body, and impact on education is in its infancy. Only since the 1970's have organizations seriously begun to issue exercise guidelines, and not until the 1990's did the American College of Sports Medicine, American Heart Association, the Centers for Disease Control and Prevention (CDC), the Presidents

Council of Physical Fitness and Sports, and the National Institutes of Health firmly state that moderate intensity physical activity offers benefits to health and wellness (Rowland & Freedson, 1994; The U.S. Department of Health & Human Services, 1996). Healthy children learn better; factors including physical activity, fitness, and cognitive processing are inextricably linked and an increase in the overall health status of a learner has the potential to positively impact overall academic achievement (Devaney, Schochet, Thornton, Fasciano, & Gavin, 1993; Symons, Cinelli, James, & Groff, 1997).

The objective of this study is to examine the effect that an acute bout of physical activity has on subsequent cognitive tasks as compared to performance on the same cognitive tasks following sedentary behavior. The research on the impact of acute physical activity on cognitive function in children is a new area of inquiry (Schuler, Chodzko-Zajko, & Tomporowski, 1993), very little research is available, specifically for children. For this reason the scope of the literature review will examine various areas of inquiry including chronic and acute physical activity. Research into cognitive responses to physical activity produced two common methodologies. The predominate method of inquiry examines effects of chronic physical activity programs (weeks or months) while the second examines the effect of acute (individual session) physical activity (Tomporowski, 2003). When exploring the effects of activity on cognitive function, chronic programs attribute cognitive changes to the cumulative effect of activity (i.e. improved cardio respiratory fitness), while acute programs attribute changes to the immediate (i.e. glucose utilization) effects of activity. Within the literature, few studies specifically address the effects of a single acute bout of physical activity on children’s cognitive performance (Schuler, Chodzko-Zajko, & Tomporowski, 1993). Just as different types of physical activity have been examined in studies, a wide variety of subject pools, and theories have been introduced to explain how physical activity levels could impact cognitive function. The subsequent sections will review the more prevalent adult studies, existing child studies, as well as addressing the theoretical basis for the current study.

1.1 ADULT STUDIES

The literature has consistently documented the positive affect of fitness and a physically active lifestyle on older adults (Barnes, Yaffe & Satariano, 2003; Hirsch & Hirsch, 1998; Weuve, Kang, Manson, Breteler, Ware & Grodstein, 2004). Physical activity has been shown to relate to cognitive function (Emery, 1995; Hassm'n & Koivula, 1997). Active fit adults consistently demonstrate faster simple and choice reaction times indicating they are faster at making decisions (Chodko-Zojko 1991; Dipietro, Seeman, Merrill, & Berkman, 1996; Rowland, 1990). Studies also support the premise that physically fit/active adults have higher cognitive performance scores (Chodzko-Zajko & Moore, 1994; Hultsch, Hammer, & Small, 1993) indicating cognitive benefits might be received from physical activity. Consistently throughout the literature it is firmly established that physically active and physically fit adults consistently have improved performance on cognitive tasks over their sedentary peers. Based on these results on older adults, the obvious question is, what effect would physical activity have for school aged children during critical stages of their learning.

1.2 CHILD STUDIES

There have been relatively few pediatric studies addressing the mind body connection. The limited number of studies is further confounded by difficulty in comparing methodologies in the existing studies such as categorizing the type of cognitive process being assessed and how physical activity/fitness is expected to affect different types of intelligence (Spirduso & Asplund, 1995).

Purported improvements in school settings using physical activity programs include reduced disruptive behavior, increased concentration, and improved scores in reading, writing, and mathematics. These results have been touted to occur even when the increase in physical activity resulted in reduced time for other academic subjects (Symons, 1997).

Studies support the premise that cognition and physical activity in children have a connection. Using a survey to establish physical activity levels, Tremblay, Inman, and Willms (2000) found a weak relationship with academic achievement in mathematics and reading in 12-year-olds. The Trois Rivieres study in Quebec, Canada was a six year cross sectional longitudinal study of students (grades 2 through 6). One class of 546 students served as the treatment group while the preceding and succeeding grades served as controls. The treatment consisted of a 14% reduction in academic time and an additional one hour per day of physical education. For four of the six years the treatment group outperformed the controls significantly, even though the control groups started with better academic scores (Shephard, Volle, LaBarre, Jequier, & Rajic, 1984).

In a Hong Kong study, schools were banded by prestige groups (high, medium, and low) with students from the schools completing a survey (Lindner, 2002) about the type, frequency, and duration of up to five activities and to rank their own academic potential/performance during the 1998-1999 school year. Academic assessment values were received for subjects in the study in the form of grades from participating schools. Results of the study demonstrated evidence for a positive link between activity participation and academic performance however the study did not make definitive conclusions due to affordances related to school banding.

In the Australian School Health, Academic Performance and Exercise study, researchers increased physical activity time for the treatment groups from 30 minutes 3 days a week to 75 minutes a day, and emphasized either cardiovascular or skill development with reduced time in other academic disciplines. Students with increased physical education time, especially activity with an emphasis on fitness, did not fall behind their peers in arithmetic and reading and also demonstrated significant improvements in classroom behavior. A follow-up study found the treatment group also maintained a higher level of classroom behavior and improved scores over the control group in arithmetic and reading (Dwyer, Coonan, Worsley, & Leitch, 1979; Dwyer, Coonan, Leitch, Hetzel, & Baghurst, 1983). Another Australian study used a questionnaire analyzing physical activity and sport performance of 7 to 15-year-olds during the previous week as well as fitness measures (long jump, 50 meter sprint, push ups, sit ups, 1.6 kilometer run). The activity questionnaire and fitness test scores were correlated with student academic performance using a five point rating scale (excellent, above average, average, below average, poor) to assess the scholastic ability of students. Results of the study demonstrated that academic ratings were consistently correlated with physical activity ratings from the questionnaire and fitness test scores for both males and females (Dwyer, Sallis, Blizzard, Lazarus & Dean, 2001).

Gabbard and Barton (1979) found that physical activity could affect cognitive function (mathematical computations) in second graders using 20, 30, 40, and 50 minute sub maximal cycle ergometer exercise sessions. The study found significant differences between 6 sessions with the 40 and 50 minute time frames demonstrating the best mean math scores. There was no significant difference between the pre and post mean math scores for the no exertion sessions. Research findings for this study are consistent with the literature recommending a minimum of 20 to 40 minutes of moderate activity to affect psychological mood states. Results of this study also support the proposal that an acute bout of physical activity can have an affect on cognitive function. A similar design (McNaughten & Gabbard, 1993) used 20, 30, and 40-minute moderate intensity walking with sixth grade students at three different times during the school day followed by a 90 second mathematical computation test. Although no significant differences were found for scores during the morning (8:30 am) activity session, the children's performance for the afternoon sessions (11:50 am and 2:20 pm) was significantly improved on the mathematical computation scores after walking the 30 and 40 minutes. These studies demonstrate that an acute bout of physical activity can have an immediate effect on cognitive processing in children.

1.3 THEORETICAL BASIS

Suggested mechanisms for improved cognitive function related to physical activity include improved cardiorespiratory fitness, improved cerebral blood flow, changes in hormonal levels, change in arousal level, enhanced self-esteem (Tremblay, Inman, & Willms, 2000), improved self concept, less depression, increased ability to concentrate, and improved behavior in the classroom setting. This has prompted development of many theories including the Activation Theory, Inverted U Hypothesis, the Moderator Model, and Oxygen Hypothesis among others, the research suggests that these theories are plausible and offer an explanation for how the level of physical activity can play a role in cognitive function. An examination of Table 1 (below) presents a visual representation of eight theories and a brief description of their mechanism. The table permits a comparison of these mechanisms enabling consideration of how they may interact. This is important as the overarching challenge with this line of research however is trying to discern the pertinent variables. For example, animal research (Milgram et al., 2005) has consistently used varying environmental (nutrition, sleep) factors including a stimulating environment (toys, exercise) as a major component when examining the effects of activity on cognitive function. This stimulating environment could be classified as a theory itself as illustrated by Kemper (2001) in his discussion of action or interaction. Kemper (2001) explains that although it is easy to measure physical activity on a treadmill (action) to elevate heart rate (improved blood flow, mood state, etc.), a stimulating environment (running in the park) may require more attentional resources (interaction) than running on a treadmill alone. Running in the park may require the same level of physical activity as on a treadmill, but could require a significantly higher level of sensory input when crossing a busy street, attending to other people, distractions and a variety of sights, sounds, and noises. A stimulating environment can vary from person to person; with one person who is afraid of dogs reacting differently to a dog in the park than someone who likes dogs. Although it may be possible to elevate heart rate to a certain level, evaluating what constitutes a stimulating environment proves more challenging, and a stimulating environment could be an important component of improved attention. Even though the literature is overwhelmingly supportive of the tenet that physical activity can impact cognitive function, it is evident that the process is extremely complex and a single 'answer' in the form of a physiological process is difficult to identify, and with a fair amount of overlap occurring between many of the theories it is unlikely that physical activity alone improves cognitive function. Rather it is more likely (Kemper, 2001) an interaction occurring from stimulation of neuronal activation and the sensory system facilitated by physical activity. The next section will begin a more detailed explanation of these theories, beginning with the Inverted U hypothesis to facilitate a better understanding of individual theories as well as possible interaction between theories.

Table 1: Cognitive Function Theories

Theory	Mechanism
Inverted U	An optimal level of arousal exists for peak performance.
Activation Theory and Neurotransmitters	Stimulate motor and sensory cortex, impact of activity on catecholamines, cortisol, seratonin, etc.
Cognitive Reserve Hypothesis	High levels of physical activity at a younger age result in higher cognitive function later in life.
Moderator Model	Increased exercise frequency because people feel it will help prevent cognitive decline.
Mood State	Physical activity results in ‘feeling’ better, improved self-esteem, reduced stress.
Cerebral Blood Flow and Oxygen Hypothesis	Increased blood flow with higher level of oxygen, glucose and nutrients to the brain.
Structural Changes including Synaptic Development	Increased vascular density, neurogenesis.
Stimulating Environment	High level of sensory input increases alertness/arousal.

1.3.1 Inverted U Hypothesis

The Inverted-U Hypothesis is sometimes referred to as the Yerkes-Dodson Law. The basis of the principle is that the human organism performs best on a continuum of arousal for different activities and that physical activity can increase physiological arousal. Acute physical activity could (Raglin, 1997) raise arousal levels impacting fluid intelligence during or shortly following physical activity. The arousal continuum has been defined (Gould & Krane, 1992) as ranging from deep sleep to intense excitement. Having the appropriate level of arousal can either enhance or retard performance for a given task. For example many children are very excited on Christmas Eve, and this high level of arousal can impede the task/goal of going to bed. More specifically related to skilled movement; precise skilled movements (fine motor skill) require high attentional requirements and are best performed at a lower arousal level. Large muscle (gross motor) tasks require a low level of attention and would be best performed at a high level of arousal.

Two theories related to the Inverted U Hypothesis include the Catastrophe Hypothesis and the Reversal Hypothesis. The Catastrophe Hypothesis views the Inverted U theory as too limiting. Instead of a gradual decline in performance as is indicated with the Inverted U, in the Catastrophe Hypothesis the complex interaction of physiological arousal and cognitive anxiety increase until a point is reached that has an abrupt impact on performance (Gould & Krane, 1992). The theory postulates that arousal can improve performance, however negative arousal (anxiety) of a certain degree will result in a catastrophic decline in performance (Hardy, 1990).

The Reversal Hypothesis is based on how each individual interprets their arousal level. One person can interpret a certain level of arousal in a positive way, while a second individual perceives the same level of arousal in a negative way (Kerr, 1990). An example would be having two students participating in the same activity (high ropes course). One student may find success and find the activity exciting while a second student has a negative experience and this produces anxiety. A continuation of this hypothesis also predicts that what an individual may initially find enjoyable (positive arousal) and exciting could easily change (reverse) to anxiety and fear.

Other explanations for how arousal can improve cognitive processing include action decrement (Walker, 1958) that proposes that arousal permits an increase in retrieval of information of long-term memory traces. Subsequent research (Revelle & Loftus, 1990) has explained how arousal affects memory with the tick rate hypothesis. This hypothesis proposes that a higher arousal level increases the sampling of environmental cues and a quicker response rate. This hypothesis further predicts that an elevated arousal level should improve long term retrieval of information because of the rate that information is associated with both internal and external context.

1.3.2 Activation Theory and Neurotransmitters

The activation theory hypothesizes that sufficient physical activity can improve brain activation. This theory has overlap with other theories as regarding increased arousal, however it looks primarily at effects on the brain. Proposed mechanisms with this theory include changes in alpha wave activity and changes in neurochemicals that mimic those found in other learning situations. Poehlman, Gardner, and Goran (1992) studied older adults and found that over an eight week training period norepinephrine and plasma levels increased significantly. Research on humans and animals (Spirduso, 1983) has also reported increased norepinephrine and plasma, endorphins, and seratonin levels from various durations of aerobic activity. There could be some obvious overlap with this theory and theories examining structural changes and neural development, which is discussed in greater detail below, and arousal which was previously discussed. For example increased levels of brain wave activity or changes in neurochemical levels could be classified as a specific measurement of a subjects level of arousal.

1.3.3 Cognitive Reserve Hypothesis

The association between early life physical activity and delayed late-life cognitive deficits has been described as the cognitive reserve hypothesis. Brain reserve has been described using a computer analogy as hardware with cognitive reserve as software. Combined together these contribute to global reserve, however the literature often makes no discrimination between the three terms. The premise is that physical activity stimulates trophic factors and neuronal growth in the brain resulting in a higher brain reserve capacity. Individuals who have been physically active demonstrate higher cognitive function and resilience to neuropathological damage (Dik, Deeg, Visser, & Jonker, 2003). The cognitive reserve hypothesis is further demonstrated by Colcombe, Erickson, Raz, Webb, Cohen, McAuley, and Kramer (2003). who examined the effects of aerobic exercise on the brain of older adults and concluded that aerobic exercise preserved white (myelin sheath) and gray (neurons) matter in the parietal, frontal, and temporal areas, which are vital to higher order thinking.

Another component to be considered with regard to growing developing children and the cognitive reserve hypothesis is the impact that hormonal change could play. Although limited research exists in this area with regard to children, a study using adult women (Cotman & Berchtold, 2002) illustrates the point. The study discussed how voluntary exercise increases levels of brain-derived neurotrophic factor, which in turn stimulated neurogenisis. The study however also discussed how steroid hormones influence the brain and that women with reduced levels of estrogen, can have compromised neuronal function. Estrogens neuroprotective effects appear to occur at the mitochondrial level through regulation of calcium homeostasis protecting it from free radicals that impede energy production. In growing and developing children with fluctuating hormone levels during different stages of maturation this could be a consideration. However no literature was found addressing the interaction that hormonal changes including estrogen levels might play with regard to acute physical activity specifically with regard to adolescent females.

1.3.4 Moderator Model

Van Boxtel, Paas, Houx, Adam, Teeken, and Jolles (1997) studied subjects (aged 24-to-76 years) using multiple cognitive assessments (intelligence, verbal memory, and cognitive speed) compared with aerobic fitness level using a submaximal bicycle ergometer test. Conclusions indicated that fitness level impacted cognitive processes requiring greater attentional resources. The study supports the moderator model that individuals who maintain an adequate level of fitness throughout life can slow age related decline in attentional resources helping them to perform at a higher level on cognitive assessments than their less fit peers (Tomporowski & Ellis, 1986).

1.3.5 Mood State

Physical activity can have a positive effect on psychological variables (U.S. Department of Health & Human services, 1996) and can impact cognitive processing. Evidence suggests physical activity has psychological benefits in four broad areas: higher quality of life, enhanced mood, stress reduction, and improved self-concept (Berger, 1996). Adult studies demonstrate significant results in areas including depression (U.S. Department of Health and Human services, 1996), self-esteem, self-concept, reduced anxiety and reduced stress (CDC, 1997). Calfas and Taylor (1994) reviewed 20 studies with subjects ranging from age 11-to 21-years. They concluded from their meta-analysis that physical activity provides moderate psychological benefits for youth. Chung and Baird (1999) reviewed the literature concerning the psychological effects of physical exercise and found a positive correlation between physical exercise and mental health variables (depression, anxiety, and self-esteem). They concluded by proposing guidelines and recommendations for counselors to consider using physical exercise as an added counseling tool.

Specifically with regard to a school setting, anxiety can interfere with the ability to perform well, and can manifest itself in physical symptoms including tension, inability to communicate, stomachaches, and headaches, which in turn can result in poor grades, lowered self-esteem, and other stress related physical ailments (Austin & Partridge, 1995). Physical activity can reduce tension, anger, and depression through altering the mood state (Berger, 1996) and has been identified as a way to reduce stress (Anshel, 1996; Calfas & Taylor, 1994). Theories on how physical activity reduces stress include self-perception of control, mastery, self-efficacy, distraction, and social interactions. Possible biological mechanisms include altered autonomic, endocrine, and brain monoamine and neuropeptide responses to stress and increased body temperature.

Along with a positive impact on mood state, physical activity has been cited as a possible prescription for numerous cognitive related ailments including depression, ADD, ADHD, as well as having an ability to moderate cognitive ability. For theories such as the oxygen hypothesis, determinants such as time and intensity of physical activity are important. With mood state, the type of activity performed can be significant as well. The literature has demonstrated that to address the optimal level of activity to facilitate cognitive development, the first step may be to find an activity that is enjoyable. Physiological benefits (caloric expenditure, strength, cardiovascular conditioning, etc.) can be gained from any activity, but participating in an activity that is personally enjoyable has an implication for mood state (Berger, 1996). Berger (1996) cites three characteristics that affect the level of mood enhancement: rhythmical abdominal breathing, absence of competition, and closed/predictable activity. The highest levels of positive mood alteration appear to occur with moderate levels of activity (Thayer, Newman, & McClain, 1994), which raise energetic arousal and length of the activity has been cited (Pierce, Madden, Siegel, & Blumenthal, 1993) as needing to be in the 20 to 40 minute range.

A complication of using mood state as an explanation for improved cognitive function is whether the impact is from mood state or arousal (Ellis, Thomas, McFarland & Lane, 1985). If an individual has a positive mood (elevated emotional state), perhaps the mood state is simply a means through which arousal can be elevated

1.3.6 Cerebral Blood Flow and Oxygen Hypothesis

The cerebral blood flow and oxygen hypothesis theories propose that physical activity results in increased cerebral blood flow and oxygen transport to the brain resulting in increased resources for performance and ability to function optimally.

Tomporowski (2003) cited studies that implemented a moderate intensity aerobic exercise and reported improvement in cognitive performance during and following activity. Blomquist and Danner (1987) examined the effects that physical conditioning had on 66 adults (aged 18-to 48-years) information processing. At the conclusion of a 12-week period subjects were classified based on their improvement in predicted maximal oxygen uptake. To measure information processing researchers used a memory search task, a name retrieval task, an intelligence test, and a memory test. Analysis of the results showed both groups of subjects improved in every category, with the exception of the intelligence test. The fit subjects also tended to perform better than the less fit group although this finding was not statistically significant.

Long term (chronic physical activity), a higher level of health-related fitness, and even a short term single (acute) bout of physical activity, could increase cortical oxygen availability (oxygen hypothesis) and impact cognitive function. In 2001, Bunce reviewed research that investigated cortical oxygen availability and cognitive function. A reduction in cerebral oxygen (high altitude, hypoxia) was found to reduce scores on cognitive performance tasks, including reaction time and movement time (Fowler, Taylor, & Porlier, 1987; Kramer, Coyne, & Strayer, 1993), while administration of oxygen positively affected subjects' short term memory performance in tasks in subjects as young as 18-years-of-age (Moss & Scholey, 1996).

1.3.7 Structural Changes including Synaptic Development

Permanent physiological changes (Eitner, Salazar, Landers, Petruzzello, Han, & Nowell, 1997) are another possible explanation for improved cognitive performance in active individuals. One of the most exciting structural changes is the creation of new neurons (neurogenesis). In the 1940's theories such as Gesell's Maturation Theory supported a genetic (nature) view of development. During the 1960's however researchers used tracer chemicals to show glial cells or neurons could be regenerated in adult rats (Altman & Das, 1965). The 1980's ushered in further change as researchers demonstrated that the environment (nurture) affects brain weight and neural connections in rats (Ronzenzweig & Bennett, 1996). By the 1990's environment was established to affect neural development. Rats using a running wheel (van Pragg, 1999) or swimming pool grew brain cells at a significantly higher rate than rats completing a simple learning task. Studies using rats (Isaacs, Anderson, Alcantara, Black, & Greenough, 1992) also suggested that physical activity in the form of endurance training promoted metabolic support for synaptic development. Adult rats that followed a 30-day training period showed development of new blood vessels in their brains. Milgram, et al. (2005) examined cognitive function in beagles that were fed a diet fortified with fruits, vegetables, vitamins, provided with cognitive stimulation, and exercised at least twice a week. Beagles receiving this intervention were found to demonstrate improved cognitive processing.

Research has also shown that adult humans can generate new brain cells. Autopsies completed on throat cancer patients (Eriksson, Perfilieva, Bjork-Eriksson, Alborn, Norborg, & Peterson, 1998) found that in fact, new cells (neurogenisis) were being generated in the hippocampus region of the human adult brain. What is less understood is the exact mechanism facilitating development of these new brain cells, and what function these new cells would serve. When examining possible structural changes as a theory to explain cognitive improvement the overlap with theories such as the Inverted U Hypothesis becomes evident. For example how much physical activity is required to facilitate the most improvement (neurogenisis), and is there a point of diminished return (Inverted U)? This was demonstrated in a study by Rhodes, et al. (2003). In this study mice were bred to over exercise, but the neurogenesis reached a plateau and improvement ceased. These types of overlapping of theories are common in the literature. Calvin (1993) proposed in his unitary hypothesis that structural changes resulting from physical activity likely resulted in the development of speech in humans and that for pre-planned movement, language, throwing, and novel manipulations, the brain has a common neural circuitry. Theories of this nature provide insight into how neurogenisis from physical activity has potential to impact cognitive function in other areas due to the overlapping circuitry for preplanned ballistic movements such as throwing and writing.

The literature supports the theory that environmental factors such as physical activity can affect brain structure but exactly what this means is unclear. Although at birth the human brain has already achieved a significant level of development a great deal of learning and development continues to occur throughout life and it is obviously important further examine how environmental factors affect the brain (Shore, 1997). One such environmental factor that has the potential to impact cognitive function is physical activity.

1.4 PHYSICAL ACTIVITY RESEARCH

A review of the literature reveals that the study of physical activity and the effect it has on the human body and cognitive development is a relatively new area of study. It was not until the 1990's that organizations such as the American College of Sports Medicine, American Heart Association, the Centers for Disease Control and Prevention, the Presidents Council of Physical Fitness and Sports, and the National Institutes of Health have made recommendations that physical activity offers benefits to health and wellness (Rowland & Freedson, 1994; The U.S. Department of Health and Human Services, 1996). These recommendations have ushered in new lines of inquiry including the impact of physical activity on cognition and academic achievement.

In 2002 the California Department of Education released a study indicating that fit kids perform better academically. The study utilized the state mandated Fitnessgram fitness test and the Stanford Achievement Test (SAT) for students in 5th, 7th, and 9th grade. Over 900,000 students had their reading and math scores from the SAT's compared to their fitness scores. For each grade level assessed, students with a higher fitness level also demonstrated higher achievement scores. With students who met the minimum (healthy fitness zone) Fitnessgram levels in three or more of the fitness areas demonstrating the greatest gains in academic achievement. Overall females especially those of a higher fitness level performed better than males on the achievement tests.

Sports, Play, and Active Recreation for Kids (SPARK) was implemented (Sallis, McKenzie, Kolody, Lewis, Marshall, & Rosengard; 1999) to examine 1,538 students from a school district in Southern California. The two-year study assessed students (fourth, fifth, and sixth grades) on variables including physical fitness, psychosocial variables, and physical activity. The items were measured using a variety of measures including surveys, physical activity monitors, parental surveys, and fitness tests. The curricular intervention (SPARK) promoted physical activity in classes a minimum of three times per week for 30 minutes. The Metropolitan Achievement Test was used to measure academic achievement. The study found that spending more time in physical education did not have a detrimental effect on standardized test scores for the children and indicated favorable effects on academic achievement. This included the fact that teachers trained in the SPARK program, and physical education specialists spent more time in physical education and less time in other academic classes than the control group with no adverse impact to academic achievement. However no cognitive improvement was reported due to the modified curriculum as no significant changes occurred in academic achievement scores.

The premise of this research study is that physical activity needs to be viewed as a process and not a product. The process of quantifying the intensity level within individual (acute) bouts of physical activity has been consistently performed using heart rate monitors in a variety of venues (Allen, 1988; Strand & Reeder, 1993) and is well documented and validated for children (Epstein, Paluch, Kalakanis, Goldfield, Cerny, & Roemmich, 2001; Trieiber, Musante, Hartdagan, Davis, Levy, & Strong, 1989).

It is also important to recognize that a structured form of high intensity exercise is not needed to produce the beneficial effects that many people aspire to reach. Moderate physical activity of at least 30 minutes is recommended for children with heart rate being a recommended method to assess physical activity level (Franks, 1997; Montoye, Kemper, Saris, & Washburn, 1996). In a study of sedentary adults, 30 minute bouts of physical activity each week were effective in improving blood pressure and cardiorespiratory fitness (Dunn, Marcus, Kampert, Garcia, Kohl, & Blair, 1999). Studies have also shown an association between levels of physical activity and physical fitness in young children (Pate, Dowda, & Ross, 1990). The question is whether acute activity can influence arousal and affect cognitive function. The optimal level for arousal in adults appears to be achieved using moderate to vigorous intensities of 40 to 80 percent of maximum oxygen uptake performed for at least 20 minutes (Brisswalter, Collardeau, & Rene, 2002). Also as was previously discussed, the type of activity (enjoyment) can play a significant role in mood state and continued participation.

The importance of maintaining continued participation in physical activity in children to improve health and fitness is obviously important. The American Academy of Pediatrics (1992) recommends that if a child is allowed to explore and move, as they desire, that no special intervention (In the form of a structured regimented exercise program.) is necessary to develop adequate levels of health related fitness. The American Academy of Pediatrics (1992) further stated that no general consensus on the amount or type of exercise for optimal health or function of children has been determined. This seems to indicate that organization recognizes the importance of physical activity but is reticent to 'prescribe' a structured plan for children to follow. Sallis and Patrick (1994) examined guidelines for adolescent physical activity finding recommendations that adolescents need to be active daily and that at least three times a week the activity should be moderate to vigorous for at least 20 minutes. The next question then is that if a child does have a healthy body, what impact does this have on cognitive processes.

1.5 COGNITIVE PROCESSES

As the literature has demonstrated a wide variety of measures have been used to infer cognitive improvement from physical fitness or physical activity. Measures have included behavior, test scores, teacher perception, and ability of students to remain on task (Ahamed, MacDonald, Reed, Naylor, Liu-Ambrose, & McKay, 2007; Coe, Pivarnik, Womack, Reeves, & Malina, 2006; Dwyer, Coonan, Leitch, Hetzel, & Baghurst, 1983; Sallis Et al., 1999). Many the previously used measures (test scores, teacher perceptions, etc.) are either subjective, or dependent upon instruction (math, science) over a period of time and would be ineffective to elucidate the effect of acute physical activity on cognitive processes.

Using response times in movement tasks (mental chronometry) to study and analyze cognitive processes by analyzing movement and response times in perceptual-motor tasks to examine the effects is more congruent for examining the effects of acute physical activity. Fortunately assessment methods utilizing mental chronometry are well established in the literature. The subsequent sections will review literature pertaining to attention, memory capacity, vigilance, problem solving, and examine how it can be used to assess the impact of acute physical activity on cognitive function.

1.5.1 Attention

Historically one of the most established measures used to assess cognitive function is reaction time. Reaction time has been evident in the literature for over 100 years (Donders, 1869). Donders (1869) used three different tasks including simple reaction time, discrimination reaction time, and a choice reaction time task. Each task was designed to permit examination of the increasingly complex processes of perception and movement (simple RT), perceptual discrimination (discrimination RT), and response selection (choice RT) by examining awareness/attention and the ability/inability of individuals to interpret and process information.

Attention, or the ability to selectively attend to one task while ignoring other information (Strayer, Drews, & Johnston, 2003) is a process that can be divided into a number of categories depending on the level of difficulty (Sohlberg & Mateer, 1989). A basic response to a specific auditory stimulus (simple reaction time, choice reaction time) is classified as focused attention; while progressively harder tasks would include the ability of sustained attention (vigilance) to a continuous repetitive activity. Selective attention (probed memory) alludes to ability for remembering information while being presented with competing stimuli. The highest levels of attention discussed by Sohlberg and Mateer (1989) include alternating attention where attention is shifted between different tasks and divided attention requiring an ability to respond simultaneously to multiple tasks (dual task). A high level of attention is also required for executive attention (function) with a goal of achieving a specific objective and a need to attend to incoming information, synthesize the information with desired goals and select an action. There is a limit to how much information a person is able to attend to at one time, examining this ability refers to working memory capacity.

Using reaction time tasks to specifically examine the relationship between cognitive function and activity/fitness levels has a rich history in the literature going back over 70 years (Burpee & Stroll, 1936). Chronically active (fit) subjects have regularly reported improved reaction times scores over less fit subjects (Pierson & Montoye, 1958). Studies reporting improved reaction time scores have used older adults (Chodko-Zojko 1991; Dipietro, Seeman, Merrill, & Berkman, 1996; Rowland, 1990) and have fairly consistent results with fit subjects having improved simple and choice reaction time scores over unfit peers. The literature on younger individuals is not as consistent. When examining young adults, improved performance on simple and choice reaction time tasks related to activity and fitness levels were not observed (Spirduso, 1983; Spirduso, 1980; Spirduso, 1975). Other studies have also reported a lack of significance in reaction time tasks for young subjects due to level of activity or fitness, however it is proposed that activity could have an impact on more complicated cognitive tasks (Bashore, 1989). More research is needed to examine if the effects of physical activity on cognition with regard to reaction time activities is limited to older adults.

Beyond simple reaction time, other attentional reaction time tasks incorporate decision making, dual tasks, and vigilance where response times and accuracy are monitored providing insight into cognitive function. For these higher-level attentional tasks acute physical activity has been documented to have a positive impact on performance. Zervas, Apostolos, and Klissouras

(1991) reported choice reaction time improvements in accuracy and response times for boys (age 11-to 14-years) following acute physical exertion with similar results being reported for adults (McMorris & Graydon, 2000). These studies reinforce that acute physical activity can have a positive impact on cognitive performance, and highlight the need to further explore this line of research with children of both genders. From an educational point of view these improvements in performance following physical activity on attention tasks are important, however with regard to cognitive performance and a possible link to learning, more critical is whether or not physical activity can contribute to improved memory and learning.

1.5.2 Memory Capacity

There is a limit to how much information an individual is able to process at one time with early studies (Miller, 1956) placing this short-term (working) memory at seven chunks of information at one time. These chunks of information could come in the form of numbers, letters, words, etc., researchers (Cowan, 2001) have proposed a capacity of below four chunks of information for children.

Rather than simply reacting to a simple stimulus, Sternberg (1969) developed a probed memory task requiring subjects to remember a list of digits and subsequently asking them to recall if a specific number had been part of the list. As the number of items on the list increases, more processing is required for the subject to complete an exhaustive serial search through memory when asked to recall if a specific item was part of the list. Requiring subjects to remember a list of unique numbers or letters increases the cognitive processes that are required to make a decision.

As the ability to process information is limited, and that resources within the body are shared (Navon & Gopher, 1979), a dual task paradigm is a method to assess individual's ability to do two tasks simultaneously. The dual task paradigm is well established in the literature (Oberauer, Schulze, Wilhelm, & Wittmann, 2000) as a measure of working memory capacity and has been documented to have a high correlation with other complex tasks such as reading (Conway, Kane, & Engle, 2003). This aligns with previously discussed theories (Calvin, 1993) that many complex tasks may share a common neural circuitry, and is important when considering whether improved performance on tasks of this nature following physical activity has any relationship to higher levels of performance in a school setting. When interference occurs while trying to perform two tasks at one time, the performance will be impaired compared to completing the tasks individually. Dual task paradigms focus subjects' attention on a primary task and examine their ability to perform a secondary task without degradation in performance. If reduction in performance does occur then the assumption is that the same cognitive resources were used to complete both tasks limiting the ability to process information (Wickens, 1991). For example many individuals are able to ride a stationary bike and read a book at the same time. To place this in perspective of a common real world setting, teachers often let students complete seatwork while they continue to teach. A student could be in class working individually trying to read and complete word problems for an algebra lesson while the teacher continues to talk about how to solve word problems. In a given period of time, the students who attends to the teacher will likely not complete as many problems, while the student who focuses on solving problems will likely miss some important points made by the teacher, and likely students may have reduced performance on one if not both of the tasks. There is simply too much interference with trying to do both of those tasks at the same time.

Examining the skills needed to evaluate cognitive processes is a complex process. The dual task activity is an important tool used during this evaluation. It is also important to recognize the limitations of evaluation tools. The dual task does not effectively evaluate an individual's ability to concentrate and respond to subtle stimuli over an extended period. To evaluate this component, a vigilance task is required.

1.5.3 Vigilance

A simple definition of vigilance would be, waiting for something to happen. Vigilance requires a person to respond to a stimulus, however often it is a subtle stimulus requiring concentration and continual monitoring to respond to infrequent unpredictable events over a sustained time period. Early research on vigilance (Mackworth, 1950) found that even with relatively simple tasks individuals were unable to maintain attention. In Mackworth's World War II research he found that radar operators would miss submarines and other objects they should have easily identified. The explanation for why this occurs is a reduction in alertness when an individual's requirement to respond is minimal. This is why lifeguards normally rotate stations every 20-minutes and it is recommended to give them a break from lifeguarding each hour as well. A classroom teacher might consider this inability to remain on task as daydreaming, however to be successful on monotonous repetitive vigilance tasks requires a higher level of arousal. An example of this can be found in the research examining falling asleep while driving (Dinges, Jauregui, & Nguyen, 1998; Maycock, 1996). The driving research found that on dangerous windy and curving roads drivers were less likely to fall asleep because they were required to constantly attend to the task at hand. The study also surveyed drivers to elicit responses as to the most effective ways to overcome drowsiness while driving; responses included pulling off the road to participate in an acute bout of physical activity. The point being that although the current study is not concerned with tiredness and fatigue, drivers recognized that acute physical activity served as a method to increase their level of alertness and need for vigilance during the complex task of driving. Real world examples of vigilance could include working on an inspection line trying to detect flawed widgets as they pass by, or a student in a classroom sitting for an extended period watching a presentation attending for a few key points. The ability to be vigilant and attend to important information is critical; the next question then is whether individuals are able to use this information to solve actual problems.

1.5.4 Problem Solving

Arguably the most complex of all higher order cognitive processes is problem solving (Goldstein & Levin, 1987). Simply recalling basic information or responding to a stimulus is one thing, but actively making decisions on how to proceed in a dynamic environment requires higher order thinking. A problem solving task which is well established and has been cited extensively in the literature (Ewert & Lambert, 1932; Mayer, 1992) is the Tower of Hanoi. The task is popular as it has measurable optimal levels of performance and is able to be completed in a relatively short period of time. The assumption of the task is that cognitive processes required and the ability to solve the problem is generalizable to other real world problems (Newell & Simon, 1972). Higher levels of physical activity and fitness have been indicated to have a beneficial effect specifically with regard to activities requiring higher levels of executive control and it has been reported that the brain can be affected by physical activity even in adolescents (Hillman, Castelli, & Buck, 2005).

The evaluation of cognitive processes is complicated and involves many facets. As discussed above, these include the ability to attend to information while ignoring irrelevant information (attention), the ability to remember information (memory capacity), maintaining attention in situations requiring an infrequent response (vigilance), and making decisions (problem solving). Assessment incorporating each of these components provides evaluations well supported within the literature that provide a broad cross section of cognitive abilities.

1.6 PURPOSE AND RATIONALE

Throughout history a strong mind and a strong body have been intricately linked, and the current trend in the United States is that young people are generally inactive, unfit, and increasingly overweight (American Heart Association, 2004). In society today individuals go on special diets and take supplements (Many with no empirical evidence to support their use.) in the hope that they can improve their physical and mental performance (Matheson, 2000). When behavior such as this is commonplace, it would be ill advised not to further examine physical activity, which the research has supported for promoting positive health benefits. The risks associated with a sedentary lifestyle, associated increase in childhood obesity, and the increased risk for hypo kinetic disease (Freedman, Dietz, Stinivasan, & Berenson, 1999) support a rationale for more research on pediatric physical activity.

Current literature indicates that children and adults can gain myriad of health benefits from being physically. Cited benefits have included better stress management, lower levels of depression, improved nutritional choices, reduced tobacco use, positive interpersonal relationships, reduced anxiety, a reduction in disruptive behaviors, and lower fatigue levels

(Bouchard, Shephard, Stephens, Sutton, & McPherson, 1990; Hechinger, 1992; Meredith & Dwyer, 1991).

The physiological benefits of physical activity and the fact that activity and fitness have shown positive benefits for psychological/mental health and quality of life are all indicators that the topic warrants further study (Biddle,Sallis, & Calvill, 1998; Sallis & Patrick, 1994). The bottom line is that studies consistently demonstrate a high correlation between fitness and specific cognitive functions, a relationship that occurs at too high a level to be happening by chance (Spirduso & Asplund, 1995). The question remains as to what factor(s) could be affecting cognitive function. Sibley and Etnier (2003) cited possible factors such as altered arousal levels, increased cerebral blood flow, developmental factors, and altered neurotransmitters as a few of the reasons why the topic of how physical activity can affect cognitive function deserves further study.

Previous research on the relationship between physical activity and cognition in children have typically assessed cognitive change using broad measures such as achievement tests (Sallis, et al., 1999), performance in academic classes (Tremblay, Inman, & Willms, 2000), and grades in school (Lindner, 2002), The purpose of this study is to investigate the effect of acute physical activity on specific areas of cognition including choice reaction time, probed memory, dual task, vigilance, and executive function.

1.7 HYPOTHESIS

This study hypothesized that a significant difference would exist for choice reaction time, probed memory, dual task, vigilance, and the Tower of Hanoi. No differences were expected for simple reaction time. The literature review has supported improved reaction time scores for fit and older adults, but the same results have not been consistently reported for children. Research has also reported that reaction time scores during moderate exercise (Brisswalter, Collldeau, & Rene, 1995) can be adversely impacted, and as the simple RT task is the first cognitive task completed following physical activity little or no impact from the intervention is anticipated.

1.8 LIMITATIONS

The first limitation of the study deals with the nature of the population used. The literature review revealed limited information dealing with acute physical activity and cognitive function in children. It is not possible to control all variables of growing and developing children; this is further confounded in a study of a preliminary nature. First and foremost to be considered is the normal growth process. It can never be stated with absolute certainty if the performance scores in a pretest posttest situation have been affected by growth (Micheli & Micheli, 1985). The current study made efforts to control for this by completing paired subject data collection within 10 days of each other. However a small change, even the smallest change (neurogenisis, etc.) between pre and post-test could affect their score on the cognitive tasks.

The second limitation is due to the lack of specific data on acute physical activity in children. The reviewed literature has demonstrated the positive effects of physical fitness and physical activity on older populations as well as adult populations. The available literature examining the effects of acute physical activity on children is limited. Specifically very little literature was found that examined the effect of acute physical activity on information processing ability and none utilizing quantifiable cognitive tasks such as those used in the current study, making this study a preliminary endeavor into this line of research.

A third limitation involves the cognitive tasks. As the tasks were completed twice, a practice effect is possible. Also due to the preliminary nature of the work as discussed in the second limitation, selection of settings for cognitive tasks with regard to their duration, difficulty, and the sensitivity level of each task to assess the impact of acute physical activity was preliminary as well.

2.0 METHODOLOGY

The methodology of the study includes subject characteristics and an explanation of the instrumentation used in the study. A description of each task (simpler reaction time, choice reaction time, dual task, vigilance, probed memory, and the Tower of Hanoi) is included as well as a breakdown of the subcomponents for each task and their purpose and rationale. Also included is a description of heart rate equipment, a detailed description of each cognitive task, as well as procedures, design, and analysis.

2.1 SUBJECT CHARACTERISTICS

Subjects were volunteers recruited with no emphasis placed on ethnicity or race from a Junior/Senior High School in Western Pennsylvania. The University of Pittsburgh Institutional Review Board approved the study (Appendix B). Prior to participation in the study parents returned the IRB consent form with both parental and student consent.

Following approval by the Institutional Review Board at the University of Pittsburgh, an explanation letter and a consent form was sent to the female 7^{th} and 8^{th} grade students at the school. Of the 168 invitations to participate in the study, 39 students elected to participate (Breakdown of subject ages in Table 2.). One subject withdrew prior to completion of the study, and data from a second subject was unusable, as she had been diagnosed with a congenital disorder that affected movement and motor skill. The resulting pool consisted of 37 subjects.

Table 2. Subject Age Distribution

Age	Number of Subjects
12	20
13	14
14	3
Total	37 (M=12.54 years, SD .650)

2.2 INSTRUMENTS

Six different cognitive tasks measured in this study were general attention, selective attention, memory capacity, memory function and executive function. The equipment used and a specific explanation of each of the areas is listed below.

2.2.1 Task Purpose and Rationale

The tasks were chosen to examine a specific cognitive component, but as was discussed in the instrumentation section, tasks could be further divided into subcomponents for analysis and are not mutually exclusive of each other (See Table 3) with a fair amount of overlap occurring between individual tasks.

Table 3: Task Subcomponents

Task	Response/Completion Time	Movement Time	Reaction Time	Time on Target	Correct Responses	Incorrect/Misses	False Hits	Number of Moves
Simple RT		X*	X*					
Choice RT		X*	X*		X*			
Dual Task			X	X*		X*	X	
Vigilance					X*	X*	X	
Probed Memory					X			
Tower of Hanoi	X*							X

*p<.05

The tasks (See Table 4) utilized varying units of measure. The six cognitive tasks used in the study can be further divided into 16 subcomponents. For eleven of these, a lower score would indicate improved performance. The exceptions to this would include correct responses (choice reaction time), correct responses (probed memory), time on target (dual task), and hits (vigilance) where a higher score would indicate improved performance.

Table 4: Instrumentation and Measurement

Task	Instrument	Unit of Measure	Assessment
Activity Level	Active/Sedentary		Physical Activity
	Heart Rate	Beats per Minute	
Simple Reaction Time	Attention (Psych E)		Focused Attention
	Reaction Time	Milliseconds	
	Movement Time	Milliseconds	
Choice Reaction Time	Decision Making (Psych E)		Focused Attention
	Correct Responses	Percent Correct	
	Reaction Time	Milliseconds	
	Movement Time	Milliseconds	
Probed Memory	Memory Capacity (Psych E)		Working Memory Selective Attention
	Correct Responses	Percent Correct	
Dual Task	Attentional Capacity (Psych E)		Divided Attention
	Reaction Time	Milliseconds	
	False Hits	Number	
	Misses	Number	
	Time on Target	Percentage	
Vigilance	Memory Duration (Psych E)		Memory Function Sustained Attention
	Hits	Number	
	Misses	Number	
	False Hits	Number	
Tower of Hanoi	Executive Function		Executive Function Problem Solving
	Moves Taken	Number	
	Time to Complete	Seconds	

A specific explanation of the instrumentation used for each cognitive task is included below.

2.2.1.1 Heart Rate

Heart rate monitors have been shown to be valid for use in classifying level of physical activity categories (active and sedentary, Sirard & Pate, 2001). The Polar E600 heart rate monitor used in this study was a wristwatch that acted as a receiver and an elastic strap worn around the chest attached to a transmitter with electrodes. The transmitter sends a signal to the monitor. Heart rate monitors have proven to be a valuable tool for researchers and provide valid measurements of heart rate when compared to electrocardiograms (Crouter, Albright, and David, 2004; Treiber, Musante, Hartdagan, Davis, Levy, & Strong, 1989).

2.2.2 Cognitive Tasks

Cognitive Assessment was completed using the Psych E self-contained computer program for conducting psychomotor assessment and a computerized version of the Tower of Hanoi. The program ran on an IBM-compatible personal computer which recorded all scores and times. The computer used was a Compaq (Pentium 4, 1.6 Ghz, 256 RAM) utilizing Windows XP operating system. Attached to the computer was an external keyboard modified for data collection, a Gateway 16 inch flat screen monitor, and a Logitech Optical Mouse (See Figure 1). The selected test items required a total administration time of approximately 20 minutes. Test items were selected by program designers following a literature review of methods to assess psychomotor function (Hope, Woolman, Gray, Asbury, & Millar, 1998).

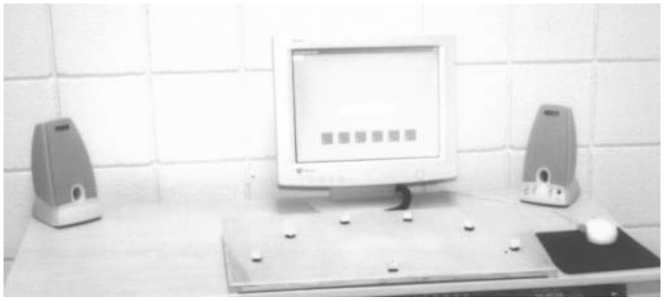


Figure 1: Computer Station

2.2.2.1 Discrete Simple Reaction Time

To complete this test, the subject held down the s button on the modified keyboard (See Figure 2) using their index finger with their preferred hand. Following a random interval (1 to 10 seconds) an audible signal tone (beep) occurred. Upon appearance of the signal, the subject was directed to lift her index finger from the button and press the target key button (Number 7 for right hand preference, and number 6 for left hand preference.) with their index finger as quickly and as accurately as possible. The correct responses including the total response time and its subcomponents (movement time and reaction time) were recorded separately to within one millisecond. The test consisted of 20 repeated trials. Simple reaction time serves as a general measure of attentional capacity examining both the motor response system and alertness.

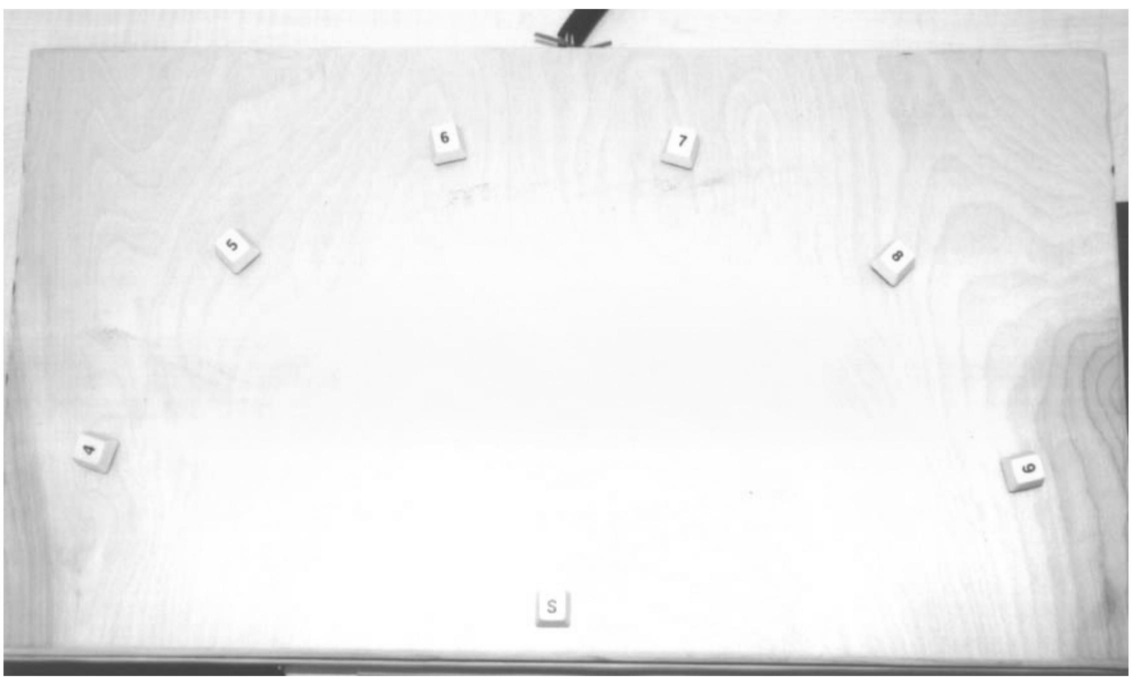


Figure 2: Modified Keyboard

2.2.2.2 Discrete Six Choice Reaction Time

To complete this test the subject held down the button labeled 'S' using their preferred index finger. As the subject held down the button a representation of the 6 target keys (keys numbered 4-9 on the response board) was displayed on the computer monitor. Following a random interval (1 to 10 seconds) one of the numbered keys on the computer screen would light up. The subject was required to lift their index finger off the S button and press the corresponding key on the response board as accurately and as quickly as possible. The computer recorded the total time and the subcategories of reaction time and movement time for each correct response to within one millisecond for the 20 trials. The number of correct and incorrect responses was also recorded.

2.2.2.3 Dual Task

This test required the modified keyboard and a computer mouse. The test utilized a primary task of tracking, along with a secondary reaction task. The purpose of the test is to keep the subject focused on the primary task and measure how the primary task impairs performance on the secondary task. To complete the primary task the subject used a computer mouse with their dominant hand in an effort to keep the cursor on a circular target that moved in a smooth but random pattern on the computer screen. The subject would keep the index finger of their non-dominant hand lightly touching (but not depressing) the 'S' button on the modified keyboard. At random intervals and locations during this primary task a small sun shaped symbol would appear on the computer screen at which time the subject would quickly tap (depress and release) the 'S' button with their non dominant index finger. The computer recorded the percentage of time the cursor was on the target for the primary task, along with false hits, misses, and reaction time to the nearest one millisecond for the secondary task. The dual task served as a measure of selective attention as the task required the subject to attend to the primary task while responding to a secondary task when appropriate.

2.2.2.4 Vigilance

For this test, three digit numbers would flash on the computer screen. The numbers were presented at a rate of 100 per minute. During the test 92% of the three digit numbers would be different from the previous number in one of the digits. The Remaining 8% of the numbers presented during the test were duplicates of the previous number. The subject was required to lightly touch but not depress the ‘S’ button on the modified keyboard using the index finger of their dominant hand. As the numbers were presented the subjects tapped the ‘S’ button each time a duplicate number was presented. The computer recorded the number of correct responses (hits), the number of duplicates the subject did not identify (misses), and the incorrect duplications (false alarms). This test took approximately four minutes to complete.

2.2.2.5 Probed Memory

The purpose of this test was to assess memory capacity of short-term memory. To complete this test subjects were presented a sequence of eight letters on the computer screen. All letters used were consonants to minimize the chance that the subject could make words out of the letters. Subjects were instructed to remember the eight letters that were presented. The sequence of letters were presented at a rate of one every second with all remaining visible until the last consonant was displayed and they remained visible for one second after presentation of the last letter, After the sequence was blanked out one letter was displayed on the screen. The subject is asked to move the mouse approximately ½ inch and click either yes or no on the computer screen to identify whether or not the displayed letter had been part of the list. Twenty presentations occur with 50% of the probe consonants belonging to the original list. The computer automatically records the percentage of correct responses.

2.2.2.6 Tower of Hanoi

A computerized version of the Tower of Hanoi mathematical puzzle was also used as a cognitive problem solving activity. This puzzle has been used for research purposes (Ewert & Lambert, 1932; Mayer, 1992) as a novel problem solving activity that requires higher-level executive function. The puzzle (See Figure 3) consists of three vertical pegs and representations of discs of varying diameter that can be stacked to make a cone. The puzzle begins with all of the discs placed on one of the vertical pegs with the largest diameter disc on the bottom and the smallest diameter disc on the top creating the cone shape. The object of the puzzle is to move the discs to another designated vertical peg by moving only one disc at a time, and by never placing a larger disc on top of a smaller disc.

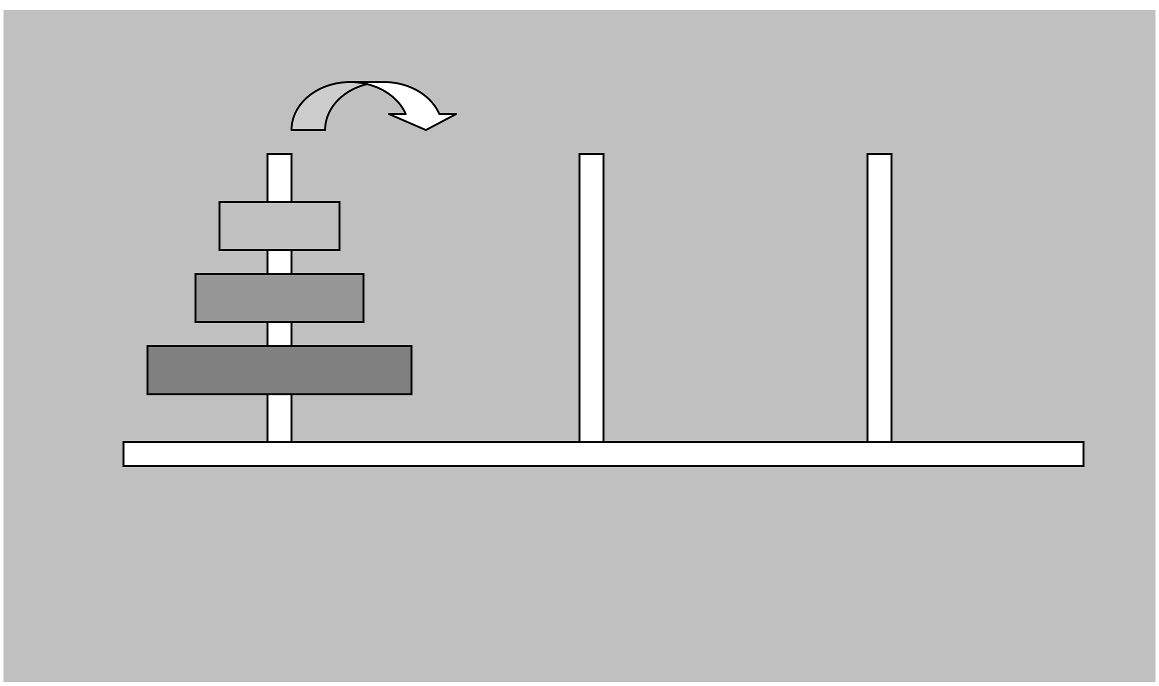


Figure 3: Tower of Hanoi

For the purposes of this study a three-disc version of the Tower of Hanoi was used. A three-disc version has a simple recursive solution with a definable optimal performance of seven moves. The total time taken to solve the problem along with the number of moves required were recorded. The purpose of the task was to assess problem-solving and executive planning ability of subjects.

2.3 PROCEDURES

The study was conducted over an eight-month period consisting of four sessions. One session served as an orientation to show students how the heart rate monitor worked. Two sessions were used to record data for cognitive tasks after either active or sedentary behavior. A fourth session was used to collect health related fitness information. The presentation of the independent variable for each subject was randomly ordered whether the activity or sedentary behavior session was completed first. With some subjects completing the physical activity treatment first and the remaining subjects completing the sedentary behavior treatment first. Data collection for each test item was performed at approximately the same time of day for each subject normally coinciding with a regularly scheduled physical education class or study hall. On a subsequent day that was not the next day, but was within seven days, each subject participated in the remaining independent variable task.

During physical activity subjects participated in aerobic activity for 30 minutes with the objective being to keep their heart rate within or above the defined physical activity level for a minimum of 20 minutes. This was achieved by walking hallways and stairwells within the school to elevate the heart rate to the desired level. Immediately following the activity treatment (within five to ten minutes) each subject completed the battery of cognitive tasks. The cognitive tasks were completed at a station set up inside the school library.

The sedentary behavior involved students sitting quietly in the school library completing schoolwork, which consisted primarily of reading for 30 minutes. The goal was for the heart rate to remain below the designated threshold for sedentary behavior. Immediately following the sedentary behavior (within five to ten minutes) each subject completed the battery of cognitive assessments at a station set up inside the school library.

The cognitive tasks that were completed following the physical activity and sedentary activity sessions consisted of six tasks. The cognitive tasks were completed in the same order following each session. Simple reaction time was completed first followed by choice reaction time, dual task, vigilance, probed memory and tower of Hanoi.

2.4 DESIGN AND ANALYSIS

The design of the study included one independent variable, level of physical activity (active, sedentary). The dependent variables were the measures from six cognitive tasks including simple reaction time (SRT), choice reaction time (CRT), probed memory, vigilance, dual task, and tower of Hanoi.

Level of physical activity was part of the design. Each subject participated in two 30-minute sessions of physical activity. Physical activity has been defined as any bodily movement resulting in energy expenditure (Sirard & Pate, 2001). For the purposes of this study one 30-

minute session was classified as sedentary, and a second 30-minute session was classified as active. The level of physical activity was measured using a Polar E600 heart rate monitor.

For the purposes of this study the sedentary behavior level of physical activity consisted of the subject sitting at a desk participating in an age appropriate activity. These activities included school related instructional lessons that the students regularly completed during their study period. Typical activities included completing math homework and reading from a book. The objective for the sedentary behavior session was for the heart rate to remain below the define (220–the age of the subject *.50) sedentary training heart rate level for 30 minutes. The physical activity session used the aerobic activity of walking. The subjects walked designated hallway areas in the school The selected areas included level walking areas, a ramp, and stairwells. The goal and definition of physical activity for the purposes of this study was for the subject to maintain the heart rate within or above a bandwidth training heart rate level (220-the age of the subject *.60-.80) for 20 of the 30 minutes.

Data analysis utilized a paired-samples one-tailed *t*-test to compare the subject performance on cognitive tasks between the levels of physical activity. Analysis of the variables was considered significant when *p* was found to be less than or equal to .05.

3.0 RESULTS

The purpose of this investigation was to examine the effect of an acute bout of physical activity on children's performance of cognitive tasks. The study used two levels of physical activity (active, sedentary) to examine its effect on six cognitive tasks (simple reaction time, choice reaction time, dual task, probed memory, vigilance, Tower of Hanoi). The question is: following an acute bout of physical activity do children demonstrate improved memory, planning, problem solving, and decision-making? However, prior to examining the results of the cognitive tasks, the differences between the two levels of physical activity are evaluated.

3.1 ACTIVITY LEVEL DESIGN CHECK

To confirm that there were physical activity differences between the sedentary and active levels, physical activity level was analyzed using matched pairs of heart rate scores following physical activity and sedentary behavior. The analysis reported a statistically significant elevation in average heart rate during the thirty minutes of acute physical activity (M=126.38 bpm, SD=8.66) when compared to sedentary (M=85.16 bpm, SD=9.59) behavior [$t(36)=21.08$, $p<.0005$]. The effect size calculation (3.50) was large reinforcing the difference between heart rates during physical activity and sedentary behavior.

3.2 COGNITIVE TASK HEART RATE

Following sedentary behavior and following physical activity, the monitoring of subject heart rates continued while they completed the cognitive tasks. Comparison of these heart rate scores revealed some interesting results. Heart rates were analyzed using matched pairs of heart rate scores collected during the two computer assessments (following sedentary behavior, following physical activity). These heart rates were then examined according to the amount of time subjects' heart rates were below their training zone, within their training zone, time above their training zones, and average heart rate while they completed the cognitive tasks. Analysis for the amount of time the heart rate was below the training zone on the cognitive tasks following sedentary behavior (M=1401.81 seconds, SD=228.50) and the heart rate scores on the cognitive tasks following (M=1192.45 seconds, SD=105.74) physical activity [t(36=-5.1, p<.0005)] were significantly different. The effect size calculation (1.25) was large reinforcing that the amount of time subjects heart rates were below the training zone for the two sessions was quite different. This demonstrates that heart rates were below the training zone for a significantly longer period of time (M=1401.81 seconds) following sedentary behavior when compared to following physical activity (M=1192.45 seconds). Although significance was only reported for the amount of time heart rates were below the training zone, the trend was for all heart rate scores to be elevated during the cognitive task following physical activity. This was true for average heart rate (88 bpm following activity, 85 bpm following sedentary), as well as the time above the training zone (three minutes following activity, one minute following sedentary), and the time within the training zone (5.6 minutes following activity, 0.0 minutes following sedentary).

3.3 SIMPLE REACTION TIME

3.3.1 Reaction Time

Following physical activity the subjects RT demonstrated significantly faster simple RT (M=475.65 msec, SD=141.16) than following sedentary behavior [M=585.27 msec, SD=345.03, $t(36)=-1.78$, $p<.05$] with an effect size calculation of 0.29. A significant difference was found on the task with the distribution of the scores between sedentary behavior and physical activity overlapping resulting in a lower than anticipated effect size calculation.

3.3.2 Movement Time

Following physical activity subjects (M=363.41 msec, SD=123.66) responded with significantly faster movement times compared to following sedentary behavior [M=545.49 msec, SD=234.92, $t(36)=-6.212$, $p<.05$] with a large effect size of 1.02 reinforcing that subjects had faster movement times following physical activity.

3.4 CHOICE REACTION TIME

The analysis of choice reaction time involved examining three components of the task including the percentage of correct responses, reaction time, and movement time for the task.

3.4.1 Percent of Correct Responses

A paired-samples one-tailed t-test analyzing the percentage of correct responses for this task revealed a statistically significant decrease in the number of correct responses following physical activity (*M*=98.37 percent, *SD*=3.13) as compared to following sedentary behavior [*M*=99.45 percent, *SD*=1.57, t(36)=-1.75, p<.05] with an effect size of 0.30. This indicates that following sedentary behavior the subjects made fewer mistakes than following physical activity. To place this in perspective, subject performance on this task following both physical activity and sedentary behavior was at a high level. Following physical activity 28 subjects scored 100 percent on the task, while 6 scored 95 percent and 3 scored 90 percent. Following sedentary behavior 33 subjects scored 100 percent while 4 scored 95 percent.

3.4.2 Choice Reaction Time

Following physical activity (M=628.11 msec, SD=189.6) RT was significantly faster than when sedentary [M=693.27 msec, SD=187.93, -2.24, p<.05] with a small to moderate 0.40 effect size calculation indicating that although significance was achieved a distinctive separation of subjects paired data following physical activity and following sedentary behavior was not evident.

3.4.3 Choice Movement Time

For choice reaction time a significant decrease in movement time was reported using the paired samples t-test with subjects following physical activity (*M*=449 msec, *SD*=111.59) performing significantly faster than following sedentary behavior [*M*=536.11 msec, *SD*=178.59, *t*(36)=-4.2, *p*<.05]. Further supporting the level of significance achieved with this task was the 0.70 effect size calculation that is large and further quantifies the difference that existed between the two groups.

3.5 PROBED MEMORY

No significant difference was reported in correct responses between physical activity (*M*=74.46 percent, *SD*=10.59) and sedentary behavior [*M*=71.75 percent, *SD*=12.65, *t*(36)=1.36, *p*<.05]. Subjects following physical activity correctly identified a higher percentage of probed memory items than following sedentary behavior with the results indicating that the difference was not significant across the test.

3.6 DUAL TASK

Analysis of the dual task involved examining four components of the task. The four components of this task included reaction time, the number of false hits that occurred, the number of times a subject missed (misses), and the amount of time the subject could keep the cursor on the target (time on target).

3.6.1 Reaction Time

No significant difference was found between physical activity (*M*=514.81 msec, *SD*=100.76) and sedentary behavior [*M*=519.22 msec, *SD*=92.83, t(36)=-0.362, *p*<.05] treatments for the dual task RT scores. Following physical activity subjects completed the reaction time task faster than following sedentary behavior, however the level of performance was not significantly different across the task.

3.6.2 False Hits

No significant difference was found between physical activity (*M*=5 number of false hits, *SD*=11.38) and sedentary behavior [*M*=5.24 number of false hits, *SD*=14.68, *t*(36)=-.088, *p*<.05] for the number of false hits on the dual task activity. This indicates that although following physical activity subjects had improved performance (fewer false hits) than following sedentary behavior, the level of performance was not significantly different across the task.

3.6.3 Misses

A significant difference was found between physical activity (*M*=1.84 misses, *SD*=1.34) compared to sedentary behavior [*M*=2.76 misses, *SD*=1.36, *t*(36)=-2.8, *p*<.05] for the number of misses recorded on the dual task activity with a reported 0.50 effect size calculation. These results reflect that the subjects responded with more accuracy to the randomly appearing stimulus (target) following physical activity.

3.6.4 Time on Target

A significant difference for time-on-target was found following physical activity (*M*=10.41 msec, *SD*=19.35) maintaining the time-on-target longer [*M*=1.11 msec, *SD*=6.74, *t*(36)=3.09,

$p<.05$] than sedentary behavior and a 0.50 effect size calculation. These results indicate that following physical activity subjects demonstrated a significantly higher level of performance (time-on-target) across the test compared to following sedentary behavior. This is further supported by the 0.50 effect size calculation, which would be classified as medium, reinforcing that a difference did exist between the two groups.

3.7 VIGILANCE

Analysis of vigilance included examining three components of the task including the number of hits (correct selections), the number of misses (failure to identify a duplication), and false hits (incorrect response).

3.7.1 Number of Hits

Following physical activity (*M*=9.97 hits, *SD*=2.88) there were a significantly higher number of hits than after sedentary behavior [M=8.05 hits, SD=2.82, $t(36)=4.07$, $p<.05$] for the vigilance activity with an effect size calculation of 0.70. These results indicate that following physical activity subjects' performance was significantly different than the scores across the test compared to following physical activity. This is further supported by the 0.70 effect size calculation that would be classified as large, reinforcing that the two groups were quite different.

3.7.2 Number of Misses

Following the physical activity treatment reported significantly fewer misses (*M*=4.97 number of misses, *SD*=2.88) than following sedentary behavior [*M*=6.89 number of misses, *SD*=2.75, *t*(36)=-4.18, *p*<.05] and a effect size calculation of 0.70. These results indicate that following physical activity subjects' made significantly fewer misses as compared to following sedentary behavior across the test. This is further supported by the 0.70 effect size calculation that would be classified as large further reinforcing that the two groups were quite different.

3.7.3 False Hits

Data from two children was removed from the analysis for vigilance false hits due to equipment malfunction, as a computer key remained depressed briefly for two subjects recording repeated false hits and extreme outliers. No significant difference was found between the following physical activity (*M*=6.09 false hits, *SD*=5.53) and following sedentary behavior [*M*=8.59 false hits, *SD*=8.08, *t*(34)=-2, *p*<.05] treatments for the number of false hits.

3.8 TOWER OF HANOI

Analysis of the Tower of Hanoi involved examination of two components including the number of moves it took the subject to complete the task and the amount of time it took the subject to complete the task.

3.8.1 Number of Moves

Analysis of the total number of moves following physical activity (*M*=26.35 moves, *SD*=8.93) and following sedentary behavior [*M*=27.08 moves, *SD*=11.3, $t(36)=-.37$, $p<.05$] treatments reported no significant difference. These results indicate that following physical activity subjects' required fewer moves to complete the task than following sedentary behavior but that the difference was not significantly different across the task.

3.8.2 Time to Complete

Following the physical activity intervention (*M*=77.89 seconds, *SD*=43.12) completed the Tower of Hanoi task significantly faster than following sedentary behavior [*M*=116.95 seconds, *SD*=73.59, $t(36)=-4.12$, $p<.05$] with a 0.70 effect size calculation. These results indicate that following physical activity subjects' solved the puzzle significantly faster than following sedentary behavior across the task. This is further supported by the large 0.70 effect size calculation that reinforces scores between the two groups (following physical activity/following sedentary behavior) are different.

4.0 DISCUSSION

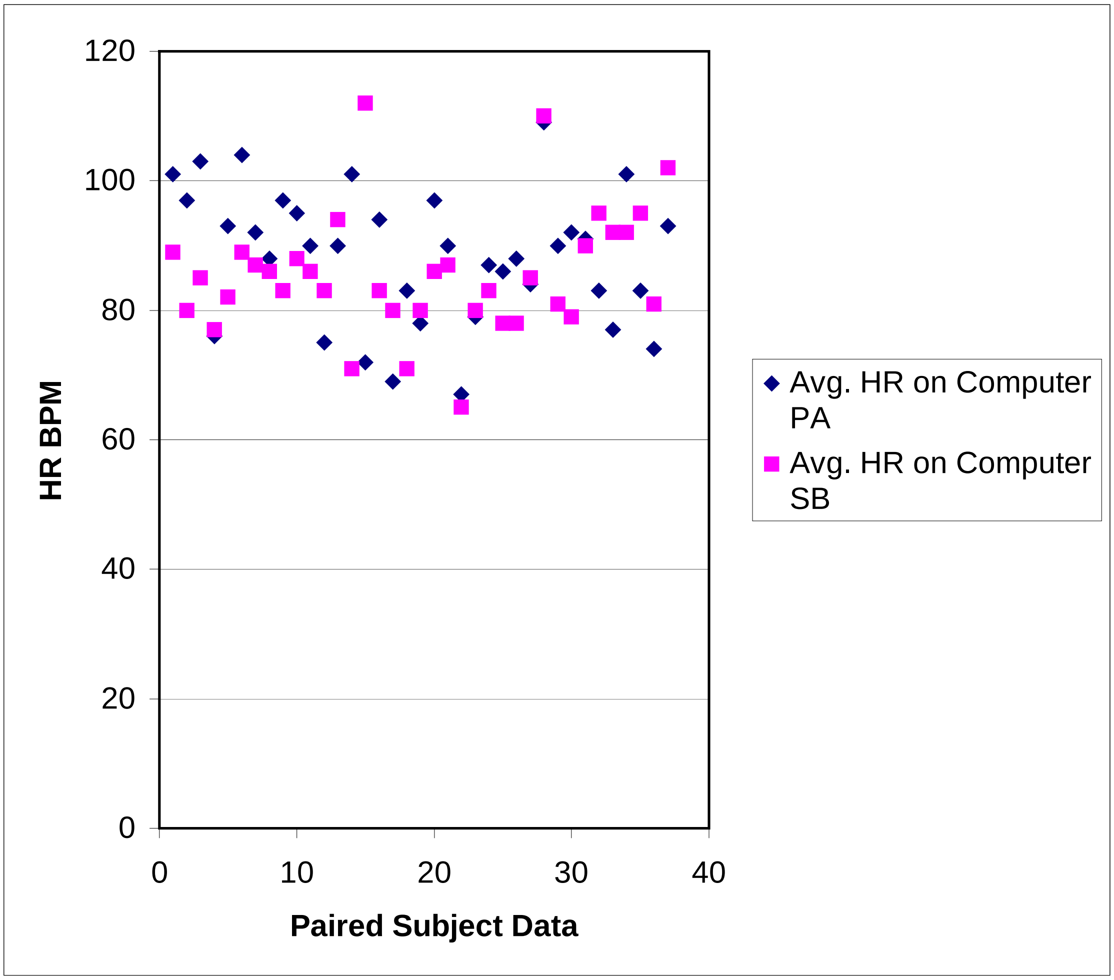
The main finding of the study suggests that the level of acute physical activity used in this study did enhance subjects' performance on the cognitive tasks. When the cognitive tasks were broken down into their components, five of the six tests used reported levels of significance in favor of the physical activity intervention. The one activity that did not report significance showed a positive trend in favor of the physical activity treatment as well. To better understand the importance of how the physical activity treatment affected the cognitive tasks, each specific component of the study is addressed individually.

4.1.1 Physical Activity

The physical activity treatment was successful in elevating the heart rate to a level significantly higher than the sedentary behavior. This was achieved by walking hallways, ramps, and stairwells in the school where the data was collected. For the sedentary component the students remained sedentary by sitting quietly at a table in the school library and completing individual school related seat work (reading, math). The subjects generally reported enjoyment with the physical activity and boredom during sedentary behavior. Numerous theories support the idea that physical activity can affect performance (inverted U principle, Duffy, 1962; zones of optimal functioning, Jokela & Hanin, 1999) and as previously addressed a wealth of literature exists supporting the premise that a physically active lifestyle can have far reaching effects ranging from increased attentional capacity to improved classroom behavior. The scope and use of physical activity in the current study was to introduce an acute bout of physical movement above the resting level. The goal was to raise average heart rate for 20 minutes to a level significantly higher than achieved when a subject sat at a desk doing work for the same duration in order to analyze the effect of acute physical activity on a battery of cognitive tasks. As was discussed in the results section, this goal was achieved with the heart rates for physical activity being significantly higher than sedentary behavior. The importance of this component of the study was not the obvious fact that movement can elevate heart rate above the resting level but that it provides a clear, quantifiable documented treatment so that the effect of acute physical activity on cognitive processing could be analyzed as compared to sedentary behavior. The foundation for the current study established a quantifiable measure that physical activity and sedentary behavior were significantly different as the average HR score for every subject was higher following physical activity.

Heart rate scores collected during the computerized cognitive task activities following each activity session also produced interesting results. As discussed in the results section (cognitive task heart rate design check) significance was achieved for the paired samples with regard to the time the heart rate was below the training zone. The average heart rate for the cognitive task following physical activity (M=88 bpm) was higher than following sedentary behavior (M=85 bpm) for the computerized testing as well, but did not achieve a level of significance.

Table 5: Average HR During Computer Cognitive Tasks



An intriguing characteristic of this information occurs when results of the paired data of subjects' heart rates while completing the computerized cognitive tasks are presented as individual pairs rather than as a group. As can be seen in Figure 5, there is not a clear trend for the average heart rate to be higher while completing the computerized cognitive tasks following physical activity. In fact for 14 of the 37 subjects their average heart rates were higher while completing the computerized cognitive tasks following sedentary behavior. Also visible on Figure 5 is the close proximity of a number of data points. For 12 subjects the average heart rate scores were within 4 beats. In short following physical activity there was not a consistent elevation in heart rate for subjects for the duration of the cognitive tasks.

The most logical explanation for these results is that the subjects for the study had varied levels of aerobic fitness and recovery heart rates. It is also possible according to mood state discussed in the literature review, that physical activity reduced levels of stress affecting HR. The implications of this to the current study are interesting. From an arousal (Inverted U) standpoint it is possible that the physical activity intervention was not of significant magnitude to elevate arousal levels during the computer task. It is also possible that subjects were nervous while completing the computer task following sedentary behavior, which elevated the heart rate. Unfortunately average heart rate scores do not provide the detail needed for specific conclusions.

4.1.2 Simple Reaction Time

Simple reaction time was included as an assessment of alertness and it was proposed that no significant difference would be found between physical activity and sedentary behavior for performance on this task. Previous studies had reported significant differences between groups of subjects based on fitness levels and habitual activity levels particularly with older subjects, however as previously discussed the results for children has been less consistent especially for simple RT with a low level of attentional demands. Analysis of the data from the current study however demonstrated significance for both reaction time and movement time following physical activity when compared to scores following sedentary behavior. On this task faster (lower scores) are better, so on Table 6 and Table 7; faster RT scores are at the bottom of the chart. Close examination of the individual matched pair data on these tables reveal that consistently subjects had faster RT and movement times following physical activity compared to their performance following sedentary behavior.

Table 6: Simple Reaction Time, Thinking Time

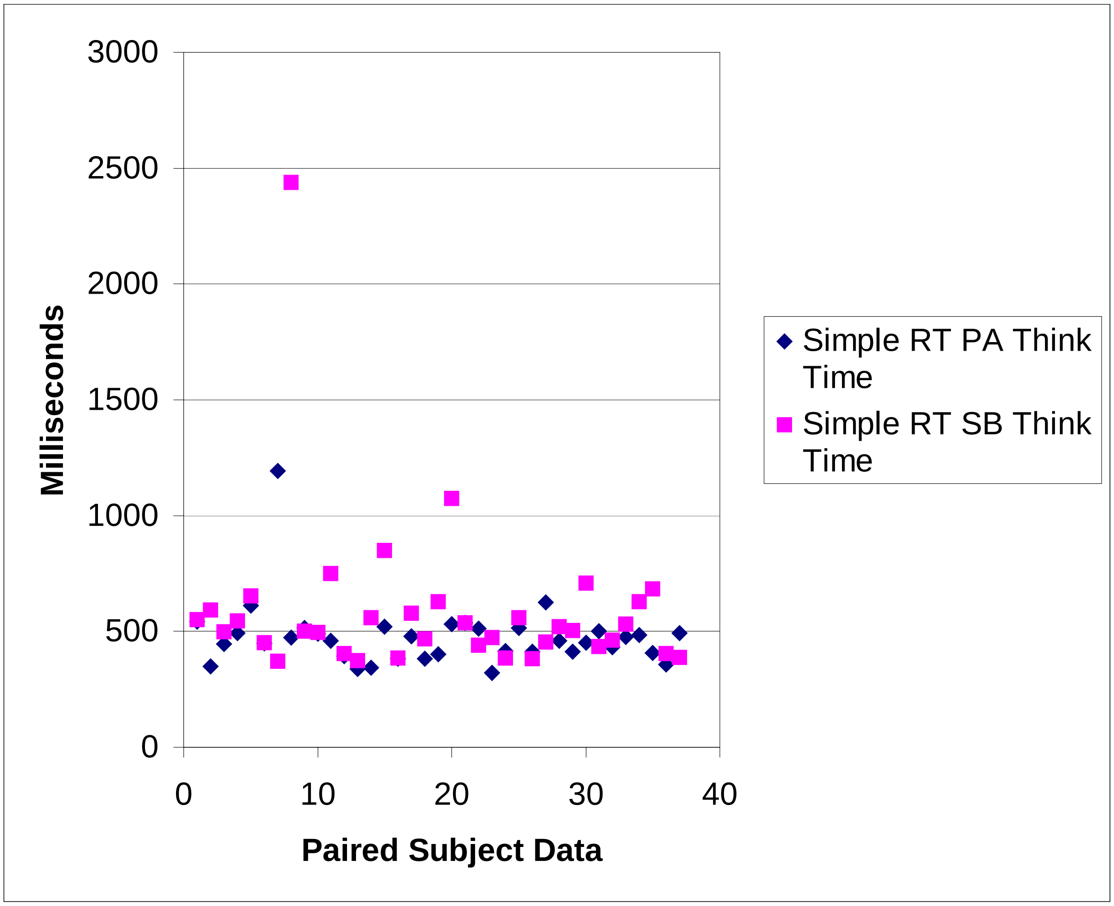
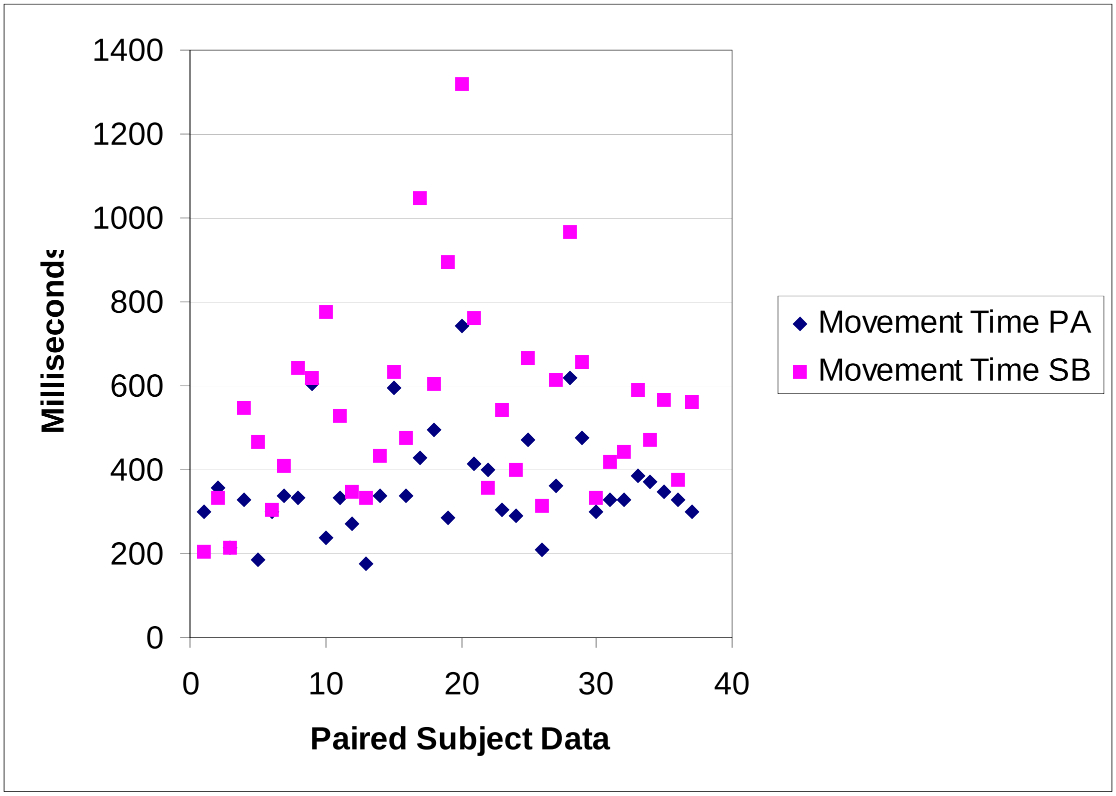


Table 7: Simple Reaction Time, Movement Time



The reported results are consistent with the literature for older adults. Previous studies, which did not show a significant difference for children, also included mixed gender indicating a possible need to increase the intensity and duration of activity for adolescent boys. As the current study was single gender, it is plausible that the physical activity was sufficient to elicit an arousal level to a point where improved performance could be observed which may not have been observed with subjects of mixed gender and varying ages. Another explanation is that the physical activity warmed the muscles preparing them for movement.

4.1.3 Choice Reaction Time

The choice reaction time activity required subjects to attempt to correctly respond to one of six possible choices requiring a higher level of attention. The task represents increased difficulty compared to the simple reaction time task in that the requirement to select the correct movement response from a number of choices is analogous with decisions people make on a daily basis. The increase in response alternatives in this task subsequently increases reaction time with more time needed (Hick's law) to prepare the appropriate movement response (Hick, 1952) providing increased sensitivity to the effect of physical activity and sedentary behavior. Analysis of the correct responses for this task was used to ensure that subjects were in fact selecting the correct response and were not simply reacting as quickly as possible to the stimulus regardless of outcome. The hypothesis for the choice reaction time task was that scores following physical activity would be significantly higher than sedentary behavior. Results of the analysis support this hypothesis, as both reaction time and movement time were significantly higher following physical activity compared to sedentary behavior.

The only result from the choice reaction time activity that is contradictory to the hypothesis deals with the percentage of correct responses. Subjects were instructed to move as quickly as possible, but to be sure they were selecting the correct target key in their response. The results reported sedentary behavior outperformed physical activity. Although the analysis of the one-tailed t-test for correct responses did achieve the level of significance, in this case the results are misleading. On the task, following both physical activity and sedentary behavior, subjects performed at near perfect (physical activity, M=98.37 % correct, SD=3.13; sedentary behavior, M=99.45 % correct, SD=1.57), and in fact the majority of the subjects had perfect scores. Analyzing the data on a subject by subject basis, four individuals had one more correct response following sedentary behavior as compared to physical activity. The literature (Kashihara & Nakahara, 2005) is also supportive of these findings in that exercise although improving choice reaction time did not effect the percentage of correct responses that subjects made.

An explanation of the results for choice reaction time is comparable to those given for simple reaction time. Once again although more research on the specific effects of acute physical activity on children is needed, the current results are consistent with research on adults (Hunter, Sjoberg, 1975; Kashihara & Nakahara, 2005; Levin & Gutin, 1971; Thompson, & Adams 2001), which concluded that exercise can improve reaction time, with the fastest RT achieved when exercise heart rates reach at least 115 beats per minute (Levin & Gutin, 1971; Sjoberg, 1975). However since children are not miniature adults, results from adults are not necessarily generalizable to children. Specifically what level of heart rate intensity during acute physical activity (and for what duration) would be required to elicit the desired effect of improved cognitive performance on tasks such as RT in a growing and developing child. The previously mentioned heart rate guidelines (Levin & Gutin, 1971; Sjoberg, 1975;), would be consistent with the results from the current study where during physical activity subjects heart rates (M=126 bpm) did achieve a level exceeding 115 beats per minute while sedentary behavior (M=85 bpm) did not. Results from the current study are also supported by research completed by Kashihara and Nakahara (2005) who reported that vigorous exercise improved choice reaction time but only for the first eight minutes after exercise. In the current design with subjects beginning the cognitive tasks immediately following physical activity or sedentary behavior the choice reaction time task would normally have occurred close to this eight minute window. A recommendation for future research would be to randomize the presentation of the cognitive tasks tracking the order in which they are presented and analyzing whether a reduction in performance occurs after eight minutes. Given the significance of the results, replication of the study while collecting fractionated reaction as previously mentioned would have been beneficial.

4.1.4 Probed Memory

The purpose of the probed memory task was to evaluate the affect of physical activity on short-term memory. Unlike simple and choice reaction time tasks, which were selected for use as a tool to examine reaction and movement time, probed memory was selected as a task to explore the effect of acute physical activity on working memory. The hypothesis for the dual task activity was that subjects would have significantly improved scores following physical activity when compared to sedentary behavior.

Although the statistical analysis did not report a significant difference for this task, as addressed in the results, the physical activity scores (M=74.5% correct) were slightly better than sedentary behavior (M=71.8% correct). One possible explanation for the lack of significance is that physical activity does not have an effect on short-term memory recall as presented in this task. With physical activity and sedentary behavior seeming to neither increase nor decrease forgetting (trace decay) of the presented items. Another plausible explanation for the lack of significance is that the rate of a one second presentation time for each letter was of such duration (too long), and the length of the list (eight letters) was not sufficient to place a cognitive load on the subjects for any differences in perception that physical activity may have elicited to come into play. There is support for this (Barrouillet Bernardin, & Camos; 2004) in that memory lists for letters is not contingent upon the length of the list (number of steps), but rather the cognitive load. A third explanation is that the one-second length of time from the presentation of the last letter and the request for recall was not long enough to assess the impact of physical activity on short term memory. If the physical activity intervention was to have an impact on short term memory, a duration of longer than one-second following presentation of the last letter would be recommended for future studies.

4.1.5 Vigilance

Vigilance tasks examine the ability of a subject to remain alert and on task over a period of time. The ability of an individual to respond properly is more challenging when the response is not required on a regular basis. Responding to a stimulus that occurs on an irregular random basis is much more challenging. Real world examples of this type of activity could include staring at a radar screen and only picking out relevant information; working on an assembly line picking out defective items; or sitting in a classroom for a long period of time and being able to pick out the important information. The hypothesis of the current study was that subjects' scores following the physical activity intervention would be significantly higher than following sedentary behavior for the vigilance tasks.

Analysis of the results from the vigilance task demonstrated that children's signal detection ability was affected by the physical activity intervention. The subject's perception, ability to make decisions, and resulting performance was different between physical activity and sedentary behavior. The established criterion for the task was to recognize when irregular duplications of a three-digit number were flashed on the computer screen. Following physical activity the ability of the subject to recognize and respond (hit) was better than after sedentary behavior. Following physical activity there was also a significant reduction in the number of misses. Finally following physical activity the subjects had improved performance over sedentary behavior with false hits. When viewed together after participation in physical activity, the subjects correctly identified more of the targets, missed fewer of the targets, and made fewer false identifications. This indicates that the strength of perception for the subject was improved following the physical activity intervention.

4.1.6 Dual Task

The purpose of the dual task was to determine the attentional demands of two different tasks completed simultaneously. The hypothesis for the dual task activity was that subjects would have significantly improved scores following physical activity when compared to sedentary behavior. The general approach in dual task studies is to determine if the attentional demands of one task interferes with the other.

With regard to attention-limit issues, after physical activity the subjects performed better than following sedentary behavior. The results reported that subjects were not impaired significantly by the simple reaction time task, nor was there a significant difference in the number of false hits on the task. The fact that physical activity recorded significantly fewer misses during the reaction time component of the activity could indicate that an increased arousal level in strength of perception existed comparable to the discussion for the vigilance task. Along with fewer misses, following physical activity the subjects also had higher time-on-target scores than sedentary behavior indicating improved attentional capacity following physical activity. Analysis and interpretation of the dual task is problematic however due to the abnormal distribution of scores on false hits and the time-on-target tracking task. As can be seen in Table 9, students performed poorly on the tracking activity indicating that it was too difficult. The task required subjects to use a mouse to move a cursor on a computer screen tracking a randomly moving target (circle) around the screen. An obvious explanation is that the target object was too small, moved too fast; the test was not sensitive enough, or a combination of all of these factors. This lack of difference between physical activity and sedentary behavior for most of the subjects is not without precedent. Tuckman and Hinkle (1986) found no change in performance between fit and unfit 4th, 5th, and 6th grade students on a maze tracing task although performance on tasks requiring creativity did improve. Intriguing is the fact in the current study, nine of the subjects did show dramatic improvement in performance following physical activity, while no subjects improved their performance following sedentary behavior This is difficult to interpret with the limited research on children in this area.

Analysis of the false hits portion of the dual task activity is also difficult to interpret. No significance was reported and as can be seen in Table 9, it is difficult to interpret a trend in the data. No valid reason could be found to exclude the wide-ranging scores and although performance was quite consistent for many subjects, there was a wide range in the number of false hits following both physical activity (M=5.24 false hits, SD=11.38) and following sedentary behavior (M=5.24 false hits, SD=14.68). One possible explanation is from the previous discussion of the tracking task. Due to the level of difficulty subjects experienced with attempting to stay on target, following physical activity their arousal level may have been heightened during this task, and they may have exceeded their level of arousal and experienced degradation in performance.

Table 8: Dual Task Time on Target

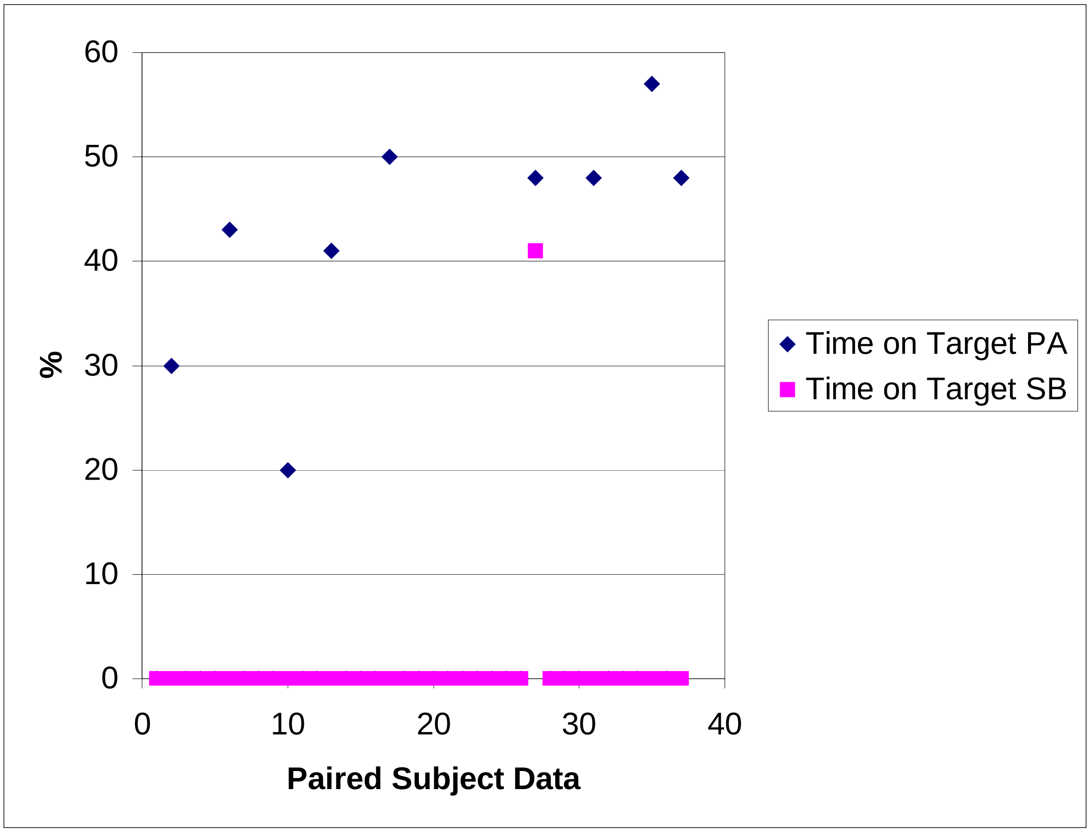
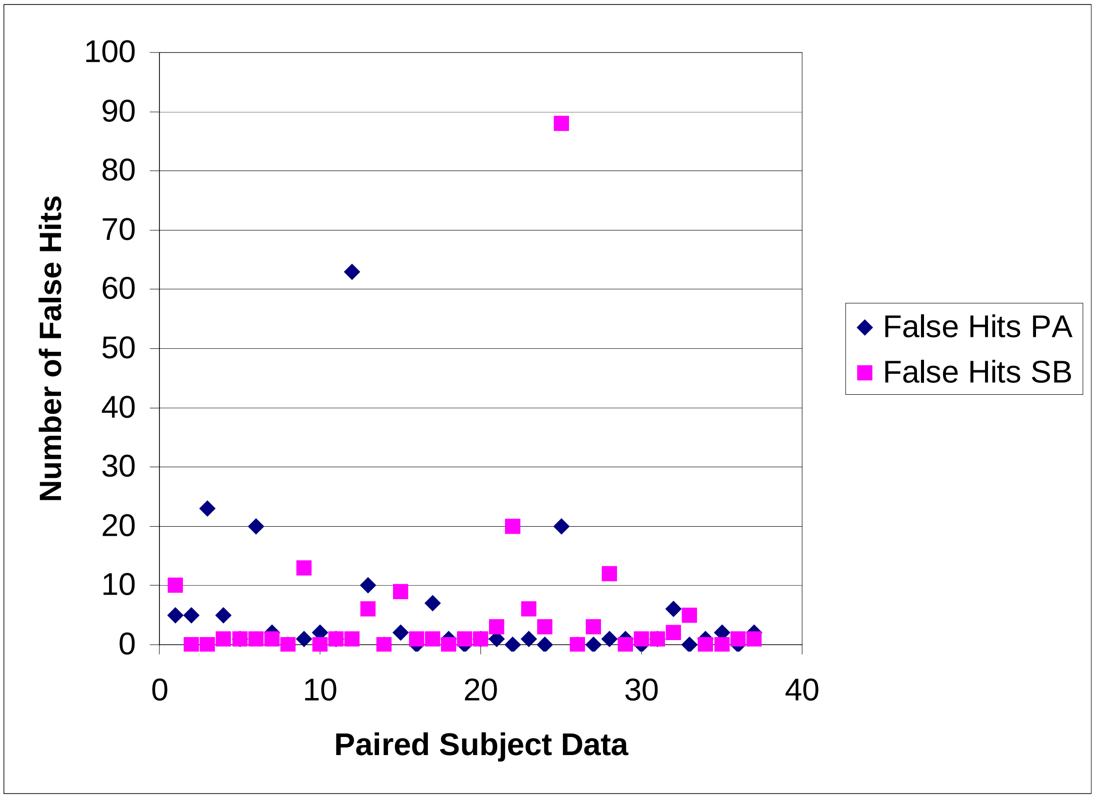


Table 9: Dual Task False Hits



4.1.7 Tower of Hanoi

The tower of Hanoi is a classic cognitive task used to analyze problem-solving strategies. Problem solving is considered a complex intellectual function requiring higher order cognitive processes (Goldstein & Levin, 1987). The other five tasks used in the study generally required the subjects to react to a presented stimulus. The Tower of Hanoi task required the subjects to use planning, thinking ahead, and reasoning abilities to solve the puzzle. The Tower of Hanoi has been suggested to be an indicator of executive function. Within the problem solving construct of the Tower of Hanoi, executive function is indicated in the subjects ability to understand the goal of the task, develop a plan to solve the problem, execute the plan, then evaluate and modify the plan as needed to solve the problem. Solving the Tower of Hanoi represents processes individuals engage in while solving real world problems and this simple problem is thought to generalize to more complex problems (Newell & Simon, 1972).

It was hypothesized that subjects would score significantly higher on the Tower of Hanoi following physical activity compared to sedentary behavior. The statistical results from the two Tower of Hanoi tasks produced mixed results. Although physical activity was not better than sedentary behavior in the total number of moves taken, on average following physical activity the subjects were able to complete the task in fewer moves and with a smaller SD. With regard to the time taken to complete the task, following physical activity the subjects were significantly faster than after sedentary behavior.

Initial evaluation would indicate that after being physically active the subjects did not improve executive function in that their ability to 'solve' the puzzle (number of moves taken) did not improve, however they were able to solve the puzzle more quickly. Problem-solving processes are different at different levels of expertise (Sternberg, 1991), however none of the subjects attained the level of expertise with the task as the task as it was presented could be solved in seven moves. The numbers of moves taken to complete the task were well above this number following physical activity (M=26.35 moves, SD=8.93) and following sedentary behavior (M=27.08 moves, SD=11.13). The most plausible explanation as previously addressed was the order of the computer tasks. The Tower of Hanoi task was always the last task presented and any effects elicited by the physical activity may have expired. At this juncture of the data collection process fatigue may have set in impairing performance on the task.

A second explanation for the lack of significance achieved in the total number of moves is related to the sensitivity of the test. A flaw in the methodology of the study was identified in that false moves were not recorded. In other words when a move took place in violation of the rules (A larger disc was placed on top of a smaller disc.) an audible alarm would sound informing the subject that they had made an invalid move. The computer would then move the disc back to its prior location, but this invalid move was not recorded in the move total. Although the specific number of times this occurred were not recorded, it did occur with enough frequency to be noticed, and it would occur numerous times during individual tests. This results in several implications that make it nearly impossible to generate any meaningful conclusions about the task. First, since false moves were not calculated independently, or as part of the total moves it cannot be stated with any certainty if any significance did truly occur in the total number of moves. If the task was not challenging enough to require the desired higher-level thinking rather than solving the problem through actual problem solving it is possible that subjects were completing the task through trial and error. Visual observation of the subjects completing the tasks seemed to indicate that following sedentary behavior the subjects made more false moves, however it was not documented. Secondly the knowledge of results in the form of the audible alarm that followed an invalid inevitably seemed to result in the subject pausing and staring at the computer screen momentarily. Pursuing this observation, theoretically a subject who made several invalid moves would report a longer completion time without the invalid moves being recorded. Without this data it is difficult to generate any conclusions with regard to executive function and the subjects ability to comprehend the task and generate a plan of action.

Although it can generally be stated that the subjects performed better on the task following physical activity, without the invalid move data, any discussion attempting to explain exactly why this occurred would be supposition and speculation.

4.1.8 Order of the Tasks

Throughout the study the order of the cognitive tasks was consistent for subjects following both activity sessions. Each subject completed the simple reaction time task followed by, choice reaction time, probed memory, dual task, vigilance, and lastly the Tower of Hanoi. Following theories such as the oxygen hypothesis, glucose utilization, and arousal, performance should be higher earlier in the testing (higher heart rate, arousal, etc.) than 20 to 30 minutes later at the end of the session (reduced HR, arousal, etc.). From a cognitive performance standpoint the presentation of the tasks in the current study went roughly from simple (simple reaction time, attention) to complex (Tower of Hanoi, problem solving/executive function) and it is possible that any effects of the physical activity intervention were moderated by the time the subjects completed the more complex tasks. Brisswalter, Collardeau, and Rene (2002) discuss that although theory currently explains how activity affects cognitive function, that moderate to heavy exercise appears to elicit the best results for decisional tasks that can last in excess of 20 minutes. For most of the subjects tasks requiring the highest levels of cognitive performance and attention (Tower of Hanoi, vigilance, dual task) would have been completed after 20 minutes, so the affect of the activity may have faded. Also the intensity of the acute physical activity (physical activity M=126.38 bpm, SD=8.66) could not be classified as heavy exercise and may not as Brisswalter, Collardeau, and Rene (2002) discussed, elicited the best results that could have lasted in excess of 20 minutes.

4.2 CONCLUSIONS

The results of this study are consistent with previous research (Spirduso & Asplund, 1995) in that the incidence and level of improvement on the cognitive tasks in this study are too high to be occurring by chance alone. As can be seen in Table 10, the breakdown of each cognitive task identifies fifteen components, which were analyzed. Of these, subjects demonstrated improved performance following physical activity on fourteen of the tasks, with the level of improvement reaching significance on nine of the items.

Table 10: Summary of Cognitive Task Means

Task	Following Sedentary	Following Activity	Improved
Simple RT			
RT	M=585.27 msec, SD=345.03	M=475.65 msec, SD=141.16	Yes *
Movement Time	M=545.49 msec, SD=234.92	M=363.41 msec, SD=123.66	Yes *
Choice RT			
Percent Correct	M=99.45, SD=1.57	M=98.37, SD=3.13	No *
Choice RT	M=693.27 msec, SD=187.93	M=628.11 msec, SD=189.6	Yes *
Choice MT	M=536.11 msec, SD=178.59	M=449 msec, SD=111.59	Yes *
Probed Memory			
Percent Correct	M=71.75, SD=12.65	M=74.46, SD=10.59	Yes
Dual Task			
RT	M=519.22 msec, SD=92.83	M=514.81 msec, SD=100.76	Yes
False Hits	M=5.24, SD=14.68	M=5, SD=11.38	Yes
Misses	M=2.76 misses, SD=1.36	M=1.84 misses, SD=1.34	Yes *
Time on Target	M=1.11 msec, SD=6.74	M=10.41 msec, SD=19.35	Yes *
Vigilance			
Hits	M=8.05 hits, SD=2.82	M=9.97 hits, SD=2.88	Yes *
Misses	M=6.89 misses, SD=2.75	M=4.97 misses, SD=2.88	Yes *
False Hits	M=8.59 false hits, SD=8.08	M=6.09 false hits, SD=5.53	Yes
Tower of Hanoi			
Number of Moves	M=27.08, SD=11.3	M=26.35, SD=8.93	Yes
Time to Complete	M=116.5 msec, SD=73.59	M=77.89 msec, SD=43.12	Yes *

* denotes $P<.05$

However the exact mechanism through which this improvement is facilitated remains elusive. Although modern technology permits analysis of brain activation, the mystery as to how the black box of the brain functions persists. It is still not possible to point to a part of the brain and identify a specific memory. No single behavior or test exists that can be tied to executive function (Burgess, 1997). Esterson (1993) indicated that Sigmund Freud theorized that different functions of the mind operated at different levels. His tripartite division of the Id, Ego, and Superego was forward looking and innovative for his time, while James Watson and Francis Crick (Macgregor & Poon, 2003) did not discover the molecular structure of DNA until the 20th century. Recent discoveries such as DNA prove that there is a wealth of knowledge to be uncovered about function of the human body. The effect of acute physical activity on cognitive function involving complex interactions is no different, and even when researchers such as Crick (1994) pose that mental activities are due entirely to the behavior of nerve cells, glial cells, and the atoms, ions, and molecules that they are made from and influenced by, it could be argued that physical activity effects nerve cells, glial cells, and the atoms and molecules they are made from. Specific research exploring the impact of activity on cognitive function continues to be extremely limited providing limited insight of exactly how physical activity affects brain function (Hillman, Erickson, & Kramer, 2008). No simple answer or single theory fully explains the results. The best answer is likely that children are not miniature adults and with regard to cognitive performance and physical activity, factors including the individual, the task, and the environment are interacting which do not have a simple explanation but reflect a number of more elemental processes (Hughes, 2002).

Another result of this study was that following physical activity there was no decrease in performance on the cognitive tasks. This is consistent with previous research studies that have consistently supported that a physically active lifestyle can affect cognitive function at some level. These studies have been wide ranging including animal studies where promoting physical activity in rats stimulated growth of new brain cells (van Pragg, 1999) and that a nutritious diet and exercise in dogs (Milgram, et.al., 2005) improved cognitive processing. As well as human studies primarily on older adults consistently demonstrating that fit adults perform better on a variety of cognitive tasks (Van Boxtel, Paas, Houx, Adam, Teeken, & Jolles, 1997). With the reported results of previous studies (Dwyer, Sallis, Blizzard, Lazarus, & Dean, 2001; Linder, 2002) and the general conclusion drawn from this study, it is safe to say that moderate levels of acute physical activity do not have a detrimental effect on cognitive tasks.

The exact mechanism through which activity affects cognitive function remains elusive. The results of this study support the need to further examine the potential that acute physical activity has to improve cognitive processing in children. As discussed, the general trend of subject performance on the cognitive tasks following acute physical activity was improved as compared to their performance following sedentary behavior, however a specific cause and effect based on the theories reviewed and the results of this study could not be determined. The change in performance is most likely due to a complex interaction transcending components of any one theory. The physical activity intervention task elevated heart rate (cerebral blood flow, oxygen hypothesis), subjects generally enjoyed the task (mood state), and arousal levels (Inverted U) should have been higher than the sedentary task with potential to impact brain activity (activation theory). It is a complex problem to examine, but with the ever increasing amount of information processing that is required in schools using computers, the internet, as well as traditional pedagogical methods, factors affecting students ability to process information merits further study.

As a preliminary study, the practical application from the results of this study for current educational settings is limited. The tasks used within the study did require varying levels of attentional demands from the subjects and the results do permit some basic generalizations. The definition of attention is the ability to ignore irrelevant information while concentrating on relevant information. In a school setting the ability to attend to what one person is saying (teacher) while ignoring concurrent distractions (other students, noises in the hallway, etc.) should not be underestimated. The results from the cognitive tasks indicate that generally, attention improved following physical activity and that physical activity did not elicit deleterious effect on cognitive performance. Analysis of the experimental hypothesis for this study were mixed. This study hypothesized that there would be no significant difference on subject scores on the simple reaction time task when scores following physical activity and following sedentary behavior were analyzed. Analysis of the results however led to a rejection of the null in favor of the alternative hypothesis that following acute physical activity subjects will have improved simple reaction time scores as subjects had significantly higher scores for both reaction time and movement time following acute physical activity. It was further hypothesized that following acute physical activity subjects would have improved performance for choice reaction time, probed memory, dual task, vigilance, and the Tower of Hanoi by performing each task better than their scores following sedentary behavior. As can be seen in Table 10, subject performance was higher across the board following physical activity for probed memory, dual task vigilance, and the Tower of Hanoi. Also with the exception of probed memory significance was achieved for one or more of the components of the remaining tasks resulting in acceptance of the null hypothesis for these items. The complicated analysis results when examining choice reactions time as subjects performance was improved significantly following physical activity for the choice reaction time (accept null hypothesis) and choice movement time (accept null hypothesis), but for the percentage correct on this task subjects improved significantly following sedentary behavior (reject null hypothesis). In sum of the fifteen components analyzed, fourteen of them demonstrated improvement following physical activity and these results indicate that generally, attention improved following physical activity and that physical activity did not elicit deleterious effect on cognitive performance.

4.2.1 Delimitations

Through the course of this study, several limitations were identified. The initial observation is that the cognitive tests often required in excess of 30 minutes to complete. It was apparent that repetition of computer tasks became monotonous for some subjects, particularly when completing the computer task following sedentary behavior. This could have affected performance on the tasks.

Improvements could be made with regard to data collection as well. Examination of the tasks revealed that simple reaction time functioned well, however as discussed the choice reaction time task could be improved primarily by examining the percent correct component. The probed memory task as discussed needs to be reevaluated to increase sensitivity. The dual task functioned well, however a more sensitive dual task tracking measurement is needed to record subjects ability to stay within a bandwidth of the target (like an archery target) as opposed to the either on or off the target used in the current study. The Tower of Hanoi task used two dependent variables (moves taken and total time). Throughout the course of the study it was identified that collecting data with regard to false moves would have been invaluable. The calculation for moves only included correct moves. If a false (invalid) move was made, the disc was returned to the previous position for the subject to attempt again, but this false move was not counted. These improvements in data collection would likely result in longer task administration and a need to eliminate one or more tasks to complete the assessments in a comparable amount of time.

Although the previously discussed moderator model is normally used with older adults, the impact of early life physical activity and current fitness level was not controlled for in the study. The design did not incorporate data concerning current or previous levels of physical activity and what effect historical activity patterns could have on cognitive health and function. Previous research (Sibley & Etnier, 2003) findings suggest that physical activity benefits are possible across the lifespan including childhood. It is thus plausible that subjects in the study who maintained adequate levels of fitness throughout their life could have reduced age related declines in attentional resources and improved performance on cognitive assessments (Tomporowski & Ellis, 1986).

The current study controlled nutritional factors during the data collection process by completing all data collection during the morning, prior to students lunch period. Proper nutrition can play a major role in students' general health and well-being. Type and quality of nutritional intake (time, amount, etc.) for each child could not be controlled.

It is also important to note that this study is preliminary in nature as no other studies were identified which examined the effects of acute physical activity on cognitive tasks as used in the current study.

4.2.2 Recommendations for future research

The current study demonstrated that significant improvements in performance can occur following physical activity for components of five tasks used (simple RT, choice RT, dual task, vigilance, Tower of Hanoi), and although not significant, a positive trend for the remaining activity (probed memory). In the context of the current study it can be safely stated that physical activity had a beneficial effect on cognitive processing. This is in agreement with the literature that found physical activity, although not always significant, did consistently improve performance on a variety of cognitive tasks. The question for future research is how to better define the specific process involved.

Another recommendation would be to expand the repeated measures in the design by retaining the sedentary behavior, and expanding the following physical activity with higher and lower intensities of physical activity.

Further examination also needs to be completed on how physical activity affects mood state. The subjects in the current study verbally reported enjoyment with the physical activity level, however no quantitative data was collected to compare mood states. The potential for acute physical activity to affect mood state has support in the literature (Berger, 1996; Raglin, 1997) and subsequently might affect arousal level and perceptual ability. This has interesting implications with regard to attention and arousal and raises familiar questions. Specifically what is the optimal level of physical activity to positively affect cognitive performance? The results of the current study are consistent with previous work (Tomporowski, 2003) that found an acute bout of physical activity can improve cognitive function, but that much more research needs to completed with regard to the psychological effects of physical activity specifically in children. Specific prescriptions for the exact type, duration, and intensity level for maximum benefit are not well defined and require more study.

In the current study a wide range of psychomotor activities were used to examine the effect of acute physical activity and these test items did provide a great deal of information. However in future studies, selecting fewer, and more detailed assessment may prove worthwhile with continued research to establish a standard for performance in children. For example with regard to the decision-making (Green & Swets, 1966) ability of children, research establishing specific academic age related criteria needs to be conducted for decision-making tasks. Established criteria for performance would allow for an improved analysis from several perspectives. Signal detection theory posits that a specific criteria or decision rule (β) is established that a subject would base decisions upon. An established criterion permit improved analysis of the correct detections (hits), and incorrect decisions (misses), and the ability to analyze mean scores following physical activity to other mean scores (d-prime) providing insight into how physical activity affects detection sensitivity and decision making ability. Collection of more detailed physiological measures would also be beneficial. Comparison of test scores following physical activity and sedentary behavior combined with information on heart rate, skin resistance, and/or pupil diameter could provide important data on the amount of effort a subject is expending.

Appendix A

EXTENSIVE LITERATURE REVIEW

If approached and asked, how are you doing in school, what would your response be (Assuming of course that you are actually in school.)? Would you state that you increased aerobic physical activity, supplied oxygen and glucose to the brain, increased your neural connections, reduced your stress level, improved your body composition, raised your self-esteem (etc.), or would you simply state that you got a B on your math test. Is there a common link between the aforementioned statements? Current research has addressed these questions and numerous other related topics, and in fact there is a common link, that common link is physical activity. Studies by Dwyer, Sallis, Blizzard, Lazarus, & Dean (2001); Linder (2002); Tremblay, Inman and Willms (2000) and others have supported the idea that students who are physically active have academic performance standards exceeding those of their sedentary peers. What is less understood is exactly how this occurs.

Legitimate concerns about children's physical health in the context of increasing incidence of obesity and other declining levels of health related fitness have been raised in the current literature (American Academy of Pediatrics, 1992). The incidence of chronic diseases in the United States is increasing; the educational system is constantly under scrutiny with theories on how to improve learning in schools, students report low self-esteem, and increased incidence of behavior related disorders. The subsequent literature review and proposed study will examine these issues and explore reported links between movement, level of physical activity, cognitive function, and psychological functioning. Throughout history philosophers, scientists and educators have reflected upon the relationship between the mind and the body, but not long ago they were still considered separate entities. The past fifty years however have brought about dramatic discoveries and changes in the way we should think about this mind body connection and current evidence supports that physical activity in fact enhances early brain development and maintains cognitive function (Jable, 1998).

Preparing the foundation on which this study will be built requires the examination of cognitive function as related to physical activity and fitness from multiple perspectives that initially may appear unrelated. During this process relevant terms will be defined and related literature will be discussed. A significant portion of this paper will deal with the effects of physical activity on the human condition (both physiological and psychological), from this base; the study will evaluate the effects of physical activity upon cognitive function. The review will begin with the currently existing common denominator between learning and physical activity for children in the form of health and physical education programs. Over the past twenty years a significant amount of research has addressed how physical activity affects the human body and from this wealth of research, numerous factors will be reviewed and shown to have bearing on academic achievement and cognitive function. Finally issues concerning how physical fitness/activity is assessed, defined, and prescribed along with the challenges of studying a pediatric population as it relates to this proposed study will be examined.

This review will justify an evident need for further research examining the relationship between physical activity and cognitive function in children (the mind body connection). The proposed study will use children (11-15 years-of-age) in a cross experimental design to explore the effects of active and sedentary behavior upon short-term cognitive function. Variables to be examined include physical fitness level, sedentary behavior, and physical activity as compared with short term cognitive processing.

A.1 PHYSICAL ACTIVITY, EXERCISE, AND FITNESS

Physical activity, exercise, and physical fitness are three basic concepts identified through this literature review. Physical activity has been defined as the skeletal muscles of the body producing movement, which results in the expenditure of energy above the resting level (CDC, 1997; Malina, R.M, 1996). Exercise, on the other hand, is defined as a subset of physical activity that is planned, structured, repetitive, and completed in an effort to maintain or increase the fitness level (CDC, 1997). Both physical activity and structured exercise programs have been shown to improve fitness levels (Rowland & Freedson, 1994). Much of the existing pediatric research data on physical activity, exercise, and fitness levels had its inception in physical education settings. This may be the result of recognition that physical education is the best venue through which a majority of children have the potential to receive physical activity and instruction to promote lifetime physical activity and fitness. Furthermore, physical education may be among the most effective methods to reduce the public health burden of chronic disease (Journal of School Health, 1997). It may seem justified, therefore, to further examine the role and effects of physical education in our schools. Interestingly, however the positive effects of an active lifestyle on the components of health related fitness and chronic disease prevention might not be the most significant issue relating to the current status of physical education as a discipline. As the review of literature will demonstrate physical activity also has an effect on cognitive processing, but the questions to be answered include whether or not the effects have a measurable beneficial impact on school aged children.

A.2 THE CURRENT STATUS OF PHYSICAL EDUCATION

Academic accountability is a current theme in the United States and a great deal of time and money has been recently spent developing methods to improve the academic achievement of children. Politicians, administrators and educators have developed outcomes, standards and other curriculum modifications in an effort to ensure a quality education. This, combined with increased technological expenses, has led many schools to view the minor or special subjects as expendable (Goodwin, 1997). Schools are forced to make difficult decisions concerning curriculum, finances, and scheduling in an effort to achieve the best possible academic outcome. One of the programs that has suffered through such cut backs has been health and physical education (Francis, 1999; Public Health Service, 1995; Lavin, 1993; Malina, R.M, 1996). The standard argument is that an increase of physical education programs in schools would damage academic progress (Shephard, 1997). With high stakes academic achievement tests and federal No Child Left Behind legislation, many schools ponder if it would be beneficial to shift resources to the tested disciplines. To save money, according to this argument, schools should concentrate educational resources by cutting back or eliminating ancillary programs. Elimination of ancillary programs such as physical education would allow for more time to be spent in the core academic subjects. Wilkins, Graham, Parker, Westfall, Fraser, & Tembo (2003) examined this premise in a study of elementary schools in Virginia. Although this study had a number of methodological concerns, the authors concluded that for the years examined in their study that reducing instruction for the arts and physical education did not yield anticipated benefits in the 'core' standardized test content areas. Many educators and administrators currently see physical education as no more than a prep period for other instructors (Smith & Cestaro, 1996). This premise is foolhardy and premature. An objective examination of the literature, demonstrates that the study of physical activity, its effects on the human body, and impact on education is actually still in its infancy. Only since the 1970's have organizations seriously begun to issue exercise guidelines, and it was not until the 1990's that organizations such as the American College of Sports Medicine, American Heart Association, the Centers for Disease Control and Prevention (CDC), the Presidents Council of Physical Fitness and Sports, and the National Institutes of Health have firmly recommended that moderate intensity physical activity offers benefits to health and wellness (The U.S. Department of Health & Human Services, 1996; Rowland & Freedson, 1994). Combinations of these fact based recommendations and recognition that healthy children learn better and that no level of curricular intervention can replace and individual's health (Symons, Cinelli, James, & Groff, 1997), lead to an important conclusion. Health, physical activity, fitness, and cognitive processing are inextricably linked and an increase in the overall health status of a learner has the potential for a positive impact on overall academic achievement (Devaney, Schochet, Thornton, Fasciano, & Gavin, 1993). Other authors (Tremblay, Inman, & Willms, 2000) have even suggested that an increase in physical activity could help by raising self-esteem, which could positively affect a student's academic performance. So while many schools are cutting back on physical activity and physical education, organizations such as the American Academy of Pediatrics (2000) are advocating an increase in physical activity during the school day. In fact, the school setting provides a unique opportunity to offer programs for increased physical activity. Although, as will be discussed shortly, the effects of physical activity on physiological function in children are somewhat inconclusive, it is important to note successful interventions for obesity and hypertension have occurred in the school environment (Centers for Disease Control & Prevention, 1997; Bar-Or, 1994).

A.3 PHYSIOLOGICAL BENEFITS OF PHYSICAL ACTIVITY AND EXERCISE

The positive benefits of physical activity on respiratory, musculoskeletal, cardiovascular, and the endocrine system have been well documented (U.S. Department of Health & Human Services, 1996; CDC, 1997). It is well documented that sedentary lifestyle is linked to increased risk for a variety of chronic diseases and other problems, including obesity, diabetes, hypertension, and coronary artery disease in adults (American Academy of Pediatrics, 1992). Many of the chronic diseases attributed to a sedentary lifestyle in adults originate in childhood (American Academy of Pediatrics, 1992). The benefits of a physically active lifestyle, which are well documented in adults, have not been supported as thoroughly in the literature for children (Pate, R.R., Dowda, M. & Ross, J.G., 1990). Although not as extensive, the pediatric research indicates that some of the benefits that adults enjoy from physical activity may be realized during adolescence and childhood (Centers for Disease Control, 1997; US Department of Health & Human Services, 1996). In cross-sectional studies, increased physical activity has been associated with lower levels of body fat, decreased alcohol and tobacco use, and an increase in bone mineral density, as well as positive consequences for aerobic endurance, and muscular strength; with the potential to positively affect risk factors for cardiovascular disease, obesity, hypertension, diabetes, stroke, cancer, osteoporosis, and depression among others (CDC, 1997; Frances, 1999; Bar-Or, 1994). Children who are physically active also report better blood lipid profiles and lower blood pressures than their sedentary peers (Suter & Hawes, 1993). Unfortunately there are not enough longitudinal studies that track children through adulthood to evaluate the long-term effects of a physically active lifestyle (Bar-Or, 1995). In short there is no guarantee that a physically fit child will become a physically fit adult. However it appears that the short term benefits of physical activity seen in adults can be realized during childhood, with the potential to, if maintained, reduce the risk for health problems related to a sedentary lifestyle (American Academy of Pediatrics, 2000). In short, the importance of a healthy body, and the numerous benefits of a physically active lifestyle are well documented in children and adults. With the physical component established, the next question is whether the healthy body is linked to a healthy mind.

A.4 PSYCHOLOGICAL BENEFITS OF ACTIVITY/FITNESS

Present research has demonstrated that physical activity can have a positive effect on psychological variables (U.S. Department of Health & Human services, 1996). Evidence suggests that physical activity has psychological benefits in four broad areas: higher quality of life, enhanced mood, stress reduction, and improved self-concept (Berger, 1996). Studies on adults have demonstrated significant positive results in areas including depression (U.S. Department of Health & Human services, 1996), self-esteem, self-concept, reduced anxiety and reduced stress (CDC, 1997). The positive effects of physical activity on psychological function do not appear to be limited to adults, as was noted by Calfas and Taylor (1994) in a review of 20 studies with subjects ranging from age 11-21. The general conclusion from their meta-analysis was that physical activity provides moderate psychological benefits for youth. The effectiveness of exercise on stamina, mood, and self-esteem has even led to it being considered as a counseling intervention, as was discussed by Chung and Baird (1999). Their review of literature concerning the psychological effects of physical exercise generally supported a positive correlation between physical exercise and mental health variables (depression, anxiety, and self-esteem) and even concluded by proposing guidelines and recommendations for counselors to consider using physical exercise as an added counseling tool.

The studies reviewed used the terms activity, exercise, and fitness in exploring how the environment can affect psychological function. These terms were previously defined and as they are not synonymous, an obvious question is what, or how much does an individual need to do to reap positive psychological benefits. The first step may be to find an activity that is enjoyable. As previously discussed physiological benefits (caloric expenditure, strength, cardiovascular conditioning, etc.) can be gained from activity, but participating in an activity that is personally enjoyable has an implication on mood state (Berger, 1996). When specifically addressing mood enhancing physical activity, Berger (1996) cites three characteristics that seem to affect the level of mood enhancement: rhythmical abdominal breathing, absence of competition, and closed/predictable activity. Berger (1996) notes that training guidelines that seem to correlate with positive mood alteration contraindicate the guidelines normally recommended for fitness training. The highest levels of positive mood alteration appear to occur with moderate levels of activity (Thayer, Newman, & McClain, 1994), which serves to raise energetic arousal while still appealing to those who want a less intensive enjoyable experience. In order to generate the desired benefit the length of the activity has been cited (Pierce, Madden, Siegel, & Blumenthal, 1993) as needing to be in the 20 to 40 minute range.

A.4.1 Self-Perception/Social Skills

Feeling good about one's self and working well with others is an important step in being successful in any endeavor. In a pilot study Colchico, Zybert, and Basch (2000), found that a 12-week physical activity program seemed to enhance physical, psychological, emotional, and social health of 30 urban African American and Hispanic adolescent girls. The results of the study demonstrated significant improvements in muscular strength, muscular endurance, flexibility, cardiovascular endurance and body composition with an apparent increase in cognitive self-perception. Boyd and Hrycaiko (1997) also used adolescent and pre-adolescent females to examine the effect of physical activity on self-esteem. The pretest posttest design of 181 subjects ranging in age from 9 to 16, who participated in a six week exercise program, was particularly effective in improving self-esteem and self-concept in the preadolescent group, especially in subjects who started with a lower score. Discussion of why statistically significant improvements were only achieved for the younger age group included the high socioeconomic status of the subjects and a school that was already sensitive to the issues of self-esteem and self-concept. This was reflected in the high scores of subjects in the pretest that in turn limited room for improvement on the assessment tool (Self Description Questionnaire). It was also thought that the intervention was not challenging enough for the older group.

Enhancement of social skills is another area where physical activity has been theorized to have a positive impact. Physical activity in the form of cooperative games, team sports, and individual sports which offer unique opportunities to learn cooperation, teamwork, and the ability to follow rules that is often not available to the same degree in the regular classroom. Whether a change in behavior here constitutes a change in cognitive function or a simply development of coping strategies, bonding, or some other effect, it does deserve mention as part of this research study if for no other than tangential reasons as educational gains are more likely to be successful in a positive learning environment. Bluechardt and Shephard (1995) used 45 learning disabled students (approximately 9-years-of-age) to examine the effect of physical activity on social skills. The treatment group received two 90-minute exercise sessions, with a strong social skills component, per week over a ten-week period while the control group received an equal amount of individualized attention in the classroom. Both groups showed improvement over the course of the study. The trend indicated in the data seemed to indicate that physical activity could have made an impact in several areas but it could not be statistically supported. Other possibilities include a halo effect, Hawthorne response, or simply a reaction to individualized attention. The conclusion in this article fails to address one important point, however. The physical activity program with embedded social skills did improve self-ratings of competence and subjects did improve in motor proficiency. The teachers also rated the students higher in social behavior. So, although the activity group did not significantly perform any better than the classroom intervention, it did not have a negative impact. The difference being, that the physical activity group had an opportunity for positive effects on the subjects' health related fitness that the classroom intervention did not offer, and that the physical activity group could potentially reap other benefits, such as a reduction in anxiety and stress.

A.4.2 Anxiety/Stress

Anxiety has been defined in an educational setting as feelings of tension that can interfere with the ability perform well in certain situations, and can also manifest itself in physical symptoms including tension, an inability to communicate, stomachaches, and headaches, which in turn can cause a domino effect resulting in poor grades, lowered self-esteem, and other stress related physical ailments (Austin & Partridge, 1995). Physical activity can aid in stress reduction by reducing tension, anger, and depression through altering the mood state (Berger, 1996). Calfas and Taylor (1994) reviewed 20 studies that examined the relationship between stress and physical activity in youth ranging from 11 to 21-years-of-age. Of the 20 studies reviewed, 11 studies addressed anxiety and stress variables with 8 finding physical activity to have had an effect upon reducing anxiety and stress. Anshel (1996) supports this finding with his study of 60 unfit male undergraduate students. The study used aerobic exercise, placebo, and progressive relaxation as treatments. Students who participated in the aerobic exercise group responded to acute stress more successfully. The conclusions supported the use of chronic aerobic exercise to assist in coping with acute stress. Although many methods may serve as effective coping strategies, it would seem that physical activity offers the greatest potential. Not only does it appear as effective as methods such as progressive relaxation, but you gain physiological benefits as well that could assist in other areas such as self-esteem.

Many factors could affect how physical activity affects anxiety and depression, in a review of over 35 studies, Dishman (1995) found that studies hypothesized many reasons for how exercise could reduce anxiety and depression. These theories include self-perception of control, mastery, self-efficacy, distraction, and social interactions. He also cites possible biological mechanisms that were reported including altered autonomic, endocrine, and brain monoamine and neuropeptide responses to stress as well as increased body temperature. Dishman (1995) discusses what is becoming a common mantra throughout this literature review, that although results would seem to lead researcher to examine dose and response of physical activity and its effect on various functions including stress, anxiety and depression, research over the past decade has made few inroads in this area.

A.4.3 Self-Esteem/Self Efficacy

A number of studies have concluded that a relationship exists between physical activity and self-esteem. Tremblay, Inman, and Willms (2000) concluded in a study of 6th grade students that, even after controlling for socioeconomic status, physical activity levels had a significant impact on self-esteem. Calfas and Taylor (1994) reviewed 10 studies that examined how physical activity could affect self-efficacy, self-concept, or self-esteem. In their review, 9 of the 10 studies found that physical activity did affect self-esteem. The type of activity that seemed to produce the best self-esteem scores in most studies was aerobic in nature, which is the same conclusion, reached in a previous study by Labbe and Welsh (1993). In their study, 124 fourth and fifth grade children participated in a running program 3 times per week for an 8-week period. The results support research relating to the benefits of physical activity in several respects. Consistent with previous research, children in the running group had improved resting pulse rate, improved self-efficacy scores, and in a follow up six months later they maintained a higher health locus of control. This occurred even though the physical improvements had diminished without continued training. The control group in this study was not sedentary. They also had a physical education class 3-times per week, with the difference being that they participated in normal activities and not running for aerobic conditioning. It would have been interesting to see how the results would have compared with a sedentary control group.

How individuals feel about themselves has started to move from a general response and into more specific domains as research in this field progresses. Previous research examining the relationship of physical fitness and self-esteem did not produce significant results as expected. One possible explanation for this is that the wrong assessment instrument was used. A study by Marsh and Redmayne (1994) supports this possibility. Just as physical fitness has been subdivided into components, (muscular strength, muscular endurance, body composition, etc.) they propose that self-concept has similar components for categorization. Examples of physical self-concepts would include a general physical ability as well as appearance, flexibility, strength, endurance, and balance. Other self-concept components (physical, academic, and social) would be broken into subcategories as well sub-components. Their study did show support for this using a hierarchical, multidimensional physical self-concept model. The relevance of this line of thought to the current research study has to deal with how physical activity/fitness might affect academic self-concept. So although Marsh and Redmayne (1994) discussed the idea of a broad global construct to measure self-concept as being passé, unfortunately at this point in time measuring specific components of self-concept would be too challenging. One instrument has not been proven to differentiate between the various self-concept categories. For this reason, great objectivity needs to be used in examining what was assessed and the type of instrument utilized in past, current, and future research dealing with self-concept.

A.5 ACTIVITY, EXERCISE AND COGNITIVE FUNCTION

The basic premise of this research project is to examine the effects of physical activity on short term cognitive processing in children. It would be illogical to complete such a study if the premise is not at least theoretically possible. The problem here is that although research has made great strides, it is at this point still not possible to look inside the brain, identify specific change that has occurred, and state with absolute certainty that learning has resulted due to treatment. But, as previous components of this literature review have demonstrated, physical activity has been documented (to varying degrees depending on the study) to affect physiological and psychological processes. In short, it is plausible that activity levels could have some impact on cognitive processing. It is also common sense that being physically active is not going to turn a child into a gifted musician or athlete. Although the human race always seems to want a simple answer, it is most likely multiple factors (innate ability, motivation, practice, etc.) that play a role (Larson & Zaichkowky, 1995) in the fruition of a child's potential. So, if physical activity has the potential to impact cognitive processing but is not a panacea for intellectual growth, then research will need to define what effect it does have. When comparing fitness and cognitive function, studies do not consistently report a robust relationship, however the incidence and level of improvement is too high to be occurring by chance alone (Spirduso & Asplund, 1995). To understand the link between cognitive function and physical activity it would be beneficial to gain more of an interdisciplinary view on the matter.

Understanding how fitness, movement, or exercise affects cognitive function is a topic not limited to the field of motor behavior. It can include disciplines as far ranging as archeology and encompass times before prehistoric man. The idea that activity and movement could be related to cognitive function is not a new one. In fact, activity has been correlated with cognitive function in ways many people would never have imagined. One researcher has proposed that the very reason that humans are able to write and speak in sentences may be linked to evolution and our ability to perform ballistic movements. Calvin (1993) stated such a premise with his unitary hypothesis, where he proposed that for pre-planned movement, language, throwing, and novel manipulations; the brain has a common neural circuitry. He theorizes that the circuitry for performing ballistic movements, such as throwing, may be used to sequence other muscles, as well. One such observation includes how young children screw up their faces and tongues when learning to write. Although his evolutionary perspective is unique, he does make an interesting argument concerning evolution of man and how the development of tools and language seem to parallel each other. His argument is that man's improvement in cognitive processing is directly related to his ability to perform ballistic movements. A simplified assessment of this article concludes that the language of man developed out of a need to eat. As man evolved and learned to perform pre-planned ballistic movements (i.e. throw things at animals) to obtain food in order to survive, this same pre-planning allowed for the development of language and other cognitive skills. Although intriguing, this line of discussion is predominately theoretical in nature, as it would have happened millions of years ago. Fortunately, the link between cognitive function and physical activity is not limited to anthropological studies.

Bjorklund and Brown (1998) hypothesized that physical play can provide a break from intellectual tasks and that rough and tumble play may assist in developing social cognition. Their article posits that play and other forms of physical activity may facilitate school learning and that educators need to realize that cognition and physical activity do not inhabit mutually exclusive domains. The authors reinforce a need to explore interdisciplinary methods in an effort to understand development consistent with the developmental systems perspective. Contemporary motor behavioralists have a similar premise called embodiment (Thelen, Schoner, Scheier, & Smith, 2001). The theory of embodiment is that cognition, emotion, and language is inextricably linked to perceptual and motor abilities, an idea which sixty years ago would not have been considered.

As recently as the 1940's the dominant theories such as Gesell's Maturation Theory supported a genetic view of development that required little, or no stimulation from the external environment. This thinking was challenged in the 1960's when researchers were able to use tracer chemicals to show that glial cells or neurons could be regenerated in adult rats (Das Altman, 1965). The 1980's brought about further change as researchers were able to demonstrate that the environment affects brain weight and neural connections in rats (Ronzenzweig, 1980) indicating a possible influence on their ability to learn. More specifics on the potential for environmental impact on neural development was discovered in the 1990's when the type of environment was shown to affect neural development. For example van Pragg (1999) demonstrated that rats using a running wheel or swimming pool grew brain cells at a significantly higher rate than rats who completed a simple learning task. Other animal studies have continued to reinforce the positive affects of a healthy lifestyle including physical activity. Milgram, et.al. (2005) completed research supported by the National Institute on Aging which examined the cognitive function of beagles who were fed a diet fortified with fruits, vegetables, vitamins, and were provided with a variety of cognitive stimulation and also exercised at least twice a week. Beagles in the treatment receiving the nutrition and physical activity intervention demonstrated improved cognitive processing. Canine studies could have important implications for humans as both species engage in complex cognitive strategies and have complicated brain structures. So although the research has demonstrated the positive affects that physical activity can have on primates, rats, and beagles, the current literature review is concerned with humans. In the late 1990's, researchers discovered that the drug bromodeoxyaridine, which was used to track brain cell division in rats, was also used in cancer patients. When autopsies were completed on throat cancer patients (Eriksson, 1998) who had received bromodeoxyaridine it was demonstrated that, in fact, new cells were being generated in the hippocampus region of the human adult brain. Since three quarters of the human brain develops outside the womb, it is obviously important to understand how the environment affects the unfinished brain that nature has provided (Shore, 1997). Studies examining the developing brain in children are limited, however a significant number of studies have been completed on adults.

A.5.1 Adult Studies

In adult populations, physical activity has been shown to relate to cognitive function (Emery, 1995; Hassm'n & Koivula, 1975). Active fit adults, when compared to sedentary low fit groups, have demonstrated faster simple and choice reaction times. This would indicate that physically fit adults are faster at making decisions (Rowland, 1990; Chodko-Zojko 1991). Dipietro, Seeman, Merrill, and Berkman (1996) came to this conclusion in a study of 70-79 year old subjects where the effect of physical activity on the decline of cognitive function was explored. Previous studies have also indicated that physically fit or physically active older adults have higher cognitive performance scores than their less active peers (Hultsch, Hammer, & Small, 1993; Chodzko-Zajko & Moore, 1994). They concluded that cognitive benefits might be received from physical activity.

Van Boxtel, Paas, Houx, Adam, Teeken, & Jolles (1997) completed a study using subjects ranging in age from 24-to-76. Multiple cognitive assessments (intelligence, verbal memory, & cognitive speed) were compared with their aerobic fitness level as determined using a submaximal bicycle ergometer test. Their conclusions indicated that fitness level had a greater impact on cognitive processes requiring more attentional resources. The study also supported the moderator model, which hypothesizes that individuals who maintain an adequate level of fitness throughout life can slow the normal age related decline in attentional resources. The general indication is that chronic physical activity and resulting physical fitness in adults helps them to perform at a higher level on cognitive assessments than their less fit peers (Tomporowski & Ellis, 1986). The affect of fitness level on cognitive processing for an acute bout of physical activity is less clear however.

There is support that an acute bout of physical activity can positively affect mood states (Raglin, 1997). This is an important consideration for a number of reasons. The normal assessment method used to measure chronic physical activity and a resulting classification of fitness has been maximum oxygen uptake, often no consideration is given to other components of health related fitness, and rarely have studies made an effort to relate the physical demands of the cognitive assessment in the study to the fitness intervention that was utilized. Whether or not such a point is relevant would depend on the proposed theory behind why cognitive processing is improving. For example if the theory is that chronic physical activity improves fitness level and cognitive processing through improved neural networking, then it would appear logical to use a cognitive assessment tool for crystallized intelligence. If it is desirable to measure fluid intelligence with the theory being that increased arousal (inverted U hypothesis) is the catalyst for improved cognitive processing then physical activity needs to be assessed differently. Chronic physical activity in this case could raise an individual’s basal metabolic rate and have a long-term effect on arousal level, or an acute bout of physical activity could raise arousal levels thus impacting fluid intelligence during or shortly following the activity. In the latter case the type of physical activity is not as important as the need to raise arousal levels. In fact fitness level in this situation may not be important at all as an aroused individual should perform better (Than when in their non aroused state.) regardless of fitness level. The optimal level for arousal in adults appears to be achieved using moderate to vigorous intensities of 40 to 80 percent of maximum oxygen uptake performed for at least 20 minutes (Brisswalter, Collardeau, & Rene, 2002). Further support for an acute bout of physical activity affecting cognitive processing in adults is reinforced in a review completed by Tomporowski (2003). The review demonstrates that studies, which implemented a moderate intensity aerobic exercise, report improvement in cognitive performance during and following the activity.

As the aforementioned articles demonstrate, the literature has (and continues to) consistently documented the consistent positive affect of fitness and a physically active lifestyle on older populations (Weuve, Kang, Manson, Breteler, Ware, & Grodstein, 2004; Hirsch & Hirsch, 1998; Barnes, Yaffe, & Satariano, 2003). Spirduso and Asplund (1995) summarize the adult research quite succinctly when they admit that although many studies do not demonstrate a high correlation between fitness and specific cognitive functions, a relationship consistently occurs at too high a level to be happening by chance. The fact that some studies demonstrate significant results when others do not may be simply due to the wide variety of fitness and cognitive assessment methods utilized. Although the adult research is quite promising, children are not miniature adults, and it is required to examine whether the results of the above studies can be generalized to younger populations or are age specific.

A.5.2 Child Studies

Research examining the effect of physical activity on cognitive function in children is not as extensive as the adult research. There have been a number of studies completed on young adults; for example, Anshel (1996) studied the emotional, behavioral, and somatic responses to acute stress. In this investigation, the effect of chronic aerobic exercise and progressive relaxation on motor performance following acute stress was examined. The 60 unfit male undergraduate students who were in an aerobic exercise group (cycle ergometer) improved significantly in cardiovascular fitness over the course of the ten-week study. The aerobic group also improved markedly on a pursuit rotor apparatus motor task over the placebo (sedentary group discussion) and performed better than the relaxation and control (no intervention) groups. The above-mentioned study is typical in that although generalization of results of studies of this nature seems plausible, there have been relatively few pediatric studies specifically addressing the mind body connection. The limited number of studies is further confounded by difficulty in comparing methodologies as many researchers do not adequately define or delineate the parameters of the mind body connection. For example, in both adult and youth studies few researchers categorize the type of cognitive process being assessed (i.e. crystallized intelligence, fluid intelligence) and whether specific types of physical activity or fitness level is more likely to affect certain types of intelligence (Spirduso & Asplund, 1995). Care must also be used when examining adult studies and attempting to replicate them in pediatric populations, as children are not miniature adults, with many secular and developmental changes that need to be considered.

Current theory and science do support the hypothesis that an increase in physical activity can affect cognitive performance in children. Research has shown that when schools offer quality physical activity programs that there can be improvement in academic achievement. Purported improvements include reduced disruptive behavior, increased concentration, and improved scores in reading, writing, and mathematics. These results have been touted even when the increase in physical activity resulted in reduced time for other academic subjects (Symons, 1997). Long term (chronic physical activity), a higher level of health-related fitness, and even short term a single (acute) bout of physical activity, could increase cortical oxygen availability (oxygen hypothesis) and impact cognitive function. Numerous methodologies have been implemented to examine these variables. In 2001, Bunce reviewed research that investigated cortical oxygen availability and cognitive function. A reduction in cerebral oxygen (high altitude, hypoxia) was found to reduce scores on cognitive performance tasks, including reaction time and movement time (Kramer, Coyne, & Strayer, 1993; Fowler, Taylor, & Porlier, 1987), while administration of oxygen positively affected subjects’ short term memory performance in tasks, such as word recall, in subjects as young as 18-years-of-age (Moss & Scholey, 1996). Another study used a survey to establish physical activity levels, (Tremblay, Inman, & Willms, 2000) and found a weak relationship with academic achievement in mathematics and reading in 12 year-olds. When reviewing studies implementing such diverse methods, commonalities must be found to effectively examine the results. In reviewing the literature of cognitive responses to physical activity, two common categorical methodologies appear to be consistent. One method examines the effects of chronic physical activity programs (several weeks of a physical activity intervention) while the second examines the effect of acute (an individual activity session) physical activity (Tomporowski, 2003). Chronic activity programs of sufficient intensity performed over a period of time should result in improved fitness scores for the intervention method employed. Acute activity sessions affect a temporary change in physiological function. Obviously when exploring the effects of activity on cognitive function, chronic programs attribute cognitive changes to the cumulative effect of activity (i.e. improved cardio respiratory fitness), while acute programs attribute changes to the immediate (i.e. glucose utilization) effects of activity. Although the two are not mutually exclusive (A series of acute bouts of activity over an extended period becomes chronic.), few studies have specifically addressed the effects of acute bouts of physical activity on children's cognitive performance (Tomporowski, 1993). This is surprising considering the previously addressed studies citing the positive effects of activity on adult cognitive processing and that nearly every child or adult study has recommended further clarification and the need for further research.

Classic studies from Canada, Australia, and France supported the premise that cognition and physical activity have a connection. The Trois Rivieres study in Quebec, Canada was a 6-year cross sectional longitudinal study of students in grades 2 through 6. One class of 546 students served as the treatment group while the preceding and succeeding grades served as controls. The treatment consisted of a 14% reduction in academic time, which allowed for an additional 1 hour per day of physical education. In four of the six years the treatment group outperformed the controls significantly in grades 2, 3, 5, and 6, even though the control group started with better academic scores (Shephard et al., 1984).

Schools in Hong Kong were banded by prestige groups (high, medium, and low) with students from the schools completing a survey (Lindner, 2002) inquiring about the type, frequency, and duration of up to five activities during the 1998-1999 school year. The survey also asked students to rank their academic potential and academic performance for the same time period. Academic assessment values were received for subjects in the study in the form of grades from participating schools. Results of the study demonstrated evidence for a positive link between activity participation and academic performance however the study did not make definitive conclusions due to affordances related to school banding. The nature of the evaluation methods utilized in the study were not able to conclude if there was a causal relationship between physical activity and academic performance. Studies of this nature do not have much of a correlation to the current research proposal due to the subjective nature of assessment used for both academic achievement and physical activity but is typical of much of the literature on physical activity and cognitive function.

In the Australian School Health, Academic Performance and Exercise study, researchers increased physical activity time for the treatment groups from 30 minutes 3 days a week to 75 minutes a day, and emphasized either cardiovascular or skill development. To accommodate this increase in physical education, time spent in other academic disciplines was significantly reduced. Results indicated that students with increased physical education time, especially activity with an emphasis on fitness, did not fall behind their peers in arithmetic and reading and in fact, demonstrated significant improvements in classroom behavior. A follow up study suggested that the treatment group also maintained a higher level of classroom behavior and improved scores over the control group in arithmetic and reading (Dwyer, Coonan, Worsley, & Leitch, 1979; Dwyer, Coonan, Leitch, Hetzel, & Baghurst, 1983). Another Australian study used a questionnaire analyzing 7-15 year old students physical activity and sport performance during the previous week. The activity questionnaire was compared to student academic performance and fitness test scores. The results concluded that academic ratings were consistently correlated with physical activity ratings from the questionnaire and fitness test scores (standing long jump, 50 meter sprint, push ups, sit ups, 1.6 kilometer run) in both genders for the ages studied (Dwyer, Sallis, Blizzard, Lazarus & Dean, 2001). Unfortunately the study did not implement any direct measure of cognitive function rather it depended on a five point rating scale (excellent, above average, average, below average, poor) to assess the scholastic ability of students.

A French study completed in 1950 also demonstrated that an increase in physical activity and a decrease in instructional time do not lead to poorer academic performance. This study is difficult to compare to the typical American school day because of the structure and type of interventions. In the study, academic instruction time was reduced by 26%. Students had a longer school day with a siesta, participated in physical activity every afternoon, and received vitamin supplements. These factors have also made it nearly impossible to reproduce in current academic settings. Although it is difficult to draw conclusions and generalizations from this study due to the methodology used and lack of scientific structure and rigor, teachers in the experimental school consistently reported better attendance, fewer disciplinary problems, and students who were calmer and more attentive during academic instruction (Shephard, 1997).

Several theories have been proposed to explain the mechanism through which physical activity would affect cognitive function. One thought which could explain why some studies show significant results while others do not is that the effect of activity or exercise on cognitive performance may depend upon the type of cognitive performance measured, as well as the type of physical activity and how long it is performed. The Activation Theory proposes just this. In the Activation Theory it is hypothesized that task performance is best at a certain arousal level. Physical activity is one method by which arousal can occur. The true challenge is that the target arousal area for a performance differs from person to person. Taking the Activation Theory one step further would lead us to the Inverted U Theory. The Inverted U Theory would plot duration and type of physical activity with corresponding cognitive performances. Theoretically, this would allow for comparisons to find the optimal arousal level allowing for the best cognitive performance. Craft (1983) used such a premise in her study of 7-10 year old normal and hyperactive young boys. Her study did not find any significant correlation with the Inverted U Theory, but she concluded intervening factors such as length of physical activity could have affected the outcome. In her study, physical activity consisted of pedaling a bicycle ergometer for 0, 1, 5, or 10 minutes. This length of time may not have been enough to provide the required arousal to affect performance (So, her study, may have actually supported the inverted U hypothesis, just not as she predicted.) or the cognitive assessment method used was either too difficult or too easy for children. Another similar study completed by Gabbard and Barton (1979) did find that physical activity could affect cognitive function (mathematical computations) in second graders. One of the main differences between the two studies was that Gabbard and Barton (1979) used 20, 30, 40, 50 minute sub maximal cycle ergometer exercise sessions as well as two no exertion pre and post tests. The study found significant differences between the 6 sessions with the 40 and 50-minute time frames demonstrating the best mean math scores. There was no significant difference between the pre and post mean math scores for the no exertion sessions. The research finding for this study are consistent with the literature recommending a minimum of 20 to 40 minutes of moderate activity to have a positive affect on psychological mood states. Results of this study also support the proposal that an acute bout of physical activity can have an affect on cognitive function. Gabbard and Barton (1979) concluded that the subjects might have exerted themselves enough to be relaxed rather aroused during the mathematical cognitive assessment thus improving their concentration level. A similar research design (McNaughten & Gabbard, 1993) used a 20, 30, and 40-minute moderate intensity walking with sixth grade students at three different times during the school day. Following the activity subjects were administered a 90 second mathematical computation test. Although no significant differences were found for scores during the morning (8:30 am) activity session, the afternoon sessions (11:50 am & 2:20 pm) demonstrated significant improvement in the mathematical computation scores for the 30 and 40 minute walking sessions. These studies demonstrate that an acute bout of physical activity can have an immediate affect on cognitive processing in children.

In a study with some similarities (cognitive processing measures) to the current research problem, Blomquist and Danner (1987) used 66 adults ranging in age from 18-to-48 to examine the effects of physical conditioning on information processing. The study used a pre-post test design over a 10 to 12 week period. At the conclusion of the 12 week period subjects were classified based on their improvement in predicted maximal oxygen uptake from beginning to end of the study. To measure information processing researchers used a memory search task, a name retrieval task, an intelligence test, and a memory test. The results showed subjects improved in every category, with the exception of the intelligence test. The more physically fit subjects also tended to perform better than the less fit group although this finding was not statistically significant. Results of the study may have been confounded by improvement from practice effects and the fact that only modest gains were made in fitness over the study. Starting with less fit subjects may have shown significant results. Interestingly, no comment was made about the lack of a sedentary comparison group. All of the subjects in the study were involved in physical activity/fitness programs; it could be argued that the physical activity affected their performance on the test and not their degree of fitness.

Cognitive function could be impacted by numerous factors related to physical activity. These factors, as discussed previously, can be quite numerous and may include improved cardiorespiratory fitness, improved cerebral blood flow, changes in hormonal levels, enhanced self-esteem and self concept, less depression, increased ability to concentrate, and improved behavior in the classroom setting. Scientists using animal studies have introduced another mechanism through which physical activity may impact cognitive function. Studies using rats (Isaacs, Anderson, Alcantara, Black, & Greenough, 1992) have suggested that physical activity in the form of endurance training may promote metabolic support for synaptic development. Adult rats that followed a thirty-day training period showed development of new blood vessels in their brains. Several of the studies reviewed did report improvement, but not significant changes. This also gives cause for reflection, because it is not really known whether the effect of a few milliseconds improvement in cognitive functioning will be long or short term. In a research study, milliseconds of difference on a reaction time test may be reported as statistically insignificant, but the ability to process information just a little faster over a lifetime (especially if the effects are cumulative) theoretically could make a huge practical difference.

Also previously addressed was that older individuals with a higher level of physical fitness perform better on cognitive activity tasks. Whether this is due to a higher level of fitness at one concrete point in time, or the process of lifelong physical activity, is a legitimate question. This association between early life physical activity and delayed late-life cognitive deficits has been described as the cognitive reserve hypothesis. The premise of the theory is that early life physical activity stimulates trophic factors and neuronal growth in the brain resulting in a higher brain reserve capacity. Studies have shown that individuals who have been physically active throughout their early years demonstrate higher cognitive function as they age. Dik, Deeg, Visser, and Jonker (2003) studied 1,241 subjects ranging in age from 62-85 and were asked retrospectively of their activity levels from age 15-to-25. To measure cognitive functioning the study used the Mini-Mental State Examination and information processing speed was assessed using a letter substitution task. The findings from the study found a positive correlation between regular physical activity in early life and level of information processing speed at older age for men but not women. Significant findings were not found for women in this study. Explanations for inter gender score discrepancies were offered by Cotman and Berchtold (2002), who reviewed how voluntary exercise increases levels of brain-derived neurotrophic factor stimulating neurogenisis. In their article they address how steroid hormones influence brain aging. Post-menopausal women have reduced levels of estrogen, which compromise neuronal function. While Estrogen replacement appears to slow this process, Dik, Deeg, Visser, and Jonker (2003) did not address this variable in their study and could be one possible explanation for the poor performance of their female subjects.

Recently the research has been reevaluating possible links between physical activity and academic performance. Ironically some of the most effective evidence available to support a possible correlation between physical activity and cognitive function are the standardized tests that have resulted in the elimination or reduction of physical education in many schools. In 2002 the California Department of Education released a study indicating that fit kids perform better academically. The study utilized the state mandated Fitnessgram fitness test and the Stanford Achievement Test (SAT) for students in fifth, seventh, and ninth grade. Over 900,000 students had their reading and math scores from the SAT's compared to their fitness scores. For each grade level assessed, students with a higher fitness level also demonstrated higher achievement scores. With students who met the minimum (healthy fitness zone) Fitnessgram levels in three or more of the fitness areas demonstrating the greatest gains in academic achievement. Overall females especially those of a higher fitness level performed better than males on the achievement tests.

A curriculum promoting Sports, Play, and Active Recreation for Kids (SPARK) was implemented (Sallis, McKenzie, Kolody, Lewis, Marshall, & Rosengard; 1999) to examine 1,538 students from a school district in Southern California. The two year study assessed the students during fourth, fifth, and sixth grades on variables including physical fitness, psychosocial variables, and physical activity. These items were measured suing a variety of measures including surveys, physical activity monitors, parental surveys, and fitness tests. The curricular intervention (SPARK) promoted physical activity in classes offered a minimum of 3 times per week with the average class lasting approximately 30 minutes. Using the Metropolitan Achievement Tests to measure academic achievement the study found that spending more time in physical education did not have a detrimental effect on standardized test scores for the children. The results of the statistical analysis were mixed. The methodology utilized classroom teachers who were trained in the SPARK curriculum while the control group continued to used the usual physical education program implemented by the classroom teacher, while specialists (three physical education teachers) were hired to instruct students in two of the seven schools. As mentioned increased time in physical education did not have a detrimental effect on standardized test scores and there was some significant evidence that the health related physical education program had favorable effects on academic achievement although not on the actual achievement test scores. Results of the study support the historical view that physically active children may be better learners.

Throughout history a strong mind and a strong body have been intricately linked, however the current secular trend in the United States is that young people are generally inactive, unfit, and increasingly overweight (American Heart Association, 2004). As the literature review has revealed, relatively few studies have examined the relation between the activity levels of children with their short term cognitive processing. Designing such studies for children is more challenging, due to questions about assessment methods and difficulty controlling for inherent dynamic variables such as motivation, growth, development, maturation and numerous other factors in this population. However in a society where individuals go on special diets and take supplements (Many with no empirical evidence to support their use.) in the hope that they can improve their physical and mental performance (Matheson, 2000), it would be ill advised not to further examine physical activity, which already has a proven track record for promoting positive health benefits. The documented risks associated with a sedentary lifestyle, associated increase in childhood obesity, and the increased risk for hypo kinetic disease (Freedman, Dietz, Stinivasan, & Berenson, 1999) easily support a rationale for more research on pediatric physical activity. With regard to physical activity and cognitive function, even with the variety of methodologies implemented, the review of literature has consistently demonstrated that an increase in physical activity will not have a detrimental impact on standardized test performance. No direct correlation has yet been found directly connecting physical activity to cognitive function but the incidence of positive correlations between the two variables is too high to be simple coincidence. The lack of consistent significant results could be attributed to inconsistencies in the evaluation instruments used. As previously reviewed cognitive function has been measured using surveys, grades, standardized test scores, intelligence tests, and a wide variety of psychomotor test batteries. Physical activity has been measured using surveys (by children and parents), a variety of fitness tests, curricular interventions, and self assessment. The purported mechanisms through which cognitive function can be affected by physical activity include both physiological mechanisms (structural changes, altered brain neurotransmitters, increased cerebral blood flow, altered arousal levels) as well as learning/developmental factors (Sibley & Etnier, 2003). With the latter being that the movement involved in activity is important and not necessarily the level of exertion. What is clear following a review of the literature is that the assessment methods used to compare physical activity and cognitive function should be thoroughly examined.

A.6 ASSESSMENT OF PHYSICAL ACTIVITY/FITNESS

In order to determine the potential for physical activity and/or fitness to impact cognitive function it is necessary to operationally define these terms. Fitness is normally categorized as health-related (cardiorespiratory endurance, muscular strength, muscular endurance, flexibility, and body composition [CDC, 1997]), or skill related (balance, agility, power, reaction time, speed, and coordination [CDC, 1997]). The studies examined for this literature review used a variety of both laboratory and field tests, each having inherent strengths and weaknesses including different levels of reliability and validity. Generally speaking, field tests normally have a higher number of subjects. However, it is sometimes difficult to establish how stringently test protocols were followed. Laboratory test are normally administered to a smaller group of subjects in a controlled environment. Questions about laboratory tests typically revolve around how this unfamiliar environment affects children's performance and how closely lab tests correlate to the non-laboratory setting. Just as important as the type of test to be used is the assessment method and the analysis of the results. For example, an isokinetic machine, push-ups, pull-ups or bench press could each be used as the test to measure upper body strength that could then be assessed using a variety of norm or criterion referenced standards to determine acceptable performance levels. A subject could perform similarly on a given test and yet receive significantly different scores affecting the analysis of the test. Yet, in order to develop standards, a definition of fitness needs to be developed. Rowland and Freedson (1994) define physical fitness as the ability of an individual to perform on field exercise tests. Overall, however, the literature fails to present scientific evidence that could be used to categorically select one preferred type of fitness test battery (Pate, 1991; Safrit, 1990), as each has pros and cons. In fact, although definitions have been given for physical fitness the viability of these definitions could be challenged as no universal definition of physical fitness, has been accepted. Even in the laboratory there are few valid and reliable Gold standards to measure overall fitness levels (Gallahue & Ozmun, 2002). The method of assessment chosen could have significant impact on a research study, for as was previously discussed, the type of activity (aerobic, duration, enjoyment, etc.) could affect a variety of physiological and psychological factors. This has also led to difficulties in comparing studies using fitness as a variable due to invalid assessment measures, the variety of assessment methods implemented, and the variations in the age groups studied (Spirduso & Asplund, 1995).

A.6.1 Assessment Methods

Whether examining fitness or activity levels, the question that must be answered is, how well did the subject do? The answer to this question may depend on whether data was analyzed using norm or criterion referenced standards. Norms take the scores from a group of subjects and use these scores as a reference point by which other subjects can be compared (Safrit, 1995). It is important to remember that norm referenced standards are only as accurate as the group used to establish the normative standard. Criterion referenced measures on the other hand use research to establish standards of what would be acceptable (Safrit, 1995). This process has limitations as well, however, because as has already been discussed, the research on certain populations, such as children, lacks close examination of the established criterion. The choice to use a norm or criterion referenced standard should depend on, among other things, upon the reason for the test administration. Fitness testing, which was primarily used for grading and awards in an educational setting and for data collection in research, has evolved into a valuable tool for providing feedback to individuals of all ages concerning the impact of their life choices. Koebel, Swank, & Swinburne (1992) completed a study which was then later addressed by Safrit (1995) where children's test scores were converted to both criterion and norm referenced standards. The results of the study found that on average no age group of either gender was able to pass the test using the norm referenced standards. In adult populations, the separation point for high and low risk individuals is normally set at the 20th percentile in criterion referenced test, with the emphasis of the fitness testing being for the subjects to meet minimum health-related standards. With this in mind, only a few of the subjects in the study were unable to meet the criterion referenced standard.

A.6.2 Physical Fitness

There has been a long running debate as to whether or not American children are physically fit (Corbin & Pangrazi, 1992). One of the reasons for this debate is the difficulty of comparing fitness tests over time. Comparing test scores of children in years past is a tenuous undertaking at best. Because the methods and technologies of assessment and evaluation used today are not the same as those used previously, it cannot be generally stated with any absolute certainty whether today's children are more or less fit than in years past (American Academy of Pediatrics, 1992). More specifically for children under the age of six, comparisons cannot be estimated because fitness data on children of that age were not normally collected in years past. About the only point that seems to be generally agreed upon is that children today have a higher percentage of body fat than children of 20 years ago (Ross & Gilbert, 1987). Time is an issue with fitness testing, not only from past to present, but also as related to the chronological and developmental age of each individual subject. Fitness testing adolescents of the same chronological age does not ensure that they are at the same developmental level, stage, or physical size. Rowland, Vanderburgh, and Cunningham (1997) emphasized the importance of the body size issue as related to maximal aerobic power in children. As children grow, their maximal oxygen uptake (VO2 max) also improves. How this improvement is related to age, body composition, and general body size is important if researchers hope to establish norms and make an accurate assessment of an individual's fitness level. Herein lies the crux of the problem, especially in research involving children, as Rowland, Vanderburgh, and Cunningham (1997) discuss when calculating VO2 max, results obtained are dependent upon the formula used, and comparisons between different formulas can be significantly different and may even show an inverse relationship between the genders. Which can be particularly confusing when attempting to compare and contrast the methodologies of articles within a literature review. With that being said maximum oxygen uptake continues to be a valuable tool through which the current cardiorespiratory fitness level and the effects of chronic physical activity can be measured.

A.6.3 Physical Activity

Numerous methods have been implemented in an attempt to quantify and assess physical activity levels. A few of the methods have included surveys, recalls (Tremblay, Inman, & Willms, 2000); measurement devices such as pedometers and accelerometers; and other assessment methods such as academic learning time (Silverman, Devillier, & Ramirez, 1991). Although these methods may have served the purpose in each individual study, it is difficult to compare or generalize. Subjective assessments of physical activity are also limited by an individual's memory (survey), or the observation ability of a teacher looking for time-on-task. Chronic physical activity of a sufficient intensity would also affect fitness level and should afford a person higher scores on surveys and with pedometers and accelerometers. One of the premises of this proposed research study is that physical activity needs to be viewed more as a process and not a product. Fortunately with improvement in technology, the process of quantifying the intensity level within individual (acute) bouts of physical activity has been consistently performed using heart rate monitors in a variety of venues (Allen, 1988; Strand & Reeder, 1993). With the use of heart rate monitors being well documented and validated on children (Trieiber, Musante, Hartdagan, Davis, Levy, & Strong, 1989; Epstein, Paluch, Kalakanis, Goldfield, Cerny, & Roemmich, 2001). Daily moderate physical activity of at least 30 minutes is recommended for children with heart rate being one of the recommended methods assess physical activity level (Montoye, Kemper, Saris, & Washburn, 1996; Franks, 1997).

A.6.4 Activity Prescription

Development of an exercise regiment by a professional in the field for a specific reason, such as rehabilitation, sport training, or for some other outcome, is normally referred to as exercise prescription. Part of this structured exercise prescription is determining how much activity or exercise is required to reach an intended goal. The proposed study will use a form of exercise prescription to determine if an acute bout of physical activity will induce an effect on short term cognitive processing. At one end of the continuum low level physical activity or sedentary behavior, while at the other end is a moderate level of physical activity. As addressed earlier, many researchers have argued that Americans are far too sedentary and need to increase their physical activity levels. There are also individuals who have a very high intensive training program. Interestingly, a structured form of high intensity exercise may not be needed to produce the beneficial effects that many people aspire to reach. Research seems to indicate that this is true for adults and children alike. In a study of sedentary adults, 30 minute bouts of physical activity each week appeared as effective as a more intensive structured exercise program to improve blood pressure and cardiorespiratory fitness (Dunn et al., 1999). For this reason, the term activity prescription was chosen over exercise prescription as research has indicated that a structured exercise program may not be in the best interest of children. Studies have also shown an association between levels of physical activity and physical fitness in young children (Pate, Dowda, & Ross, 1990). This indicates that a structured training program might not need to be undertaken to improve the level of fitness in children. Further supporting this premise, researchers Pate, Dowda, and Ross (1990) found a significant relationship between the fitness level and activity level in 8- and 9- year-old children. A program making the child less sedentary by increasing physical activity could have numerous beneficial effects. Physical activity and fitness can both be broken down using the mnemonic FITT (Allis & Patrick, 1994). When applying the FITT principle it is important to remember that the type or style of activity or exercise prescription used on adults may be inappropriate for children. Participation in extracurricular activities or sports may or may not supply sufficient activity depending on the goals and objectives of the participant. Virtually every sport has playing positions that require little movement or techniques by which an individual can get by with a minimum of effort. Furthermore, programs placing an emphasis competition and excessive training is inappropriate for preschool children (American Academy of Pediatrics, 1992).

The question of the amount of physical activity a child requires does not have a simple answer. The needs and concerns of a 12-year-old are not the same as those of a 6-year-old. The American Academy of Pediatrics (1992) suggests that, for children under the age of 6, any fitness or sport participation needs to carefully consider developmental requirements, limitations, and the fitness needs of this age group. The need for movement however is extremely important to provide the opportunity for the preschooler to do a number of things, including promotion of physical and cognitive development. The American Academy of Pediatrics (1992) suggest that if a child of this age is allowed to explore and move as they desire in a safe The American Academy of Pediatrics (1992) environment, that any special intervention would be unnecessary. The question that still remains to be answered is how much activity this actually entails. With children being placed in a variety of large group child care settings, are they being allowed to move and explore the environment as they would desire? The American Academy of Pediatrics (1992) stated that no general consensus on the amount or type of exercise for optimal health or function of children has been determined. Physical activity decreases during adolescence and for this reason more research has centered on this age group. Sallis and Patrick (1994) examine guidelines for adolescent physical activity including those that recommend adolescents need to be active daily and that at least 3 times a week the activity should be moderate to vigorous for at least 20 minutes. These establish some minimum guidelines, but the question of how much is too much still needs to be addressed.

Rowland (1993) reviewed the benefits and risks of intensive training on the prepubertal athlete. A wide range of issues was reviewed, ranging from cardiac stress and skeletal damage to sexual development and hyperthermia. In this fairly thorough review, the primary conclusion is that more research is needed on prepubertal athletes. There was not much data to support the notion that training children at a young age would be injurious to them with the exception of growth plate injuries, especially in gymnasts and baseball players. One could conclude, therefore, that not enough research has been completed to make any definitive statements on this subject. It is also important to remember that more than the child's physiological performance needs to be addressed. Children are not miniature adults and the dose of activity must be predicated upon many factors, including the child's interest, enjoyment, physical characteristics, of each individual child and the desired outcome. One study by DiLorenzo, Stucky-Ropp, Vander Wal, and Gotham (1998), concluded that for their subjects (grade 5 through 8) the child's enjoyment of physical activity was the only consistent predictor of participation.

Although the type or amount of physical activity required needs to be examined further, one point that seems to be irrefutable is that physical activity is important. It is undisputed that it should be a goal for children, adolescents, and adults to be physically active. If changes in cognitive function are correlated with fitness or activity levels, it is important to better understand what types of programs or activities children are currently involved in. And finally, although schools continue to reduce the opportunities for physical education and physical activity, even in light of all of the evidence supporting benefits by physically activity, the educational setting still has the greatest potential to promote physically active and healthy lifestyle (American School Health Association, 1997). Also, recognizing that the school setting is in a unique position to promote activity in students these summarized guidelines have been developed (American Academy of Pediatrics, 2000; Centers for Disease Control & Prevention, 1997; The Council for Physical Education for Children, 1998) and would be relevant for a variety of venues that provide services for children.

1. Establish policies that promote enjoyable, lifelong physical activity.

2. Provide physical and social environments that encourage and enable physical activity in a safe setting. Adult supervision, teaching, and instruction in safe methods of physical activity training, safe facilities, and the appropriate use of protective equipment are all components of a safe environment for physical activity.
3. Implement physical education and health education curricula that emphasize enjoyable participation in physical activity and that help students to develop the knowledge, attitudes, motor skills, behavioral skills, and confidence needed to adopt and maintain physically active lifestyles.
4. Provide extracurricular physical activity programs that address the needs and interests of all students.
5. Include parents and guardians in physical activity instruction and extracurricular physical activity programs. Encourage parents and guardians to support their children's participation in enjoyable physical activities, as well as to recognize their powerful influence as role models for active lifestyles.
6. Provide education to personnel from teaching, coaching, recreation, health care, and school administration to effectively promote enjoyable, lifelong physical activity among youths.
7. Regularly evaluate the school's physical activity programs, including classroom instruction, the nature and level of student activity, and the adequacy and safety of athletic facilities.
8. Establish relationships with community recreation and youth sports programs and agencies to coordinate and complement physical activity programs.

A.7 PURPOSE AND RATIONALE

Current literature indicates that children and adults can gain myriad of health benefits from being physically active, and although children have responded to ‘intensive’ exercise programs the desirability of implementing such programs needs to be questioned and studied further. When an activity is enjoyable, children are more likely to continue participation and glean potential benefits. Children and adults vary considerably in their experiences, genetic make up, interests and motivations. In older adults (Dipietro, Seeman, Merrill, & Berkman, 1996) the benefits of physical activity on cognitive function were not as significant when controlled for educational level.

Studies have also indicated that activity and exercise can be a valuable asset and can be uniquely provided in the educational setting. The question is one of how physical activity can be implemented to render the greatest academic outcome. How physical activity impacts academics can be viewed from two perspectives, direct and indirect. Indirect would be how physical activity relates to factors impacting education but do not directly impact academic achievement. For example, physically active individuals have a higher incidence of positive lifestyle choices such as better stress management, lower levels of depression, good nutritional choices, reduced tobacco use, positive interpersonal relationships, reduced anxiety, a reduction in disruptive behaviors, and lower fatigue levels (Bouchard, Shephard, Stephens, Sutton, & McPherson, 1990; Hechinger, 1992; Meredith & Dwyer, 1991).

A more difficult, yet poignant, question is whether physical activity has any direct impact on cognitive processing and academic achievement. The literature consistently supports the findings that physical activity and fitness are not detrimental to the educational process. Combining this with the documented positive benefits of physical activity from a physiological standpoint, as well as the fact that activity and fitness have shown positive benefits for psychological/mental health and quality of life, it is curious that the relationship of physical activity to cognitive function has not been more thoroughly examined. (Sallis & Patrick, 1994; Biddle,Sallis, & Calvill, 1998).

A.8 SIGNIFICANCE OF THE STUDY

The review of literature has demonstrated that a physically active lifestyle can have a positive impact on the level of health related fitness in children. Other anecdotal evidence in the literature review has indicated that physical activity can have a positive affect on individuals' mental state. Furthermore research has demonstrated that new brain cells can be grown in humans. This information combined with the evidence supported by the literature that fit active older adults consistently perform better on cognitive processing activities sets precedence for the significance of this proposed study. If it can be demonstrated that physically activity and physically fitness in children leads to higher levels of performance on cognitive processing activities, then the significance of the study is evident. Increased physical activity and physical fitness level can affect cognitive function which could lead to a paradigm shift in the way programs such as physical education are viewed in an academic environment.

Appendix B

INSTITUTIONAL REVIEW BOARD INFORMATION

Research Protocol Abstract

The Influence of Physical Fitness and Physical Activity On Cognitive Processing in Children

Over the past thirty years research has concentrated on investigating the effects of physical activity on the physiological components of the human body. The research however has not thoroughly examined the effects of fitness and physical activity on cognitive functioning, especially in children. The purpose of this series of studies is to examine two aspects of the mind body connection: 1.) How does fitness level of children affect cognitive processing, and 2.) How does physical activity level of children affect cognitive processing.

In older populations, physical activity has already been shown to relate to cognitive function (Emery 1995, Hassm'n, Koivula, 1975). When fit adults are compared to sedentary, low fit groups, the fit adults demonstrate faster simple and choice reaction times, thus they are faster at making decisions (Rowland 1990, Chodko-Zojko 1991). The research design in this series of studies expands these adult findings to children using a paradigm including: simple and choice reaction time tasks, a vigilance task, a dual task, and probed and semantic memory tasks.

Subjects for the study will be children ranging in age from 6-to-12 years-of-age from the greater Pittsburgh and suburban region. Subjects will be assessed using several methods. Heart rate will be monitored using a Polar Protrainer NV heart rate monitor. A psychomotor cognitive processing assessment (including simple reaction time, choice reaction time, dual task-tracking and simple reaction time, vigilance, probed memory and semantic long-term memory) will be made using the self contained Psych E computer program. Finally health related fitness will be assessed using body composition calculated using the Tanita TBF-305 Bodyfat Analyzer, back saver sit-and-reach (hamstring flexibility), curl-ups (abdominal strength), modified pull-ups (upper body strength) and physical work capacity (cardiorespiratory fitness) measured using a stationary Monark Cycle Ergometer.

Study 1 will examine how fitness level affects cognitive processing. The health related fitness levels of the subjects will be compared with their cognitive processing. The dependent variables are simple reaction time, choice reaction time, dual task-tracking and simple reaction time, vigilance, probed memory and semantic long-term memory. The hypothesis for study 1 is that the physically fit subjects will perform better on the dependent variables that the unfit subjects. A multivariate ANOVA will be calculated with follow-up ANOVA's when appropriate.

Study 2 mirrors study 1 but expands the design with the introduction of physical activity. In study 2 cognitive processing will be assessed twice, once following a 30 minute sedentary period and a second time following 30 minutes of physical activity with the subject maintaining a training heart rate. In this design fitness level and physical activity level will be compared to cognitive processing. The independent variables are fitness level (fit & unfit) and physical activity level (active, inactive). The design is therefore fitness level by physical activity level with repeated measures on the last factor. The dependent variables are simple reaction time, choice reaction time, dual task-tracking and simple reaction time, vigilance, probed memory and semantic long-term memory. It is hypothesized that the fit subjects will perform better than the unfit subjects on the dependent variables and that physically active fit subjects will score better on the dependent variables than all other treatment groups.

Research Protocols

1.0 Objectives and Specific Aims

The aim of this series of studies is to evaluate the relation of cognitive processing to physical fitness level and physical activity level. Study 1 (Table 1) will examine how cognitive processing differs in physically fit and unfit children. Study 2 (Table 2) will examine how physical activity, sedentary behavior, and fitness level affects cognitive processing.

2.1 Background

Research continues to address the issues of physical activity and physical fitness across the life span. One benefit of physical activity for an older population is improved cognitive performance (Chodzko-Zacjko 1991, Emery 1995, Hassm'en & Koivula, 1997, Spirduso, 1975) as measured using simple and choice reaction time paradigms. Adult research investigating the relationship between fitness level and cognitive function has shown a difference for choice but not simple reaction time tasks (Chodzko-Zacjko 1991, Emery, Huppert & Schein 1995, Spirduso, 1975). Differences have also been shown for response selection or the speed of decision-making. Other studies support the theory that physical fitness can affect the decision making process in an older population (Etnier, Salazar, Landers, Novell, Petruzzello & Han, 1997). Similar research designs completed on children have also shown potential, however these studies are not as numerous as those on adults. Generalizations from adult studies must not be haphazardly applied to children for as the literature demonstrates children are not miniature adults. Younger children are regarded as less capable of controlling their attentional resources (Guttentag & Ornstein, 1990). Children also differ from adults in their ability to process and recall information (Thomas, Thomas, & Gallagher 1994; French, Thomas, & Thomas, 1996, Ladewig, Gallagher, & Campos, 1996, Thomas et. al, 1994). With these differences in mind it is interesting that pediatric cognitive processing has not been more thoroughly addressed. Mokgothu (2000) examined the relation of fitness and cognitive function in Botswanan children and found limited correlations.

His recommendations for future research included examining the benefits of fitness as related to cognitive functioning. His study looked at fitness level of the subjects but did not control for the physical activity level of the subjects The current study will introduce a more sensitive tool to measure cognitive function. It is hypothesized that physically fit children will have a higher cognitive processing level and that the cognitive processing levels of children will be higher following physical activity as opposed to physical inactivity.

2.2 Significance

Research data in adults indicate a connection between habitual physical fitness and cognitive function/performance but comparable information for children is limited. Research comparing activity levels to cognitive function/performance is almost nonexistent. A relationship between either physical fitness or physical activity and cognitive processing in children would provide grounds for improving education programs and increasing time allocated for physical education and exercise activities in a pediatric population. If the hypotheses of these studies are supported the need for a physically active lifestyle in children will be given more validity.

3.0 Research Methods

3.1 Apparatus and Procedures

Physical Activity Level

The physical activity level of the subject will be part of the design. Subjects will participate in a physically active or physically inactive session while having their heart rate monitored. A Polar Protrainer NV heart rate monitor will be used to collect heart rate information. Subjects will wear a small monitor attached to the chest, which through telemetry sends a signal to a watch-sized receiver on the wrist. The heart rate monitor gives instantaneous readings and stores information on the time spent within, above, and below the training heart rate zone. For the purposes of this study physical inactivity will consist of the subject sitting at a desk doing paper and pencil activities (reading, coloring, etc.) in which the heart rate remains below the training heart rate level for 30 minutes. The physical activity session will consist of the normal games and activities in which the subjects are participating where the heart rate is within a bandwidth training heart rate level (220-the age of the subject *.50-.80) for 30 minutes

Health Related Physical Fitness Assessment

Fitness for this study is defined as falling within the age appropriate health related fitness zones for muscular flexibility, muscular strength/endurance, body composition (Cooper Institute for Aerobics Research, 1999) and physical work capacity. A child who falls within or above the health related fitness standards on all measurements will be considered physically fit.

Flexibility (Hamstring) will be assessed using the Back Saver Sit-and-Reach test (Cooper Institute for Aerobics Research, 1999). This test uses a standard sit and reach box (12 inch high box with a yardstick attached with the 9-inch mark at the edge of the box.). Subjects remove shoes and sit with hips parallel to the box and one leg straight with the foot against the box and the other leg bent with the foot flat on the floor. The subject places one hand on top of the other with the palms down and reaches as far as possible. The subject attempts this four times with the best score recorded. The same procedure is repeated for the other leg.

Muscular Strength/Endurance (Abdominal and Upper Body) Curl-ups will be used to measure abdominal strength and endurance (Cooper Institute for Aerobics Research, 1999). Equipment consists of a cardboard strip 30 inches long and 4 ½ inches wide for 10-to-17 year-olds and 3 inches wide for 5-to-9 year-olds. The subject lies on a mat with knees bent and feet flat with the arms and hands flat (palms down) at their side. The subject begins with their fingers touching the near side of the measuring strip and curls up until their fingers touch the far side of the strip and then lower until their head lightly touches the mat. Repetitions are performed to an announced cadence of one curl-up every 3 seconds.

Upper body strength and endurance will be assessed using a modified pull up test (Cooper Institute for Aerobics Research, 1999). This assessment uses a modified pull up bar where the student lies on their back to grab the bar using an overhand grip (reverse push up). The bar is adjusted so that it is 1 to 2 inches above the subject's reach when they are lying on the floor and an elastic band is placed 7 to 8 inches below the bar. The starting position has the subject hanging from the bar, arms and body straight with the heels touching the floor. The subject's body should not be touching the mat. To perform the test the subject pulls up until the elastic band touches just below the chin. The subject then lowers until the arms are straight. The test is continued until the subject performs two incorrect pull-ups.

Body Composition: The Bodyfat Analyzer (Tanita TBF-305) will be used to measure body composition. It is the size of a bathroom scale and calculates the child' body fat percentage. The instrument is attached to a small unit that displays the reading for each subject. The subject removes his/her shoes and socks and stands on a Detecto-Medic Balance scale to measure height to the nearest cm. After recording the height of the subject on paper, the body fat analyzer will be switched on. The instrument will be calibrated for 'child' and the appropriate 'gender' will be selected. The height of the subject will be entered into the unit. The subject will step on the scale and remain motionless for 15 seconds. The unit will produce a printout of the subject's height in feet and inches, weight in pounds, body mass index, fat percentage, and fat mass.

Aerobic Capacity will be assessed using a physical work capacity test. A Monark Cycle Ergometer (model 818) will be used to assess Cardiorespiratory fitness. The seat will be adjusted to 95% of the subjects leg length with the ball of the foot on the pedal at maximal leg extension. The subject will assume an upright-seated posture with hands properly positioned on the handlebars and will be given a 2-min. warm up period to familiarize him or herself with the equipment. Since the subjects are children the initial load setting will be .25 kg with a pedal rate of 60 rev/min. Using a Polar heart rate monitor the subjects heart rate will be monitored every minute. Cycling will be terminated when the subject attains a heart rate of 150 b/min. or requests termination of the test due to fatigue. Exercise intensity will be increased gradually through the stages of the test using work increments of .5, 1, 1.5, 2, 2.5, 3, 3.5kg. An estimate of PO150, PO195, VO2 at 150, and VO2 at 195 will be calculated using a linear regression equation. Using the ACSM's metabolic equation [Resistance x 2 (constant) x 60 (rev/min) x 2.33 (pedal distance) + (2 x PO) + 300 (body weight + 3.5 resting HR] absolute VO2 max will be calculated. To find the relative VO2 max, the absolute VO2 max will be divided by the subjects body weight. Upon completion of the test subjects will cool down for 2 minutes at .30 rpm.

Cognitive Assessment

Cognitive Assessment will be completed using the Psych E self-contained computer program for conducting psychomotor assessment. The program runs on an IBM-compatible personal computer and records all scores and times. The programs six tests require a total administration time of approximately 20 minutes. Program designers selected these tests from the literature, to assess psychomotor function (Hope, Woolman, Gray, Asbury, & Millar, 1998).

1.) <u>Discrete simple reaction time:</u> The subject holds down the spacebar. After a random interval (1 to 10 seconds) a small sun symbol (signal) appears in a random position on the screen. The test consists of 20 trials. On the appearance of the signal, the subject is required to lift his/her finger from the spacebar and press any of the target keys; these are the keys 4-9 on the top row of the keyboard. For correct responses, the total reaction time and its components are recorded separately to within 1 millisecond.

2.) <u>Discrete 6-choice reaction time</u>: The subject depresses the spacebar and a representation of the 6 target keys (keys 4-9 on the top row of the keyboard) is shown on the computer screen. After a random interval (1 to 10 seconds) one of these keys is highlighted and the subject is required to press the corresponding key on the keyboard. For each correct response, reaction time and movement time are recorded.

3.) <u>Duel task – tracking and simple reaction time:</u> This test has a primary task of tracking, and a secondary reaction task. The test is designed to measure impairments in the secondary task while keeping the subject focused on the primary task**.** The primary task requires the subject to use a mouse to follow a smooth but randomly moving target on the computer screen (percentage of time-on-target is recorded). At random intervals the secondary task stimulus (a small sun symbol) is presented. The time taken for the subject to press the spacebar is measured, with total response time, reaction time and movement time being recorded separately

4.) <u>Numeric vigilance</u>: Three-digit numbers are presented on the computer screen at a rate of 100 per minute. Each number differs randomly from the previous number in one of the digits. Of the numbers presented during the test, 8% are duplicates of the previous number. The subject is required to identify these duplicates and press the spacebar as they occur. Correct responses (“hits”), missed duplicates (“misses”), and incorrect duplications responses (“false alarms”) are recorded. Test duration is four minutes.

5.) <u>Probed memory:</u> This test assesses short-term memory. Subjects will be instructed that they will be shown a series of consonants, and to try to remember the letters. A sequence of eight consonants is presented with a new consonant being added every second. All the consonants in the sequence remain visible until the last consonant in the list is displayed. After an additional one second the complete sequence of 8 characters is blanked out. The subject is presented with a consonant and asked whether or not it had been part of the list; 50% of the probe consonants belong to the original list. The percentage of correct responses is recorded.

6.) Semantic long-term memory: This test displays category-word pairs selected at random from a database of 20 categories and 760 words. The words used are of two kinds: high-dominance (frequently used in everyday communication) or low-dominance (infrequently used in everyday communication). Equal numbers from each dominance category are used in the course of a single test. A category-word pair is presented to the subject who has to decide, and indicate with a key press whether or not the word represents a member of the displayed category. Separate reaction times are recorded for high dominance, low dominance and negative presentations.

3.2 Research Methods

Subjects for the two studies will be children 6 to 12 years-of-age enrolled in or attending programs in the North Versailles School District, University of Pittsburgh or Indiana University of Pennsylvania. An informed consent will be obtained for all subjects. Data will be collected over a two or three-day period depending on the study. Study 1 (Table 1) will measure subjects health related fitness level, achievement assessment and cognitive assessment. Analysis will determine if fitness level has an affect on cognitive processing. Study 2 (Table 2) will further expand study 1 by introducing physical activity or inactivity. The design for Study 2 will divide subjects into two procedural subgroups to control for a learning curve with the subjects being either physically active or inactive prior to taking the cognitive assessment. This will allow the researcher to examine the affect of physical activity on cognitive processing.

3.3 Design and Data Analysis

Subjects will be classified as fit or unfit based on their health related fitness scores. In Study 1 the fit and unfit groups will be compared on cognitive assessment measures. Thus the design of the study is fitness level (fit and unfit). The dependent variables are simple reaction time, choice reaction time, dual task-tracking and simple reaction time, vigilance, probed memory and semantic long-term memory. The hypothesis for study 1 is that the physically fit subjects will perform better on the dependent variables that the unfit subjects. A multivariate ANOVA will be calculated with follow-up ANOVA's when appropriate.

In study 2 the independent variables are fitness level (fit and unfit) and physical activity level (active, inactive). The design is therefore fitness level by physical activity level with repeated measures on the last factor. The dependent variables are simple reaction time, choice reaction time, dual task-tracking and simple reaction time, vigilance, probed memory and semantic long-term memory. It is hypothesized that the fit subjects will perform better than the unfit subjects on the dependent variables and that physically active fit subjects will score better on the dependent variables than all other treatment groups.

4.0 Human Subjects

4.1 General Characteristics – Minority Inclusion and Non-Discriminatory Statement

The study will be conducted using subjects enrolled in programs at Indiana University of Pennsylvania campus, University of Pittsburgh Campus, and elementary and secondary schools in the North Versailles School District, Allegheny County Pennsylvania. No exclusion criteria shall be based on race, ethnicity, gender, or HIV status.

4.2 Inclusion of Children in Research

1. The age ranges included are elementary school aged children (ages 6-12). The rationale for using this age range is the educational significance that this line of research could have. Supporting rationale is that it is the emphasis area (motor development) for the investigators and that research in this age group is deficient as compared to adolescents and adults.

2. Gary Clark has a Bachelors degree in recreation, a Masters degree in Physical Education and is a Pennsylvania certified Health and Physical Education teacher. He currently is completing a Ph.D. in motor development. Over the last 12 years he has been involved in a variety of programs for children from preschool to the college level. He has coached a variety of sports, directed and worked at a sport and physical activity camps, worked in the fitness industry, taught health and physical education (K-12) in the Pennsylvania public school system, and has taught a variety of undergraduate and graduate courses at the collegiate level.

Allen R. Wagner has a Bachelors degree in Health and Physical Education, a Masters degree in Physical Education, and is a Certificated School Guidance Counselor and Health and Physical Education teacher. He currently is completing a Ph.D. in motor development. He has been an educator working with children for 32 years, has taught physical education for 27 years and been a school guidance counselor for 5 years.

Jere Gallagher has a PhD in Motor development. She has conducted research using children as subjects for more than twenty years.

3. The facilities required for data collection are more than adequate at each site, including gymnasiums and classrooms. The camps and classes that operate at each location have developmentally appropriate equipment and facilities, as the preexisting programs already cater to this age group.

4. Required sample sizes for the statistical analysis that will be used have been examined to ensure a statistically powerful test. Participation of 20 subjects would suffice.

5. It is anticipated that a total of 30-60 subjects will be enrolled (approximately 20 subjects from each site).

6. Not applicable

Criterion 1: The research presents no greater than minimal risk to the involved children.

(45 CFR 46.404)

4.4 Recruitment Procedures

Potential subjects will be children enrolled in camps and educational programs at the University of Pittsburgh, Indiana University of Pennsylvania, and East Allegheny School District These programs normally incorporate the same or similar activities as the data being collected as part of their normal itinerary. All parents/guardians of children participating in these programs will receive a letter inviting them to participate in the study.

4.5 Risk/Benefit Ratio

The risks involved in the study are minimal; children may experience fatigue or soreness. Children will be individually tested and their scores will be explained to them in private. Recommendations will be given to each child on how to improve their test results with special consideration given to children with poor fitness or body composition test results.

The principle and co investigators will oversee the data safety and monitoring with at least one of the investigators being on site for all data collection. To ensure confidentiality all data collected will remain on the person of the investigators or in a locked office.

The investigators will monitor all parts of the research study including participant recruitment (all children enrolled in the programs will be invited to participate), data quality, and constant analysis of risk benefit ratio to determine the need for study modifications or termination and will review pertinent scientific literature for information that may affect safety of study participants or the ethics of the research study.

The researchers have a commitment to comply with the IRB's policies for reporting serious and unexpected adverse events as discussed in the IRB Reference Manual (Chapter 3.0, sections 3.4 and 3.5). The principle and co investigators will annually review all data and safety monitoring procedure and report to the IRB the frequency of monitoring, a summary of adverse event data, a summary of current literature that could affect safety or ethics of the study, the outcome of procedural reviews to ensure subject privacy and research confidentiality, and any changes in the benefit-to-risk ratio of study participation with final recommendations for continuing, changing, or terminating the study.

5.0 Cost and Payment

5.1Research Study Cost

There is no cost to the subject for participating in the study.

5.2 Research Study Payments

No one will be reimbursed for participation in this study.

6.0 Appendices

Qualifications of investigators

Principle Investigator

Gary Clark has a Bachelors degree in recreation, a Masters degree in Physical Education and is a Pennsylvania certified Health and Physical Education teacher. He currently is completing a Ph.D. in motor development. Over the last 12 years he has been involved in a variety of programs for children from preschool to the college level. He has coached a variety of sports, directed and worked at a sport and physical activity camps, worked in the fitness industry, taught health and physical education (K-12) in the Pennsylvania public school system, and has taught a variety of undergraduate and graduate courses at the collegiate level.

Co-investigators

Allen R. Wagner has a Bachelors degree in Health and Physical Education, a Masters degree in Physical Education, and is a Certificated School Guidance Counselor. He currently is completing a Ph.D. in motor development. He has been an educator working with children for 32 years, has taught physical education for 27 years and been a school guidance counselor for 5 years.

Jere Gallagher has a PhD in Motor development. She has conducted research using children as subjects for more than twenty years.

References

American Academy of Pediatrics (1990) Fitness, activity and sports participation in the preschool child. Pediatrics, V 90 No. 6, 1002-1004

Calfas, K.J. and Taylor, W.C. (1994) Effects of physical activity on psychological variables in adolescents. Pediatric Exercise Science, 6 406-423

Chodzko-Zacjko (1991) Physical fitness, cognitive performance, and aging. Medicine and Science in sports and Exercise, 23, 868-872.

Cooper Institute for Aerobics Research (1994) Fitnessgram, Test Administration Manual 2nd Edition, Human Kinetics

Emery C. F, Huppert F, Schein R, (1995) relationships among age, exercise, health, and cognitive function in a British sample. Gerentologist 35, pgs. 375-385.

Etnier L, Salazar w, Lander D, Petruzzello S, Han M, Nowell P. (1997) The influence of physical fitness and exercise upon cognitive functioning: a meta-analysis. Journal of Sport and Exercise Psychology. 19, pgs. 249-277. Human Kinetics.

French, K., Thomas, K. and Thomas J. (1996). Expertise in Youth Sport: The Relationship Between Knowledge and Skill. In F. Smoll, & R. smith (Eds) Children and Youth in Sport: A Biopsychosocial Perspective. Pgs. 338-358.

Gallagher, J.L., and Thomas, J.R.(1986). Developmental Effects of Grouping and Recoding

on Learning a Movement Series. Research Quarterly for Exercise and Sport, 57, pgs 117-127.

Guttentag, R., & Ornstein, P. (1990). Attentional capacity and children's memory strategy use. In J. Ennis (Eds), The development of attention: Research and theory (pp. 305-319). North Holland: Elsevier Science Publishers.

Hassm'en, Koivula (1997) Mood, physical working capacity and cognitive performance in the elderly as related to physical activity. Aging. 9136-142

Hope AT, Woolman PS, Gray WM, Asbury AJ, Millar K. (1998) A system for psychomotor evaluation; design implementation and practice effects in volunteers Anesthesia: 53: 545-549

Ladewig, I., Gallagher, J., & Campos, W. (1996). Manipulation of environmental distactors to enhance children's selective attention. Journal of Sport and Exercise Psychology, 18s, 49.

Mokgothu, C. (2000) Physical fitness and cognitive function, how are they related. Unpublished manuscript, University of Pittsburgh.

Reschly, D.J. & Grimes J.P. (1995) Best Practices in Intellectual Assessment, in Thomas A. & Grimes J. (1995) Best Practices in School Psychology. National Association of School Psychologist, Washington D.C. 65. pgs. 763-773

Rowland T (1990) Exercise and Children's Health. Champaign Human Kinetics.

Rowland, T.W. and Freedson, P.S. (1994) Physical activity, fitness, and health in children: a close look. Pediatrics, April, Vol. 93, Issue 4, 669-672.

Schmidt, R. (1997) Motor Control and Learning, A behavioral Emphasis. Human Kinetics.

Spirduso, W.W. (1975). Physical fitness, aging, and psychomotor speed: a review, .Journal of Gerontology. 35: 850-865.

Thomas, J.R., Thomas, K.T., & Gallagher, J.D. (1994). Developmental Considerations in Skill Acquisition. In R. Singer, M. Murphey, & Tennant (Eds.) Handbook of Research on Sport Psychology. NY: MacMillan Publishing Co.

B.1 COVER SHEET

IRB COVER SHEET (revised 4/28/04)

Reason for Submission:	IND #:	IRB #: 0205109
New Project [ ]	IDE #:	
Responding to Comment [ ]		
Reconsideration [ ]	If there is an IND or IDE number, please include 4 copies of the investigational drug/device brochure	**IRB Use Only:** DATE STAMP:
Disapproval Resubmission: [ ]		
Modification [ ]		
Renewal [**X**]		
Adverse Event Report [ ]		
Date of Submission:		

PART A – PROTOCOL/INVESTIGATOR/COORDINATOR INFORMATION

Title of Study: The Influence of Physical Activity and Physical Fitness on the Cognitive Processes of Children

Principal Investigator: Gary E. Clark
Title of Principal Investigator: Assistant Professor of Health and Physical Education

Address of Principal Investigator: 6301 954 North, Creekside, Pa 15732
School: Department: Division:
Phone number: (724) 465-8736 e-mail address: gnclark@nauticom.net

FAX NUMBER(s) WHERE THE APPROVAL LETTER SHOULD BE SENT: (724) 465-8736
NOTE: HARD COPIES ARE NOT SENT UNLESS THERE IS NO FAX NUMBER LISTED

Co-Investigators: Allen R. Wagner, Jere D. Gallagher, Ph.D.

Coordinator's Name: Gary E. Clark
Address: 6301 954 North, Creekside, Pa 15732
Phone number: (724) 465-8736 e-mail address: gnclark@nauticom.net

PART B – LEVEL OF RISK/TYPE OF REVIEW REQUESTED

Level of Risk: [**X**] Minimal [ ] Moderate [ ] High

Type of Review Requested: [ ] Full Board [**X**] Expedite

PART C – RECRUITMENT INFORMATION

Is this a multicenter study?
[**X**] Yes* - Indicate number of subjects to be enrolled at multicenter sites: 30-60
[ ] No
***If yes, please include 4 copies of the multicenter protocol**

Number of subjects to be enrolled at this site: 30-60
Please note: the IRB considers a subject to be enrolled if s/he signs an informed consent document. If a higher number of subjects must be enrolled for screening in order to hit a targeted number of subjects completing the study, please indicate the higher number.
.

Gender: [**X**] Male [**X**] Female **Age Range all Subjects: 6-12**

Duration of Study Per Subject: 3 Hours **Duration of Study (entire study): 12 Moths**

Sites where research procedures will be performed (please check all applicable boxes):
[**X**] University of Pittsburgh [ ] UPMC McKeesport [ ] UPMC Rehab
[ ] UPMC Bedford [ ] Magee [ ] UPMC Shadyside
[ ] UPMC Braddock [ ] UPMC Northwest [ ] UPMC Southside
[ ] Children's Hospital [ ] UPMC Passavant [ ] UPMC St. Margaret
[ ] UPMC Horizon [ ] UPMC Presbyterian* [ ] Hematology-Oncology Associates
[ ] UPMC Lee
[**X**] Other (please specify): Indiana University of Pennsylvania, East Allegheny School District
*this includes Montefiore University Hospital, WPIC and Eye & Ear Institute

PART D – SOURCE OF SUPPORT

Indicate all applicable sources of support and the sponsor:

[ ] Federal* – Sponsor:
Awardee Institution: ___________ (NOTE: If the University of Pittsburgh is the awardee institution, submission of two copies of the grant is required.)
[ ] Commercial** – Sponsor:
[ ] Foundation – Sponsor:
[ ] Other (specify) – Sponsor
[**X**] No support

***If federal funding, please provide a copy of the entire grant application.**
**** If commercial funding, please provide either a check, a payment form from the IRB website or a waiver request.**

PART E: CONFLICT OF INTEREST

Does the principal investigator or any co-investigator or research coordinator involved in this study (or in aggregate with his/her spouse, dependents or members of his/her household):

a. possess an equity interest in the entity that sponsors this research or the technology being evaluated that exceeds 5% ownership interest or a current value of $10,000? [ ] Yes [ ] No
b. receive salary, royalty or other payments from the entity that sponsors this research or the technology being evaluated that is expected to exceed $10,000 per year? [ ] Yes [ ] No
c. possess a license agreement with the University or an external entity that would entitle sharing the current or future commercial proceeds of the technology being evaluated? [ ] Yes [ ] No

If yes, please attach detailed information to permit the IRB to determine if such involvement should be disclosed to potential research subjects.

PART F: RESEARCH COSTS

1. Will testing, services, procedures be performed, samples obtained or hands-on care be provided?
   [ ] Yes [X] No
2. Will these be done at a UPMC HS facility? [ ] Yes [X] No

If response to both questions is yes, UPMC HS fiscal review is required. If the patient does not visit any UPMC HS facilities OR if the study involves only data analysis, interviews, or questionnaires, fiscal review is not required. The IRB and/or UPMC HS also have the authority to require a UPMC HS fiscal review based on their review.

PART G: ADDITIONAL APPROVALS REQUIRED

1. Has this protocol been reviewed by a prior scientific review committee?
   [**X**] Yes (Please attach an approval letter) [ ] No (Indicate the reason)

2. Does this research involve the administration, for research purposes, of a drug (investigational or FDA approved)? [ ] Yes* [**X**] No

*(Please attach written notification of receipt/review from the Investigational Drug Service)

3. Does this protocol involve the exposure of human subjects to ionizing radiation (excluding the use of standard diagnostic or treatment procedures, performed in a routine clinical manner and frequency)?
   [ ] Yes (Attach HUSC/RDRC approval letter) [**X**] No

4. Does this research study involve the deliberate transfer of recombinant DNA (rDNA) or DNA or RNA derived from rDNA into human subjects? [ ] Yes* [**X**] No

* If yes, attach written notification of prior approval by the University of Pittsburgh Biosafety (rDNA) Committee

PART H: CREDENTIALING – DEPARTMENT/DIVISION CHAIR APPROVAL

FOR RESEARCH PROCEDURES CONDUCTED WITHIN A UPMC HS FACILITY: I have reviewed this human subject research proposal and have determined that 1) the listed investigators are members or associates of the medical staff of the hospital where the research will be conducted and have been appropriately granted hospital privileges to perform the procedures outlined in the research proposal; and/or 2) the listed investigators are employees of the hospital whose job descriptions and competencies qualify them to perform the procedures outlined in the research proposal.

Department/Division Chairman Date

CERTIFICATION OF INVESTIGATOR RESPONSIBILITIES

By signing below I agree/certify that:

1. I have reviewed this protocol submission in its entirety and that I am fully cognizant of, and in agreement with, all submitted statements.
2. I will conduct this research study in strict accordance with all submitted statements except where a change may be necessary to eliminate an apparent immediate hazard to a given research subject.
    - I will notify the IRB promptly of any change in the research procedures necessitated in the interest of the safety of a given research subject.
    - I will request and obtain IRB approval of any proposed modification to the research protocol or informed consent document(s) prior to implementing such modifications.
3. I will ensure that all co-investigators, and other personnel assisting in the conduct of this research study have been provided a copy of the entire current version of the research protocol and are fully informed of the current (a) study procedures (including procedure modifications); (b) informed consent requirements and process; (c) potential risks associated with the study participation and the steps to be taken to prevent or minimize these potential risks; (d) adverse event reporting requirements; (e) data and record-keeping requirements; and (f) the current IRB approval status of the research study.
4. I will not enroll any individual into this research study: (a) until such time that the conduct of the study has been approved in writing by the IRB; (b) during any period wherein IRB renewal approval of this research study has lapsed; (c) during any period wherein IRB approval of the research study or research study enrollment has been suspended, or wherein the sponsor has suspended research study enrollment; or (d) following termination of IRB approval of the research study or following sponsor/principal investigator termination of research study enrollment.
5. I will respond promptly to all requests for information or materials solicited by the IRB or IRB Office.
6. I will submit the research study in a timely manner for IRB renewal approval.
7. I will not enroll any individual into this research study until such time that I obtain his/her written informed consent, or, if applicable, the written informed consent of his/her authorized representative (i.e., unless the IRB has granted a waiver of the requirement to obtain written informed consent).
    - I will employ and oversee an informed consent process that ensures that potential research subjects understand fully the purpose of the research study, the nature of the research procedures they are being asked to undergo, the potential risks of these research procedures, and their rights as a research study volunteer.
8. I will ensure that research subjects are kept fully informed of any new information that may affect their willingness to continue to participate in the research study.
9. I will maintain adequate, current, and accurate records of research data, outcomes, and adverse events to permit an ongoing assessment of the risks/benefit ratio of research study participation.
10. I am cognizant of, and will comply with, current federal regulations and IRB requirements governing human subject research including adverse event reporting requirements.
11. I will make a reasonable effort to ensure that subjects who have suffered an adverse event associated with research participation receive adequate care to correct or alleviate the consequences of the adverse event to the extent possible.
12. I will ensure that the conduct of this research study adheres to Good Clinical Practice guidelines.

Gary E. Clark

Principal Investigator Name	Principal Investigator signature	Date

(typed)

B.2 RENEWAL REPORT

Revised 6/14/04

INSTITUTIONAL REVIEW BOARD
UNIVERSITY OF PITTSBURGH
RESEARCH STUDY RENEWAL REPORT

Current IRB #: 0205109

Protocol Title: The Influence of Physical Activity and Physical Fitness on the Cognitive Processes of Children

Principal Investigator: Gary E. Clark

****

Provide below a brief (1-2 paragraph) updated abstract of the research study to address the current status of the study including its specific aims, rationale and significance, experimental design and methods. Also, please respond to each of the following requests for information.

Over the past thirty years research has concentrated on investigating the effects of physical activity on the physiological components of the human body. The research however has not thoroughly examined the effects of fitness and physical activity on cognitive functioning, especially in children. The purpose of this study is to examine two aspects of the mind body connection: Specifically how the physical fitness level and the physical activity level of children affect cognitive processing. In older populations physical activity has already been shown to relate to cognitive function (Emery 1995, Hassm'n, Koivula, 1975). When fit adults are compared to sedentary, low fit groups, the fit adults demonstrate faster simple and choice reaction times meaning that they are faster at making decisions (Rowland 1990, Chodko-Zojko 1991). The research design in this study expands these adult findings to children using a paradigm including, simple and choice reaction time, a vigilance task, a dual task, and probed and semantic memory tasks.

Subjects for the study will be children ranging in age from 6-to-12 years-of-age. Subjects will be assessed using several methods. Heart rate will be monitored using a Polar Protrainer NV heart rate monitor. A psychomotor cognitive processing assessment (including simple reaction time, choice reaction time, dual task-tracking and simple reaction time, vigilance, probed memory and semantic long-term memory) will be made using the self contained Psych E computer program. Body composition will be calculated using the Tanita TBF-305 Bodyfat Analyzer. Finally health related fitness will be assessed using back saver sit-and-reach (hamstring flexibility), curl-ups (abdominal strength), modified pull-ups (upper body strength) and physical work capacity (cardiorespiratory fitness) will be measured using a stationary Monark Cycle Ergometer.The fitness levels of the subjects will be determined using heart rate, body composition, and health related fitness. Fitness levels of the subjects will then be compared to their cognitive processing as measured by the Psych E computer program. Cognitive processing will be assessed twice, once following a 30 minute sedentary period in which the subject is completing paper and pencil work and a second time following 30 minutes of physical activity with the subject maintaining a training heart rate. Fitness level and physical activity level will be compared to cognitive processing.

****

1. Research Subject Enrollment:

   a. A total of __0__ subjects have been entered into this research protocol during this renewal interval

      For studies that involve children, please provide the following:

      (a) Breakdown of subjects by age: 0
      (b) Breakdown of subjects by gender: 0
      (c) Breakdown of subjects by race: 0
      (d) Were any children in foster care at the time of enrollment? [ ] N/A [0] No [ ] Yes (If yes, from whom was consent for participation in research obtained?)

   b. A total of __22__* subjects have been entered into this research protocol since its initial approval

1

10 female subjects

(d) Breakdown of subjects by race:

Caucasian 19
Other 2
African American 1
Hispanic 0

(*If enrollment into this research study, to date, is less than 20% of the projected enrollment based on the proposed annual accrual rate [i.e., proposed total number of subjects at this site/proposed total study duration] provide a rationale for this slow enrollment and a justification as to why this research should be continued).

c. Has subject accrual to date, reflected the ethnic, gender and racial demographics of Pittsburgh and the surrounding area and/or the respective patient population of the UPMC; or the demographics of the alternate site(s) where this research is being conducted?

[ ] No – Provide a justification for the failure, to date, to accrue subjects in accordance with these ethnic and gender demographics and address the steps that will be taken to correct this deficiency.
[X] Yes
[ ] N/A

2. Data and Safety Monitoring:

   a. Single site: Provide a report from the local Data and Safety Monitoring Plan as described in your research protocol.

   b. For multicenter study: Provide a report from both the local and central Data and Safety Monitoring Plan as described in your research protocol.

3. During this renewal interval:

   a. Have you followed the informed consent process as outlined in your currently approved research protocol?
   [X] Yes
   [ ] No – Provide appropriate details as to why the approved informed consent process was not followed.

   b. Have any subjects been withdrawn from the study?
   [X] No [ ] Yes **(If yes, please attach a summary of reasons for withdrawal.)**

   c. Have there been any **SERIOUS** unexpected adverse events associated with the conduct of this research protocol at other sites, if applicable?
   [X] No [ ] Yes **(If yes, please attach a summary of these events and an analysis of their significance and how it impacts the ongoing study)**

   d. Have there been any **UNEXPECTED** adverse events of moderate or greater severity associated with the conduct of this research protocol at this site?
   [X] No [ ] Yes **(If yes, please attach a summary of these events and an analysis of their significance and how it impacts the ongoing study)**

   e. Have there been any deviations from the IRB-approved protocol?
   [X] No [ ] Yes **(if yes: 1) provide a description of the event(s); and 2) provide the plan for preventing future occurrences. For any previously unreported deviation, please also provide a justification for not reporting the deviation to the IRB in a timely manner)**

f. Have there been any modifications to the currently approved research protocol or informed consent document that were not approved by the IRB prior to implementation?
[X] No [ ] Yes **(If yes, attach the detailed description of the unapproved modification (including why the modification was allowed to proceed and the steps taken to prevent recurrence.)**

g. Have there been any subject complaints?
[X] No [ ] Yes **(If yes, please attach a summary of these complaints).**

h. Have there been any breaches of subject confidentiality?
[X] No [ ] Yes **(If yes, please attach a summary of these breaches of subject confidentiality).**

i. Have you become aware of any recent scientific publications that may potentially impact the continued conduct of this research study or the benefit and risk assessment of study participation?
[X] No
[ ] Yes – Describe the potential impact of the scientific publication(s) that may potentially impact the continued conduct of this research study or the benefit and risk assessment of study participation and append a copy.

j. Have there been any changes in the study that may have fiscal impact on UPMC?
[X] No [ ] Yes **(If yes, submit changes for UPMC fiscal review and provide a copy of the revised UPMC Fiscal approval letter.)**

k. Has there been any change in the benefit and risk considerations of study participation as defined in the currently approved research protocol
[X] No [ ] Yes **(If yes, attach the IRB Modification Request describing this change and how it will be conveyed to both current and future research subjects.)**

l. Has new information been identified (e.g., risks or benefits) which affect the willingness of current or future research subjects to participate in this research project?
[X] No [ ] Yes **(If yes, provide copies of recent literature, multi-center reports and a report of the Data Safety Monitoring plan – in addition, attach an IRB Modification Request describing the new information and how it will be conveyed to both current and future research subjects, if applicable.)**

4. Is it your intention to modify the currently approved research protocol or consent form at this time?
[X] No [ ] Yes**(If yes, attach the IRB Modification Request describing the proposed modifications.)**

5. Is this research study sponsored by an external commercial entity (i.e., industry-sponsored)?
[X] No [ ] Yes – **Provide four (4) copies of the current version of the sponsor's clinical protocol and investigational drug or device brochure, if applicable.**

6. This research protocol: [X] remains ongoing (open to additional enrollment).

[ ] remains ongoing (permanently closed to additional enrollment; subjects continue to undergo protocol-related treatment(s)/interactions(s) and follow-up).

[ ] remains ongoing (permanently closed to additional enrollment; all subjects discontinued from protocol-related treatment(s)/interaction(s); collection of follow-up data continues). **Renewal may be expedited.**

[ ] remains ongoing (all protocol-related enrollment, treatment(s)/ interactions(s) and follow-up completed; data analysis continues). **Renewal may be expedited.**

[ ] is terminated (Date of termination: ______________________.
Please attach a final report. See IRB Reference Manual, Chapter 3, Section 3.3.2 for instructions.

****

I certify that the above information is correct:

___________________________ ____________

Principal Investigator Signature Date

B.3 INFORMED CONSENT

Approval Date: June 21, 2005
Renewal Date: June 20, 2006
University of Pittsburgh
Institutional Review Board
IRB #: 0205109

University of Pittsburgh

School of Education
Health, Physical and Recreation Education

140 Trees Hall
Pittsburgh, Pennsylvania 15261
412-648-8320
Fax: 412-648-7092

CONSENT TO ACT AS A SUBJECT IN A RESEARCH STUDY

TITLE: The Influence of Physical Activity and Physical Fitness on Cognitive Processing in Children-2

PRINCIPAL INVESTIGATOR:
Gary E. Clark
Assistant Professor of Physical Education
6301 954 North
Creekside, PA 15732
Telephone: 724-465-8736

CO-INVESTIGATOR:
Allen R. Wagner
Guidance Counselor
East Allegheny School District
1150 Jack Run Road
North Versailles, PA 15137
Telephone: 412-824-8012x180

Jere Gallager PhD.
Associate Dean, School of Education
5610 WWPH
University of Pittsburgh
230 South Bouquet Street
Pittsburgh PA 15260
Phone: 412-648-1774

SOURCE OF SUPPORT: None

DESCRIPTION

Why is this research being done?

The purpose of these studies is to establish the relationship between cognitive processing, physical fitness levels, and physical activity levels in children. This research design expands previous adult findings to children using a paradigm including, simple reaction time, choice reaction time, vigilance, a dual task, probed memory and semantic long term memory tasks as measures of cognitive processing. The question addressed is how does the physical fitness level and the physical activity level of children affect cognitive processing?

Who is being asked to take part in this research study?

Your child is being invited to take part in this study. Participation in this study is limited to children who are 6-14 years of age enrolled in or attending programs in the North Versailles School District as well as children involved in programs at the University of Pittsburgh or Indiana University of Pennsylvania. This group of school age children will be assessed using various measures of physical and cognitive performance. Your child's physical fitness and activity levels will be identified to determine if this impacts various aspects of cognitive performance.

1 Parent/Guardians Initials _________

Approval Date: June 21, 2005
Renewal Date: June 20, 2006
University of Pittsburgh
Institutional Review Board
IRB #: 0205109

What procedures will be performed for research purposes?

Your child will be asked to be physically active for a ½ hour period of time. This time will be spent performing a physical work capacity assessment using a stationary bicycle ergometer. Your child will be required to ride a stationary bicycle for approximately 15 minutes. Part of this time may also be spent participating in the games and activities they are normally involved in (i.e. games, football, Frisbee, swimming). Your child will also be required to complete a sit and reach, curl up, and modified pull up test. While your child is physically active they will wear an elastic band around their chest and a watch on their wrist to monitor their heart rate. Body composition and weight will be measured as well using a Bodyfat Analyzer that looks and works like a bathroom scale.

Your child will also be asked to use a computer program to assess simple reaction time, choice reaction time, movement time, short-term memory, long-term memory and attention using a vigilance task. The tasks are completed by following directions on a computer screen and pressing buttons on a computer keyboard.

RISKS AND BENEFITS

What are the possible risks, side effects, and discomforts of this research study?

Your child's risk for participation in the study is minimal. Most of the activities are a normal part of the program that your child is participating in. The child might experience fatigue or soreness from the fitness test.

What are the possible benefits from taking part in this study?

The possible benefit is knowing how your child performed on each of the assessments. The investigator will be glad to inform you of your child's scores and explain them. Every attempt will be made during the study to make this a pleasant experience for your child.

What is the effect if I decide not to take part in this research study?

If your child decides not to take part in this research study, your child will participate in the program as it is regularly scheduled.

NEW INFORMATION

If I agree to take part in this research study, will I be told of any new risks that may be found during the course of the study?

You will be promptly notified if any new information develops during the conduct of this research study, which may cause you to change your mind about continuing to participate.

COSTS and PAYMENTS

Will I be charged for the costs of any procedures performed as part of this research study?

You will not be charged for any of the procedures performed for the purpose of this research study.

Will I be paid if I take part in this research study?

There will be no compensation for participation in this research study.

COMPENSATION FOR INJURY

Who will pay if I am injured as a result of taking part in this study?

University of Pittsburgh researchers and their associates who provide services at the UPMC Health System (UPMC HC) recognize the importance of your child's voluntary participation in their research studies. These individuals and their staffs will make reasonable efforts to minimize, control, and treat any injuries that may arise as a result of this research. If you believe that your child is injured as a result of the research procedures being performed, please contact immediately the Principal Investigator or one of the co-investigators listed on the first page of this form.

 Parent/Guardians Initials _________

Emergency medical treatment for injuries solely and directly related to your child's participation in this research study will be provided to your child by the hospitals of the UPMC HC. It is possible that the UPMC HS may bill your insurance provider for the costs of this emergency treatment, but none of these costs will be charged directly to you. If your child's research-related injury requires medical care beyond this emergency treatment, you will be responsible for the costs of this follow-up care unless otherwise specifically stated below. You will not receive any monetary payment for, or associated with, any injury that your child suffers in relation to this research.

CONFIDENTIALITY

Who will know about my participation in this research study?

Your child will not be specifically identified in any publication of research results. If any individual's data is reported, name or initials will not identify the individual. The information will only be accessible to the investigators listed in the first page of this document. According to University policy, all research records must be kept for a period of at least five years. In unusual cases, your child's research records may be inspected by appropriate government agencies or be released in response to an order from a court of law. Any information obtained about your child from this research will be kept as confidential (private) as possible. An exception to confidentiality is information on child abuse and neglect that is obtained during research, if that is identified during research, it will immediately be reported to appropriate authorities.

RIGHT TO PARTICIPATE or WITHDRAW FROM PARTICIPATION

Is my participation in this research study voluntary?

Your child's participation in these research studies is completely voluntary. Your child does not have to take part in these research studies and, should you or your child change your mind, your child can withdraw from these studies at any time. Your child's current and future status with the University and any other benefits for which your child qualifies will be the same whether your child participates in this study or not.

If I agree to take part in this research study, can I be removed from the study without my consent?

If the investigator observes that your child does not want to continue or cannot complete a task, your child may be withdrawn from the study. You understand that signing this consent form does not necessarily mean that you child will participate in all of the listed tasks. Signing the consent form will permit screening of your child for the age appropriate tasks in the study. For example the vigilance and memory tasks require a level of vocabulary that young children may not possess.

Approval Date: June 21, 2005
Renewal Date: June 20, 2006
University of Pittsburgh
Institutional Review Board
IRB #: 0205109

VOLUNTARY CONSENT

All of the above has been explained to me and all of my current questions have been answered. I understand that I am encouraged to ask questions about any aspect of this research study during the course of this study, and that such future questions will be answered by the researchers listed on the first page of this form.

Any questions I have about my rights as a research participant will be answered by the Human Subject Protection Advocate of the IRB Office, University of Pittsburgh (1-866-212-2668).

____
Participant's (Child's) Name (Print)

I understand that, as a minor (age less than 18 years), the above-named child is not permitted to participate in this research study without my consent. Therefore, by signing this form, I give my consent for his/her participation in this research study.

____________________________ ____________________________
Parent's or Guardian's Name (Print) Relationship to Participant (Child)

____________________________ ________________
Parent/Guardian's Signature Date

VERIFICATION OF EXPLANATION

I certify that I have carefully explained the purpose and nature of this research to the above named child in age appropriate language. He/she has had an opportunity to discuss it with me in detail. I have answered all his/her questions and he/she provided affirmative agreement (i.e. assent) to participate in this research study.

____
Investigator's Signature Date ________________

Gary E. Clark
Investigator's Printed Name

This research has been explained to me, and I agree to participate.

____________________________ ________________
Signature of Child-Subject Date

____
Printed Name of Child-Subject

I certify that I have explained the nature and purpose of this research study to the above-named individual(s), and I have discussed the potential benefits and possible risks of study participation. Any questions the individual(s) have about this study have been answered, and we will always be available to address future questions as they arise.

____________________________ ________________
Printed Name of Person Obtaining Consent Role in Research Study

____________________________ ____________
Signature of Person Obtaining Consent Date

4 Parent/Guardians Initials ________

____
Printed Name of Child-Subject

I certify that I have explained the nature and purpose of this research study to the above-named individual(s), and I have discussed the potential benefits and possible risks of study participation. Any questions the individual(s) have about this study have been answered, and we will always be available to address future questions as they arise.

___________________________________	___________________
Printed Name of Person Obtaining Consent	Role in Research Study
___________________________________	_____________
Signature of Person Obtaining Consent	Date

B.4 PARENT CONTACT LETTERS

B.4.1 Introduction

Dear Parents/Guardians,

Hello, I would like to introduce myself and take this opportunity to invite your child to participate in an exciting research project being conducted in the East Allegheny School District in co-operation with the University of Pittsburgh.

My name is Gary Clark and I am a Doctoral Candidate at the University of Pittsburgh. I am working to complete my final research project (dissertation) so that I can graduate. My project explores the effect of physical activity level on children during the school day. My background is quite diverse with over 20 years of experience working with children from preschool through college. I have a Bachelors degree in Recreation, a Masters degree in Physical Education and I am a tenured Professional Educator in Pennsylvania as a certified Health and Physical Education teacher. I have coached a variety of sports, directed and worked at a sport and physical activity camps, worked in the fitness industry, taught health and physical education (K-12) in the Pennsylvania public school system, and have also taught a variety of undergraduate and graduate courses at the collegiate level.

The informed consent form that you find included with this letter is part of the process required by the University of Pittsburgh for any research project and explains in detail the activities that will be used. The data collection does not take long (Data is collected during 1 or 2 class periods.) and will be part of the normal school day. Most of the data collection will be done during regularly scheduled physical education classes and involve activities that the students normally participate in. All of the activities are things that I have personally used teaching physical education, in children's camps, and as an athletic coach. Personally I have found that most children find the process educational and enjoyable.

The attachments to this letter and the consent form explain all of the activities in great detail. If you would like your child to have the opportunity to participate in this program just initial or sign at the designated areas and return it to Mr. Wagner at the first floor Guidance office using the included envelope. If you have any questions please feel free to contact Mr. Wagner at 412-824-8012 Ext. 180.

Thank you,

Gary E. Clark
University of Pittsburgh

Allen R. Wagner
East Allegheny
Middle/High School

Enc: 2

Explanation of Activities

<u>Flexibility</u> (Approximately 30 seconds to complete.) will be assessed using the Back Saver Sit-and-Reach test (Cooper Institute for Aerobics Research, 1999). This test uses a standard sit and reach box (12 inch high box

with a yardstick attached with the 9-inch mark at the edge of the box.). Subjects remove shoes and sit with hips parallel to the box and one leg straight with the foot against the box and the other leg bent with the foot flat on the floor. The subject places one hand on top of the other with the palms down and reaches as far as possible. The subject attempts this four times with the best score recorded. The same procedure is repeated for the other leg.

Muscular Strength/Endurance (Normally about 60 seconds to complete.) Curl-ups will be used to measure abdominal strength and endurance (Cooper Institute for Aerobics Research, 1999). Equipment consists of a cardboard strip 30 inches long and 4 ½ inches wide. The subject lies on a mat with knees bent and feet flat with the arms and hands flat (palms down) at their side. The subject begins with their fingers touching the near side of the measuring strip and curls up until their fingers touch the far side of the strip and then lower until their head lightly touches the mat. Repetitions are performed to an announced cadence of one curl-up every 3 seconds.

Muscular Strength/Endurance (Normally about 60 seconds to complete.) Upper body strength and endurance will be assessed using a modified pull up test (Cooper Institute for Aerobics Research, 1999). This test was designed because it is easier than regular pull ups and most children are successful at doing it. The assessment uses a modified pull up bar where the student lies on their back to grab the bar using an overhand grip (reverse push up). The bar is adjusted so that it is 2 inches above the subject's reach when they are lying on the floor and an elastic band is placed 7 inches below the bar. The starting position has the subject hanging from the bar, arms and body straight with the heels touching the floor. The subject's body should not be touching the mat. To perform the test the subject pulls up until the elastic band touches just below the chin. The subject then lowers until the arms are straight. The test is continued until the subject performs two incorrect pull-ups.

Heart Rate (Child will have a chance to wear this several times.) Heart rate will be measured using a Polar Heart Rate Monitor. These monitors were designed for use in Physical Education settings. The equipment consists of a wrist watch (receiver) and a small elastic belt (transmitter) that the child will put on. The transmitter sends a signal to the receiver displaying the heart rate.

Aerobic Capacity (Normally less than 15 minutes to complete) This is measured using a stationary bicycle. The seat will be adjusted to 95% of the subjects leg length with the ball of the foot on the pedal at maximal leg extension. The subject will assume an upright-seated posture with hands properly positioned on the handlebars and will be given a 2-min. warm up period to familiarize him or herself with the equipment. Since the subjects are children the initial load setting will be .25 kg with a pedal rate of 60 rev/min. Using a Polar heart rate monitor the subjects heart rate will be monitored every minute. Cycling will be terminated when the subject attains a heart rate of 150 b/min. or requests termination of the test due to fatigue. Exercise intensity will be increased gradually through the stages of the test using work increments of .5, 1, 1.5, 2, 2.5, 3, 3.5kg. Upon completion of the test subjects will cool down for 2 minutes at 30 rpm. This is a sub maximal test and is used to predict aerobic capacity without a maximal effort.

Computer Activities A computer program (All of the computer activities combined normally take less than one class period of 44 minutes to complete.) will be used to measure the children's ability to remain on task and pay attention. The activities on the computer are fairly simple and only require the child to watch the screen, press a few keys and use the mouse.

1.) Discrete simple reaction time: The subject holds down the spacebar. After a random interval (1 to 10 seconds) a small symbol (signal) appears in a random position on the screen. The test consists of 20 trials. On the appearance of the signal, the subject is required to lift his/her finger from the spacebar and press any of the target keys; these are the keys 4-9 on the top row of the keyboard.

2.) Discrete 6-choice reaction time: The subject depresses the spacebar and a representation of the 6 target keys (keys 4-9 on the top row of the keyboard) is shown on the computer screen. After a random interval (1 to 10 seconds) one of these keys is highlighted and the subject is required to press the corresponding key on the keyboard.

3.) Duel task – tracking and simple reaction time: The primary task requires the subject to use a mouse to follow a smooth but randomly moving target on the computer screen. At random intervals the secondary task stimulus (a small symbol) is presented and the subject presses the space bar.

4.) Numeric vigilance: Three-digit numbers are presented on the computer screen at a rate of 100 per minute. Each number differs randomly from the previous number in one of the digits. Of the numbers presented during the test, 8% are duplicates of the previous number. The subject is required to identify these duplicates and press the spacebar as they occur.

5.) Probed memory: Subjects will be instructed that they will be shown a series of consonants, and to try to remember the letters. A sequence of eight consonants is presented with a new consonant being added every second. All the consonants in the sequence remain visible until the last consonant in the list is displayed. After an additional one second the complete sequence of 8 characters is blanked out. The subject is presented with a consonant and asked whether or not it had been part of the list.

6.) Tower: This computer problem solving game has the child moving a stack of blocks (discs) on the computer screen from one pile to another while keeping them in the same order.

Signatures

On the consent to act as a subject in a research study form, signatures/initials are required in several locations. Each of the locations mentioned below are marked with sticky note arrows and descriptors.

On the bottom of page 1, the Parent/Guardian initials in the bottom right hand corner.
On the bottom of page 2, the Parent/Guardian initials in the bottom right hand corner.
On the bottom of page 3, the Parent/Guardian initials in the bottom right hand corner.
On page 4 two areas that need to be completed.
On the first line at the top of the page, print the Child's name.
The next section is for the parent/guardian where there are labeled lines for:
The parent/guardian's printed name
The relationship to the child-Mother, Father, Guardian
The parent/guardian's signature
The date
The rest of the items on this page will be completed when the investigator explains everything to the child and asks them if they have any questions.

B.4.2 Thank You Letter

School of Education
UNIVERSITY OF PITTSBURGH

11/4/2005

Dear Parent/Guardian

We have had a great response to the research project we are completing with the University of Pittsburgh. In just a few days since the forms were sent out, many parents have already returned them. Mr. Clark and I wish to personally thank you for allowing your daughter to participate in this important research project. We are now beginning the physical fitness testing and computer testing with the 7th & 8th grade students beginning with the girls. Testing will be done either in their physical education class or we will call them out of their cycle classes. The results obtained from this project will be used to improve the overall educational process and the heath and wellness of all the students at East Allegheny School District.

If you have not returned the parent signature form, please do so at this time. If you have misplaced this form please have your daughter pick one up from Mr. Clark in the physical education testing area or have them stop by the 1st floor guidance office and we will give them another set of forms for your signature. If you have any question please call me in the guidance office at 412-824-8012 Ext 180.

The parent signature forms should be returned to Mr. Wagner in the 1st floor guidance as soon as possible.

Again **thank you** for participating in this important educational research.

Your partner in your child's education

Allen R. Wagner M.Ed.
Guidance Counselor
East Allegheny School District

Gary E. Clark
University of Pittsburgh
6301 954 North
Creekside, PA 15732
724-465-8736
gec11+@pitt.edu

Allen R. Wagner
East Allegheny Middle/High School
1150 Jacks Run Rd.
North Versailles, PA 15137
412-824-8012 Ext. 180
alwagner@pitt.edu

B.4.3 Photo Release

School of Education
UNIVERSITY OF PITTSBURGH

RELEASE

I/We hereby authorize the East Allegheny School District or the University of Pittsburgh, its officers, employees, agents and assigns to photograph, videotape, audiotape and/or otherwise record (hereinafter collectively referred to as "Recordings") my/our child, (name) ____________________________, before, during and after his/her participation in the Dissertation research by Allen Wagner/Gary Clark, at the East Allegheny Junior/Senior High School, in December 2005; to display my/our child's likeness on and in all such Recordings and to use such Recordings, and such likeness, for the University's purposes at any time without notice to me or my/our child, in the sole discretion of the University.

I/We understand that I/we and my/our child shall not be entitled to any remuneration of any kind for any use of my/our child's likeness or the described Recordings.

I/We further understand and agree that the University of Pittsburgh shall have and retain all worldwide rights of ownership, distribution and use of the Recordings (in all reproduction, distribution or use, at any time and in any way, commercial or otherwise, of all or any portion of the Recordings is subject to the University's prior written consent. I/We agree that I/we will assist the University, as needed, in registering intellectual property rights in any of the Recordings upon request.

I/We have read this entire Release, fully understand it and agree to be legally bound by it.

Releasor's Printed Name ________________________________

Releasor's Signature ________________________________

Date ________________________________

Gary E. Clark
University of Pittsburgh
6301 954 North
Creekside, PA 15732
724-465-8736
gec11+@pitt.edu

Allen R. Wagner
East Allegheny Middle/High School
1150 Jacks Run Rd.
North Versailles, PA 15137
412-824-8012 Ext. 180
alwagner@pitt.edu

B.4.4 Data Collection Directions

Data Collection Directions & Form

Name:______________________________		
Gender:	Male / Female	(Circle One)
Height:	Feet ________	Inches _______
Weight:	Pounds ________	
Age:	Years _______	
Birth Date MM/DD/YYYY		____ / ____ / _______

Heart Rate Monitor

Putting on the HR Monitor

Equipment needed includes the wristwatch, transmitter, and an elastic strap.
Select the proper size elastic strap for the subject.
Ask the subject to put on the wristwatch.
Show the subject the transmitter, show them the electrodes that must be in contact with the skin.
Explain that the transmitter senses their HR and sends a signal to the watch.
Describe to the subject where their sternal notch is, and explain that the transmitter should be centered over that spot.
Have the subject put on the transmitter.
Tell the subject not to press any of the buttons on the watch.
Ask the subject if they have any questions.
Press the red 'start button' on the watch and have the subject hold the watch near their chest until a HR is displayed and the coded signal locks in.
At the end of the session press the blue button twice to stop recording. The time of day screen will appear.

Activity or Sedentary Session

Record the date and time on the data form.
Press the red button to start recording, have the subject hold the watch near the chest until HR is displayed and coded signal locks in.
Following the session press the blue button twice and the time of day screen will be displayed.
Press the upper right button once, the screen will read file.
Press the red button twice, the screen will read in zone. Read and record the zones. The middle row shows time spent in target zone, the lower row shows average heart rate.
Press the upper right button once. The screen will read above, read and record the time spent above the target zone.
Press the upper right button once. The screen will read below, read and record the time spent below the target zone.

Press and hold the blue button to return to time of day screen.

Activity HR	**Sedentary HR**
Date: _____ / ______ / ________	Date: _____ / ______ / ________
Time: ____:_____	Time: ____:_____
In Zone: ______	In Zone: ______
Avg. HR: ______	Avg. HR: ______
Above TZ: ______	Above TZ: ______
Below TZ: ______	Below TZ: ______

Activity

Physical Activity

The subject will put on the Polar E600 heart rate monitor (refer to heart rate monitor section). Explain to the subject that the goal is to keep their heart rate in their training zone for 20 out of30 minutes. Walk with the subject, observe their heart rate, and provide feedback to help them stay within their training zone.

Sedentary Behavior

The subject will put on the Polar E600 heart rate monitor (refer to heart rate monitor section). Explain to the subject that the goal is simply to sit and relax for 30 minutes. Observe the activity being completed and provide feedback to keep the subject relaxed with the heart rate below the training zone.

Psych E

Enter Subject Data
Click on the Pscyh E icon to open the software program.
Click the tab titled ‘new subject’ and enter the data (subject information) from the form below into the computer, then click the O.K. button.
Click the ‘study group’ tab and highlight the following sedentary behavior tab. Highlight the subject you just entered from the subjects not in group column, and press the add button. Repeat this procedure adding the subject to the following activity group.

Psych E subject information

Forename (First Name): ___________________
Surname (Last Name): ___________________
Subject Number: _____ (Number will be assigned by computer)
DoB (dd/mm/yyyy) ___________________

Following Activity

Click on the Psych E icon to open the software program.
Click on the test setup tab and select ‘Diss’ from the test set name.
Click on the study group tab and select ‘Following Activity’ from the study group column.
Highlight the subjects name from the ‘subjects in group’ column.

Prior to starting the assessment, click the demo tab, select each test to be used and read the directions for the test. Select run test button and allow the subject to practice each test until they understand the procedure. Click the end button to stop the demonstration. Ask the subject if they have any questions.

Click the test session tab from the top of the page. The subjects name should appear. Click on their name to start the assessment. The name will appear for each test. Remind the subject of the test procedures and ask them if they have any questions. Press the start test button for each test.

Start test: Simple Reaction Time
Start test: Choice reaction
Start test: Dual task
Start test: Vigilance
Start test: Probed memory

Following Sedentary Behavior

Click on the Psych E icon to open the software program.
Click on the test setup tab and select ‘Diss’ from the test set name.
Click on the study group tab and select ‘Following Sedentary Behavior’ from the study group column.
Highlight the subjects name from the ‘subjects in group’ column.

Prior to starting the assessment, click the demo tab, select each test to be used and read the directions for the test. Select run test button and allow the subject to practice each test until they understand the procedure. Click the end button to stop the demonstration. Ask the subject if they have any questions.

Click the test session tab from the top of the page. The subjects name should appear. Click on their name to start the assessment. The name will appear for each test. Remind the subject of the test procedures and ask them if they have any questions. Press the start test button for each test.

Start test: Simple Reaction Time
Start test: Choice reaction
Start test: Dual task
Start test: Vigilance
Start test: Probed memory

Tower of Hanoi

Double click the ‘Tower Of Hanoi’ Full Folder to open it.
Double click the ‘Hanoi’ Icon.
The tower of Hanoi Screen will open.

Subject Orientation

Select the ‘Options’ button.
Select 2 Discs, Source Picket Left, and Destination Picket Right.
Click ‘OK’
Click the ‘Solve Puzzle Manually’ button
Ask the subject to read the ‘Mouse Operation’ directions displayed on the screen.
Ask the subject if they have any questions.
Allow the subject to solve the puzzle.

Assessment

Record the date and time on the subjects data sheet.
Click the ‘Reset’ button
Select the ‘Options’ button.
Set the number of Discs to ‘3’, Select the Source and Destination Picket.
Click ‘OK’
Click the ‘Solve Puzzle Manually’ button
Review the ‘Mouse Operation’ directions and see if the subject has further questions.
Allow the subject to solve the puzzle.
Record the ‘Moves Taken’
Record the ‘Time Taken’
Exit the Program

Following Activity

Date: _____ / ______ / ________
Time: ____:_____
Number of Discs _____
Source Picket __________
Destination Picket ___________
Moves Taken _________
Time Taken _________

Following Sedentary Behavior

Date: _____ / ______ / ________
Time: ____:_____
Number of Discs _____
Source Picket __________
Destination Picket ___________
Moves Taken _________
Time Taken _________

Appendix C

STATISTICAL TABLES

Table 11: Original Data Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Choice RT Following Activity Percent Correct	98.3784	37	3.13006	.51458
	Choice RT Following Sedentary Percent Correct	99.4595	37	1.57400	.25876
Pair 2	Choice RT Following Activity Thinking Time	628.1081	37	189.59662	31.16949
	Choice RT Following Sedentary Thinking Time	693.2703	37	187.93020	30.89553
Pair 3	Choice RT Following Activity Movement Time	449.0000	37	111.59923	18.34680
	Choice RT Following Sedentary Movement Time	536.1081	37	178.59619	29.36103
Pair 4	Choice RT Following Activity Total Time	1077.0270	37	237.66439	39.07178
	Choice RT Following Sedentary Total Time	1234.4595	37	256.63112	42.18990
Pair 5	Simple RT Following Activity Thinking Time	475.6486	37	141.15697	23.20606
	Simple RT Following Sedentary Thinking Time	585.2703	37	345.02566	56.72187
Pair 6	Simple RT Following Activity Movement Time	363.4054	37	123.65689	20.32907
	Simple RT Following Sedentary Movement Time	545.4865	37	234.91850	38.62036
Pair 7	Simple RT Following Activity Total Time	839.5405	37	196.30851	32.27292

	Simple RT Following Sedentary Total Time	1132.3784	37	469.50922	77.18684
Pair 8	Probed Memory Percent Correct Following Activity	74.4595	37	10.59244	1.74139
	Probed Memory Percent Correct Following Sedentary	71.7568	37	12.65000	2.07965
Pair 9	Dual Task Following Activity Reaction Time	514.8108	37	100.76150	16.56509
	Dual Task Following Sedentary Reaction Time	519.2162	37	92.83233	15.26154
Pair 10	Dual Task Following Activity False Hits	5.0000	37	11.38225	1.87123
	Dual Task Following Sedentary False Hits	5.2432	37	14.68447	2.41411
Pair 11	Dual Task Following Activity Misses	1.8378	37	1.34399	.22095
	Dual Task Following Sedentary Misses	2.7568	37	1.36230	.22396
Pair 12	Dual Task Following Activity Time on Target	10.4054	37	19.35410	3.18179
	Dual Task Following Sedentary Time on Target	1.1081	37	6.74036	1.10811
Pair 13	Vigilance Following Activity Number of Hits	9.9730	37	2.88181	.47377
	Vigilance Following Sedentary Number of Hits	8.0541	37	2.82790	.46490
Pair 14	Vigilance Following Activity Number of Misses	4.9730	37	2.88181	.47377
	Vigilance Following Sedentary Number of Misses	6.8919	37	2.74655	.45153
Pair 15	Vigilance Following Activity False Hits	8.4054	37	9.85015	1.61936
	Vigilance Following Sedentary False Hits	15.4865	37	33.90970	5.57472
Pair 16	Tower of Hanoi Total Moves Following Activity	26.3514	37	8.92940	1.46798
	Tower of Hanoi Total Moves Following Sedentary	27.0811	37	11.30236	1.85810
Pair 17	Tower of Hanoi Time to Complete Following Activity	77.8919	37	43.12500	7.08971
	Tower of Hanoi Time to Complete Following Sedentary	116.9459	37	73.59308	12.09863
Pair 18	Average Heart Rate for Activity Session	126.3784	37	8.66459	1.42445

HR Average for Sedentary Session	85.1622	37	9.59315	1.57710

Table 12: Original Data Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Choice RT Following Activity Percent Correct - Choice RT Follwoing Sedentary Percent Correct	-1.08108	3.75188	.61680	-2.33202	.16986	-1.753	36	.088
Pair 2	Choice RT Following Activity Thinking Time - Choice RT Following Sedentary Thinking Time	-65.16216	176.92583	29.08643	-124.15217	-6.17215	-2.240	36	.031
Pair 3	Choice RT Following Activity Movement Time - Choice RT Following Sedentary Movement Time	-87.10811	126.14647	20.73835	-129.16744	-45.04878	-4.200	36	.000
Pair 4	Choice RT Following Activity Total Time - Choice RT Following Sedentary Total Time	-157.43243	241.98801	39.78258	-238.11525	-76.74961	-3.957	36	.000
Pair 5	Simple RT Following Activity Thinking Time - Simple RT Following Sedentary Thinking Time	-109.62162	373.70126	61.43611	-234.21982	14.97658	-1.784	36	.083
Pair 6	Simple RT Following Activity Movement Time - Simple RT Following Sedentary Movement Time	-182.08108	178.28276	29.30951	-241.52351	-122.63865	-6.212	36	.000

Pair 7	Simple RT Following Activity Total Time - Simple RT Following Sedentary Total Time	-292.83784	450.04176	73.98641	-442.88923	-142.78645	-3.958	36	.000
Pair 8	Probed Memory Percent Correct Following Activity - Probed Memory Percent Correct Following Sedentary	2.70270	12.05281	1.98147	-1.31590	6.72131	1.364	36	.181
Pair 9	Dual Task Following Activity Reaction Time - Dual Task Following Sedentary Reaction Time	-4.40541	73.97652	12.16166	-29.07041	20.25959	-.362	36	.719
Pair 10	Dual Task Following Activity False Hits - Dual Task Following Sedentary False Hits	-.24324	16.90892	2.77981	-5.88096	5.39447	-.088	36	.931
Pair 11	Dual Task Following Activity Misses - Dual Task Following Sedentary Misses	-.91892	1.99135	.32738	-1.58287	-.25497	-2.807	36	.008
Pair 12	Dual Task Following Activity Time on Target - Dual Task Following Sedentary Time on Target	9.29730	18.28610	3.00622	3.20041	15.39419	3.093	36	.004
Pair 13	Vigilance Following Activity Number of Hits - Vigilance Following Sedentary Number of Hits	1.91892	2.87110	.47201	.96164	2.87619	4.065	36	.000
Pair 14	Vigilance Following Activity Number of Misses - Vigilance Following Sedentary Number of Misses	-1.91892	2.79263	.45911	-2.85003	-.98781	-4.180	36	.000
Pair 15	Vigilance Following Activity False Hits - Vigilance Following Sedentary False Hits	-7.08108	26.81767	4.40880	-16.02254	1.86038	-1.606	36	.117

Pair 16	Tower of Hanoi Total Moves Following Activity - Tower of Hanoi Total Moves Following Sedentary	-.72973	12.03617	1.97873	-4.74279	3.28333	-.369	36	.714
Pair 17	Tower of Hanoi Time to Complete Following Activity - Tower of Hanoi Time to Complete Following Sedentary	-39.05405	57.67146	9.48113	-58.28268	-19.82543	-4.119	36	.000
Pair 18	Average Heart Rate for Activity Session - HR Average for Sedentary Session	41.21622	11.89336	1.95526	37.25077	45.18166	21.080	36	.000

BIBLIOGRAPHY

Ahamed, Y., MacDonald, H., Reed, K., Naylor, P.J., Liu-Ambrose, T., and McKay, H. (2007). School-based physical activity does not compromise children's academic performance. Medicine and Science in Sports and Exercise. 39: 371-376.

Allen, D. (1998). An assessment of the accuracy of a new wrist-worn heart rate monitor that employs proprietary digital signal processing technology. Journal of Cardiopulmonary Rehabilitation, 8 (10), 399.

Altman, J. and Das, G.D. (1965). Autoradiographic and histolic evience of postnatal neurogenesis in rats. Journal of Computational Neurology, 124, 319-335.

American Academy of Pediatrics (2000). Physical fitness and activity in schools. Pediatrics, 105(5), p1156.

American Academy of Pediatrics (1992). Fitness, activity, and sports participation in the preschool child. Pediatrics,, 90 (6)., 1002-1004.

American Academy of Pediatrics (1990). Fitness, activity and sports participation in the preschool child. Pediatrics, 90(6), 1002-1004.

American Heart Association (2004). Physical education in schools public policy toolkit. Office of State Advocacy, Dallas, Texas.

American School Health Association (1997). Guidelines for school and community programs to promote lifelong physical activity among young people (report by National Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control and Prevention). Journal of School Health, 67(6), 202-240.

Anshel, M.H. (1996). Effect of chronic aerobic exercise and progressive relaxation on motor performance and affect following acute stress. Behavioral Medicine, Vol. 21, Issue 4, p186, 11p.

Anderson, E.A., Zhang, J.J., Rudisill, M.E., & Gaa, J. (1997). Validity and reliability of a timed curl-up test: Development of a parallel form for the FITNESSGRAM abdominal strength test. Research Quarterly for Exercise and Sport, 68 (Suppl.), A-51.

Austin, J.S., and Partridge, E. (1995). Prevent school failure: Treat test anxiety. Preventing School Failure, Vol. 40, Issue 1, p10, 4p.

Barnes, D.E., Yaffe, K., and Satariano, W.A. (2003). A longitudinal study of cardiorespiratory fitness and cognitive function in healthy older adults. Journal of the American Geriatric Society, 51: 459-465.

Bar-Or, O. (1995). Health benefits of physical activity during childhood and adolescence. Presidents Council on Physical Fitness and Sports Research Digest, 2, No. 4.

Bar-Or, O. (1994). Childhood and adolescent physical activity and fitness and adult risk profile. In: Bouchard C., Shephard, R.J., Stephens, T., (Eds.). Physical Activity, Fitness, and Health: International Proceedings and Consensus Statement. Champaign, IL: Human Kinetic Publishers.

Barrouillet, P., Bernardin, S., and Camos, V. (2004). Time constraints and resource sharing in adults' working memory spans. Journal of Experimental Psychology: General, 133, 83-100.

Bashore, T.R. (1989). Age, physical fitness, and mental processing speed. In: Annual Review of Gerontology and Geriatrics. Voume 9: Clinical and Applied Gerontology, M.P. Lawton (Ed.). New York: Springer, 120-144.

Berger, B.G. (1996). Psychological benefits of an active lifestyle: What we know and what we need to know. QUEST, 48, 330-353.

Biddle, S., Sallis, J.F., and Cavill, N.A. (1998). Yound and active? Young people and health enhancing physical activity: Evidence and Implications. London, England: Health Education Authority.

Bjorklund, D.F. and Brown, R. D. (1998). Physical play and cognitive development: Integrating activity, cognition, and education. Child Development, 69 (3), 604-606.

Blomquist, K.B. and Danner, F. (1987). Effects of physical conditioning of information processing efficiency. Perceptual and Motor Skills, 65, 175-186.

Bluechardt, M.H. and Shephard, R.J. (1995). Using an extracurricular physical activity program to enhance social skills. Journal of Learning Disabilities, Vol. 28, Issue 3, 160-169.

Bouchard, C., Shephard, R.J., Stephens, T., Sutton, J.R., and McPherson, B.D. (1990). Exercise, fitness, and health: A consensus of current knowledge. Champaign, Ill: Human Kinetics Books.

Boyd, K.R. and Hrycaiko, D.W. 91997). The effect of a physical activity intervention package on the self-esteem of pre-adolescent and adolescent females. Adolesence, Vol. 32 Issue 127, 693-708.

Brisswalter, J., Colldeau, M., and Rene, A. (2002). Effects of acute physical exercise characteristics on cognitive performance. Sports Medicine, 32 (9): 555-566.

Brisswalter, J., Durand, D. Delignieres, D, Et al. (1995). Optimal and non-optimal demand in a dual task of pedaling and simple reaction time: effects on energy expenditure and cognitive performance. Journal of Human Movement Studies, 29, 15-34.

Bunce, D. (2001). The locus of age x health-related fitness interactions in serial choice responding as a function of task complexity: Central processing or motor function? Experimental Aging Research, 27: 103-122.

Burpee, R.H. and Stroll, W. (1936). Measuring reaction time of athletes. Research Quarterly, 7, 110-118.

Calfas, K.J. and Taylor, W.C. (1994). Effects of physical activity on psychological variables in adolescents. Pediatric Exercise Science, 6 406-423.

California Department of Education (2002). State Study Proves Physically Fit KidsPerform Better Academically, News Release, REL #02-37, Sacramento.

Calvin, W.H. (1993). The unitary hypothesis: A common neural circuitry for novel manipulations, language, plan-ahead, and throwing? In Tools, Language, and Cognition in Human Evolution, edited by Kathleen R. Gibson and Tim Ingold. Cambridge University Press, 230-250.

Centers for Disease Control and Prevention. (1997). Guidelines for School and Community Programs to Promote Lifelong Physical Activity Among Young People. MMWR; 46(RR-6): 1-36.

Chaiken, S.R., Kyllonen, P.C., and Tirre, W. (2000). Organizations and components of psychomotor ability. Cognitive Psychology, 40, 198-226.

Chodzko-Zajko (1991). Physical fitness, cognitive performance, and aging. Medicine and Science in Sports and Exercise, 23, 868-872.

Chodzko-Zajko, W.J., and Moore, K.A. (1994). Physical fitness and cognitive function in aging. Exercise and Sport Science Reviews, 22, 195-220.

Coe, D.P., Pivarnik, J.M., Womack, C.J., Reeves, M.J., and Malina, R.M. (2006). Effect of physical education and activity levels on academic achievement in children. Medicine and Science in Sports and Exercise, 38: 1515-1519.

Chung, Y.B. and Baird, M.K. (1999). Physical exercise as a counseling intervention. Journal of Mental Health Counseling, Vol. 21 Issue 2, p124, 12p.

Colchico, K.C., Zybert, P., and Basch, C.E. (2000). Effects of after-school physical activity on fitness, fatness, and cognitive self-perceptions: A pilot study among urban, minority adolescent girls. American Journal of Public Health, Vol. 90, No. 6, 977-978.

Colcombe, S.J., Erickson, K.I., Raz, N., Webb, A.G., Cohen, N.J., McAuley, E., and Kramer, A.F. (2003). Aerobic fitness reduces brain tissue loss in aging humans. Journal of Gerontology: Medical Sciences, 58A(2), 17680.

Conway, A.R.A., Kane, M.J., & Engle, R.W. (2003). Working memory capacity and its relation to general intelligence. Trends in Cognitive Sciences, 7, 547-552.

Cooper Institute for Aerobics Research (1999). Fitnessgram, Test Administration Manual, 2 nd Editition, Human Kinetics.

Corbin, C.B., and Pangrazi, R.P. (1992). Are American children fit? Research Quarterly for Exercise and Sport, 63, 95-106.

Cotman, C.W., and Berchtold, N.C. (2002). Exercise: a behavioral intervention to enhance brain health and plasticity. TRENDS in Neurosciences, Vol. 25, No. 6.

Council for Physical Education for Children of the National Association for Sport and Physical Education (1998). Physical Activity for Children: A Statement of Guidelines. Reston, VA: NASPE Publications; 1-21.

Craft, D.H. (1983). Effect of prior exercise on cognitive performance tasks by hyperactive and normal young boys. Perceptual and Motor Skills, 56, 979-982.

Crick, F. (1994). The Astonishing Hypothesis: The Scientific Search for the soul. New York: Charles Scribner's Sons.

Crouter, S.E., Albright, C., and David, R. Jr. (2004). Accuracy of Polar S410 heart rate monitor to estimate energy cost of exercise. Medicine and Science in Sports and Exercise, 36(8), 1433-1439.

Davranche, K., Audiffren, M, and Denjean, A. (2006). A distributional analysis of the effect of physical exercise on a choice reaction time task. Journal of Sports Science 24(3): 323-330.

Devaney, B., Schochet, P., Thornton, C., Fasciano, N., and Gavin, A. (1993). Evaluating the effects of school health interventions on school performance: Design report. Princeton, NJ: Mathematica Policy Research, Inc.

Dik, M.G., Deeg, D., Visser, M., and Jonker, C. (2003). Early life physical activity and cognition at old age. Journal of Clinical and Experimental Neuropsychology, Vol. 25, No. 5, pp. 643-653.

DiLorenzo, T.M., Renee, C., Stucky-Ropp, Vander Wal, J.S., and Gotham, H.J. (1998). Determinants of exercise among children II. A longitudinal analysis.

Dinges, D. Jauregui, B., Nguyen, L. (1998). Changing behavior to prevent drowsy driving and promote traffic safety: Review of proven, promising and uproven techniques. AAA Foundation for Traffic Safety.

DiPietro, L., Seeman, T.E., Merrill, S.S., and Berkman, L. (1996). Physical activity and measures of cognitive function in healthy older adults: The MacArthur study of successful aging. Journal of Aging and Physical Activity, 4, 362-376.

Dishman, R.K. (1995). Physical activity and public health: Mental health. QUEST, 47,362-385. Duffy, E. (1962). Activation and behavior. New York: Wiley.

Donders, F.C. (1869). On the speed of mental processes. In W.G. Koster (Ed.), Attention and performance II. Acta Psychologica, 30, 412-431.

Duffy, E. (1962). Activation and behavior. New York: Wiley.

Dunn, A.L., Marcus, B.H., Kampert, J.B., Garcia, M.E., Kohl, H.W. and Blair, S.N. (1999). Comparison of lifestyle and structured interventions to increase physical activity and cardiorespiratory fitness: A randomized trial. Journal of the American Medical Association, 281, 327-334.

Dwyer, T., Coonan, W.E., Leitch, D.R., Hetzel, B.S., and Baghurst, R.A. (1983). An investigation of the effects of daily physical activity on the health of primary school students in South Australia. International Journal of Epidemiology, 12, 308-313.

Dwyer, T., Coonan, W.E., Worsley, L.A., and Leitch, D.R. (1979). An assessment of the effects of two physical activity programs on coronary heart disease risk factors in primary school children. Community Health Studies, 3, 196-202.

Dwyer, T., Sallis, J.F., Blizzard, L., Lazarus, R., and Dean, K. (2001). Relation of Academic Performance to Physical Activity and Fitness in Children. Pediatric Exercise Science, 13, 225-237.

Ellis, H., Thomas, R., McFarland, A., and Lane (1985). Emotional mood states and retrieval in episodic memory. Journal of Experimental Psychology: Learning, Memory, and Cognition, 11, 363-370.

Emery C. F, Huppert F, Schein R, (1995). relationships among age, exercise, health, and cognitive function in a British sample. Gerentologist 35, pgs.375-385.

Eriksson, P.S., Perfilieva, E., Bjork-Eriksson, T., Alborn, A.M., Nordborg, C., and Peterson, D.A. (1998). Neurogenesis in the adult human hippocampus. Nature Medicine, Vol. 4, No. 11, 1313-1317.

Etnier, J.L., Salazar, W., Landers, D.M., Petruzzello, S.J., Han, M., and Nowell, P. (1997). The influence of physical fitness and exercise upon cognitive functioning: A meta-analysis. Journal of Sport and Exercise Psychology, 19(3), 249-277.

Etnyre, B., and Kinugasa, T. (2002). Postcontraction influences on reaction time (motorcontrol and learning). Research Quarterly for Exercise and Sport 73(3): 271-282.

Epstein, L.H., Paluch, R.S., Kalakanis, L.E., Goldfield, G.S., Cerny, F.J., and Roemmich, J.N. (2001). How much activity do youth get? A quantitative review of heart-rate measured activity. Pediatrics, 108 (3), e44.

Esterson, A. (1993). Seductive mirage: An exploration of the work of Sigmund Freud. Chicago: Open Court.

Ewert, P.H., and Lambert, JF. (1932). Part II: The effect of verbal instructions upon the formation of a concept. Journal of General Psychology, 6: 400-411.

Faulkner, G., and Biddle, S. (1999). Exercise as an adjunt treatment for schizophrenia: A review of the literature. Journal of Mental Health, 8, 5, 441-457.

Fowler, B., Taylor, M., and Porlier, G. (1987). The effects of hypoxia on reaction time and movement time components of a perceptual-motor task. Ergonomics, 30, 1475-1485.

Francis, K.T. (1999). Status of the year 2000 health goals for hysical activity and fitness. Physical Therabpy, v79, p 405.

Franks, D.B. (1997). Evaluating physical activity and fitness in children and youth. American College of Sport Medicine Health Fitness Journal, 1 (5) 20-24.

Freedman, D.S., Dietz, W.H., Stinivasan, S.R., and Berenson, G.S. (1999). The relation of overweight to cardiovascular risk factors among children and adolescents: the Bogalusa heart study. Pediatrics: 103, 1175-1182.

French, K., Thomas, K. and Thomas J. (1996). Expertise in youth sport: The relationship between knowledge and sill. In F. Smoll, and R. Smith (Eds.) Children and Youth in Sport: A Biopsychosocial Perspective. 338-358.

Gabbard, C., and Barton, J. (1979). Effects of physical activity on mathematical computations among young children. The Journal of Psychology, 103, 287-288.

Gallahue, D.L., and Ozmun, J.C. (2002). Understanding motor development: Infants, children adolescents, and adults, 5th . New York, McGraw-Hill.

Goldstein F.C., and Levin, H.S. (1987). Disorders of reasoning and problem solving ability. In M. Meier, A. Benton, & L. Diller (Eds.), Neuropsychological rehabilitation. London: Taylor & Francis Group.

Goodwin, S.C. (1997). The benefits of homogenous grouping in physical education. Physical Educator, Vol. 54, Issue 3, p114, 6p.

Gould, D., and Krane (1992). The arousal-performance relationship: Current status and future directions. In T.S. Horn (ed.), Advances in Sport Psychology (119-142). Champaign, IL: Human Kinetics.

Green, D. M., and Swets, J.A. (1966). Signal detection theory and psychophysics. New York: Wiley.

Guttentag, R., and Ornstein, P. (1990). Attentional capacity and children's memory strategy use. In J. Ennis (eds.), The development of attention: Research and theory, 305-319. North Holland: Elsevier Science Publishers.

Hardy, L. (1990). A catastrophe model of performance in sport. In J.G. Jones & Hardy (Eds.), Stress and performance in sport. Chichester: Wiley, pp. 81-131.

Hassm'en, Koivula (1997). Mood, physical working capacity and cognitive performance in the elderly as related to physical activity. Aging. 9136-142 Hechinger, E.M. (1992). Fateful choices: Healthy youth for the 21st century. New York, NY. Carnegie corporation of New York; 173-187.

Hechinger, E.M. (1992). Fateful choices: Healthy youth for the 21st century. New York, NY, Carnegie Corporation of New York; 173-187.

Hick, W. E. (1952). On the rate of gain of information. Quarterly Journal of Experimental Psychology, 4, 11-26.

Hill, G.M. and Miller, T.A. (1997). A comparison of peer and teacher assessment of students' physical fitness performance. Physical Educator, Vol. 54, Issue 1, p 40, 7p.

Hillman, C.H., Castelli, D. and Buck, S.M. (2005). Aerobic fitness and cognitive function in healthy preadolescent children. Medicine and Science in Sports and Exercise, 37, 1967-1974.

Hillman, C.H., Erickson, K.I., and Kramer, A.F. (2008). Be smart, exercise your heart: exercise effects on brain and cognition. Nature Reviews Neuroscience, 9, 58-65.

Hirsch, M.A., and Hirsch, H.V.B. (1998). Novel activities enhance performance of the aging brain. Journal of Physical Education Recreation and Dance. Vol. 69, No. 8, 15-19.

Hope, A.T., Woolman, P.S., Gray, W.M., Asbury, A.J., Millar, K. (1998). A system for psychomotor evaluation; design implementation and practice effects in volunteers. Anesthesia, 53: 545-549.

Hirsch, M.A., and Hirsch, H.V.B. (1998). Novel activities enhance performance of the aging brain. Journal of Physical Education Recreation and Dance. Vol. 69, No. 8, 15-19.

Hughes, C. (2002). Executive functions and development: Emerging themes. Infant and Child Development, 11, 201-209.

Hultsch, D.F., Hammer, M., and Small, B.J. (1993). Age differences in cognitive performance in later life: Relationships to self-reported health and activity lifestyle. Journal of Gerontology, 48, 1-11.

Hunter, S.K., Thompson, M.W., and Adams, R.D. (2001). Reaction time strength, and physical activity in women aged 20-89 years. Journal of Aging and Physical Activity, 9, 32-42.

Isaacs, K.R., Anderson, B.J., Alcantara, A.A., Black, J.E., and Greenough, W.T. (1992). Exercise and the brain: Angiogenesis in the adult rat cerebellum after vigorous physical activity and motor skill learning. Journal of Cerebral Metabolism, 12, 110-119.

Jable, T. (1998). Aging Brain, Aging Mind: Physical Activity Benefits Both. JOPERD, 69 (8), 13-14.

Jensen, A. (2006). Clocking the mind: Mental chronometry and individual differences. Elsevier Science Publishers.

Jokela, M., and Hanin, Y.L. (1999). Does the individual zones of optimal functioning model discriminate between successful and less successful athletes? A meta-analysis. Journal of sports Sciences, 17, 873-887.

Kashihara, K., and Nakahara, Y. (2005). Short-term effect of physical exercise at lactate threshold on choice reaction time. Perceptual and Motor Skills 100(2): 275-281.

Kemper, Han C. G. (2001). Is physical exercise good for the brain of a child? Pediatric Rehabilitation, Vol. 4, No. 3, 145-147.

Kerr, J.H. (1990). Stress and sport: Reversal theory. In J.G. Jones & L.Hardy (Eds.), Stress and performance in sport, Chichester: Wiley, 107-131.

Koebel, C.I, Swank, A.M., and Swinburne, L. (1992). Fitness testing in children: A comparison between PCPFS and AAHPERD standards. Journal of Applied Sport Science Research, 6(2), 107-114.

Kramer, A.R., Coyne, J.T., and Strayer, D.L. (1993). Cognitive function at high altitude. Human Factors, 35, 329-344.

Labbe, E.E. and Welsh, C. (1993). Children and running: changes in physical fitness, self-efficacy, and health locus of control. Journal of Sport Behavior, Vol. 16 Issue 2, p85, 13p.

Ladewig, I., Gallagher, J., and Campos, W. (1996). Manipulation of environmental distractors to enhance children's selective attention. Journal of Sport and Exercise Psychology, 18s, 49.

Larson, G.A. and Zaichkowsky, L.D. (1995). Physical, motor, and fitness development in children and adolescents. Journal of Education, Vol. 177 Issue 2, p55, 26p.

Lavin, A.T. (1993). Comprehensive school health education: barriers and opportunities. Journal of School Health, 63(1): 24-27.

Levitt, S. and Gutin, B. (1971). Multiple choice reaction time and movement time during physical exertion. Research Quarterly 42: 405-410.

Linder, K.J. (2002). The Physical Activity Participation-Academic Performance Relationship Revisited: Perceived and Actual Performance and the Effect of Banding (Academic Tracking). Pediatric Exercise Science, 14, 155-170.

Macgregor, R.B., and Poon, G.M.K. (2003). The DNA double helix fifty years on. Computational Biology and Chemistry, Vol. 27 (4-5) 461-467.

Mackworth, N.H. (1950). Researches in the measurement of human performance. MRC special report 268, HMSO.

Malina, R.M. (1996). Tracking of physical activity and physical fitness across the lifespan. Research Quearterly for Exercise and Sport, Vol. 67, No. 3, 48-57.

Marsh, H.W. and Remaye, R.S. (1994). A multidimensional physical self-concept and its relations to multiple components of physical fitness. Journal of Sport and Exercise Psychology, 16, 43-35.

Masanobu, A., and Choshi, K. (2006). Contingent muscular tension during a choice reaction task. Perceptual and Motor Skills 102(3) 736-747.

Matheson, G. (2000). Is exercise brain food? The Physician and Sportsmedicine, 28 (11), 5.

Maycock, G. (1996). Driver sleepiness as a factor in a car and HGV accidents. (Technical report 169). Crowtone. UK: Transport and research laboratory.

Mayer, R.E. (1992). Thinking, problem solving, cognition. Second Edition. New York: W.H. Freeman and Company.

McMorris, T., and Graydon, J. (2000). The effect of incremental exercise on cognitive performance. International Journal of Sport Psychology. 31, 66-81.

McNaughten, D., Gabbard, C. (1993). Physical exertion and immediate mentalperformance of sixth-grade children. Perceptual and Motor Skills, 77:1155-1159.

Meredith, C.N., Dwyer, J.T. (1991). Nurition and exercise: effects on adolescent health. Annual Review of Public Health; 12: 309-333.

Micheli, L.J. and Micheli, E.R. (1985). Children’s running: Special risks? Annals of sports medicine, 2, 61-63.

Milgram, N.W., Head, E., Zicker, S.C., Ikeda-Douglas, C.J., Murphey, H., Muggenburg, B., Siwak, C., Tapp, D., Cotman, C.W. (2005). Learning ability in aged beagle dogs is preserved by behavioral enrichment and dietary fortification: a two-year longitudinal study. Neurobiological Aging, 26: 77-90.

Miller, G.A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. Psychological Review, 63, 81-97.

Mokgothu, C. (2000). Physical fitness and cognitive function, how are they related. Unpublished manuscript, University of Pittsburgh.

Montoye, H.J., Kemper, K.C.G., Saris, W.H.M., and Washburn, R.A. (1996). Measuring physical activity and energy expenditure. Champaign, IL. Human Kinetics.

Moss, M.C., and Scholey, A.B. (1996). Oxygen administration enhances memory formation in healthy young adults. Psychopharmacology, 124, 255-260.

Mota, J., and Guiomar, S. (1999). Adolescent's physical activity: Association with socioeconomic status and parental participation among a Portuguese sample. Sport, Education, and Society, Vol. 4, Issue 2, p193, 7p.

Navon, D. and Gopher, D. (1979). On the economy of the human-processing system. Psychological Review, 86: 214-255.

Newell, A., and Simon, H.A. (1972). Human problem solving. Englewood Cliffs, NJ: Prentice Hall.

Oberauer, K.S., Shulze, R., Wilhelm, O., & Witmann, W.W. (2000). Working memory capacity-facets of a cognitive ability construct. Personality and individual differences, 29, 1017-1045.

Pate, R.R. (1991). Health related measures of children's physical fitness. Journal of School Health; 61: 231-233.

Pate, R.R., Dowda, M. and Ross, J.G. (1990). Associations between physical activity and physical fitness in American children. American Journal of Diseases of Children, Vol. 144.

Pierce, T.W., Madden, D.J., Siegel, W.C., and Blumenthal, J.A. (1993). Effects of aerobic exercise on cognitive and psychosocial functioning in patients with mild hypertension. Health Psychology, 12, 286-291.

Plowman, S.A. (2001). Fitnessgram reference guide. The Cooper Institute, Dallas TX.

Poehlman, E.T., Gardner, A.W., and Goran, M.I. (1992). Influence of endurance training on energy intake, norepinephrine kinetics, and metabolic rate in older individuals. Metabolic Clinical Experiements, 41: 941-948.

Public Health Service (1995). Healthy People 2000: midcourse review and 1995 revisions. Washington, DC: U.S. Department of Health and Human Services, Public Health Service, 1995.

Raglin, J.S. (1997). Anxiolytic effects of physical activity. In W.P. Morgan (Ed.), Physical activity and mental health, Washington, DC: Taylor and Francis; 107-126.

Reschly, D.J. and Grimes, J.P. (1995). Best practices in intellectual assessment, in Thomas A. and Grimes J. (1995). Best Practices in School Psychology. National Association of School Psychologist, Washington D.C. 65, 763-773.

Revelle, W. and Loftus, D.A. (1990). Individual differences and arousal: implications for the study of mood and memory. Cognition and emotion., 4, 209-237.

Rhodes, J.S., Jeffrey, S. Girard, I, Mitchell, G.S., van Praag, H., Garland, T., and Gage, F.H. (2003). Exercise Increases Hippocampal neurogenesis to high levels but does not improve spatial learning in mice bred for increased voluntary wheel running. Behavioral Neuroscience, 117, 1006-1016.

Robertson, L.D., and Magnusdottir, H. (1987). Evaluation of criteria associated with abdominal fitness testing. Research Quarterly for Exercise and Sport, 58, 355-359.

Ross, J.G. and Gilbert, G.G. (1987). The national children and youth fitness study, II: a summary of findings. Journal of Physical Education Recreation and Dance, 58, 51-56.

Rowland, T.W. (1993). The physiological impact of intensive training on the prepurbertal athlete in intensive participation in children's sport, American Orthopaedic Society for Sports Medicine, Human Kinetics.

Rowland, T. (1990). Exercise and Children's Health. Champaign Human Kinetics.

Rowland, T.W. and Freedson, P.S. (1994). Physical activity, fitness, and health in children: a close look. Pediatrics, April, Vol. 93, Issue 4, 669-672.

Rowland, T., Vanderburgh, and Cunningham, L. (1997). Body size and the growth of maximal aerobic power in children: A longitudinal analysis. Pediatric Exercise Science, 9, 262-274.

Safrit, M.J. (1995). Complete guide to youth fitness testing. Human Kinetics, Champaign, IL.

Safrit, M.J. (1990). The validity and reliability of fitness tests for children. Pediatric Exercise Science. 2: 9-28.

Sallis, J.F. and Patrick, K. (1994). Physical activity guidelines for adolescents: Consensus statement. Pediatric Exercise Science. 6, 302-314.

Sallis, J.F., McKenzie, T.L., Kolody, B., Lewis, M., Marshall, S., and Rosengard, P. (1999). Effects of health-related physical education on academic achievement: project SPARK (Sports, Play, and Active Recreation for Kids curriculum).Research Quarterly for Exercise and Sport, 70 (2), 127-134.

Schmidt, R. (1997). Motor Control and Learning, A behavioral Emphasis. Human Kinetics.

Schuler, P., Chodzko-Zajko, W.J., and Tomporowski, P.D. (1993) Relationship between physical fitness, age, and attentional capacity. Sports Medicine, Training and Rehabilitation, 4, 189-194.

Shephard, R.J. (1997). Curricular physical activity and academic performance. Pediatric Exercise Science, 9, 113-126.

Shephard, R.J., Volle, M., Lavallee, H., LaBarre, R., Jequier, J.C., and Rajic, M. (1984). Required physcial activity and academic grades: a controlled longitudinal study. In: Children and Sport, J. Ilmarinen and I. Valimaki (Eds.) Berlin: Springer Verlag, 1984, 58-63.

Shore, R. (1997). Rethinking the brain: New insights into early development. New York, NY: Families and Work Institute, 16-17.

Sibley, B.A. and Etnier, J.L. (2003). The relationship between physical activity andcognition in children: A meta-analysis. Pediatric Exercise Science, 15, 243-256.

Silverman, S., Devillier, R., and Rmirez, T. (1991). The validity of academic learning time-physical education (ALT-PE) as a process measure of achievement. Research Quarterly for Exercise and Sport, 62, 319-325.

Sirard, J.R. and Pate, R.R. (2001). Physical activity assessment in children and adolescents. Sports Medicine, 31 (6): 439-454.

Smith, T.K., and Cestaro, N. (1996). Making physical education indispensable: a 10-point action plan. The Journal of Physical Education, Recreation and Dance, May-June, 67(5), p59(3).

Sohlberg, M.M. and Mateer, C.A. (1989). Introduction to cognitive rehabilitation: theory and practice. New York: Guilford Press.

Spirduso, W.W. (1980). Physical fitness, aging, and psychomotor speed: a review. Journal of Gerontology, 6, 850-865.

Spirduso, W.W. (1983). The 1982 C.H. McCloy Research Lecture: Exercise and the aging brain. Research Quarterly in Exercise and Spor, 54: 208-218.

Spirduso, W.W. (1975). Reaction and movement time as a function of age and physical activity level. Journal of Gerontology, 30, 435-440.

Spirduso, W.W., and Asplund, L.A. (1995). Physical activity and cognitive function in the elderly. QUEST, 47, 395-410.

Spirduso, W.W. and Clifford, P. (1978). Replication of age and physical activity effects on reaction and movement times. Journal of Gerontology, 33, 26-30.

Sternberg, S. (1969). The discovery of processing stages: Extentions of Donders' method. Acta Psychologica, 30, 276-315.

Sternberg, R. J., and Frensch, P. A. (Eds.). (1991). *Complex problem solving: Principles and mechanisms*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Strand, B., and Reeder, S. (1993). Using heart rate monitors in research on fitness levels of children in physical education. Journal of Teaching in Physical Education, 12, 215-220.

Strayer, D.L., Drews, F.A., and Johnston, W.A. (2003). Cell phone induced failures of visual attention during simulated driving. Journal of Experimental Psychology: Applied, 9, 23-32.

Strong, W.B., Stanitska, C.L., Smith, R.E., and Wilmore, J.H. (1990). Associations between physical activity and physical fitness in American children. American Journal of Diseases of Children. V144, 1123-1129.

Sjoberg, H. (1975). Relations between heart rate, reaction speed, and subjective effort at different work loads on a bicycle ergometer. Journal of Human Stress, 1: 21-27.

Suter, E. and Hawes, M.R. (1993). Relationship of physical activity, body fat, diet, and blood lipid profile in youths 10-15 years. Medical Science Sports Exercise; 25(6): 748-754.

Symons, W.C., Cinelli, B., James, T.C., and Groff, P. (1997). Bridging student health risks and academic achievement through comprehensive school health programs. Journal of School Health, August, v67 n6, p220 (8).

Thayer, R.E., Newman, R., and McClain, T.M. (1994). Self-regulation of mood: Strategies for changing a bad mood, raising energy, and reducing tension. Journal of Personality and Social Behavior, 67, 910-924.

Thelen, E., Schoner, G., Scheier, C., and Smith, L.B. (2001). The dynamics of embodiement: A field theory of infant preservation reaching. Behavioral and Brain Sciences 24:1-86.

Thomas, J.R., Thomas, K.T., and Gallagher, J.D. (1994). Developmental considerations in skill acquisition. In R. Singer, M. Murphey, and Tnnant (Eds.) Handbook of Research on Sport Psychology. NY: MacMillan Publishing Co.

Gallagher, J.L., and Thomas, J.R. (1986). Developmental effects of grouping and recoding on learning a movement series. Research Quarterly for Exercise and Sport, 57, 117-127.

Tomporowski, P.D. (2003). Cognitive and behavioral responses to acute exercise in youths: A review. Pediatric Exercise Science, 15, 348-359.

Tomporowski, P.D. (2003). Effects of acute bouts of exercise on cognition. Acta Psychologica, 112 (3), 297-324.

Tomporowski, P.D., and Ellis, N.R. (1986). Effects of exercise on cognitive process: a review. Psychological Bulletin; 99: 338-346.

Treiber, F.A., Musante, L., Hartdagan, S., Davis, H., Levy, M., and Strong, W.B. (1989). Validation of a heart rate monitor with children in laboratory and field settings. Medicine and Science in Sport and Exercise, 21 (3), 338-342.

Tremblay, M. S., Inman, J.W., and Willms J.D. (2000). The relationship between physical activity, self-esteem, and academic achievement in 12-year-old children. Pediatric Exercise Science, 12, 312-324.

U.S. Department of Health and Human Services (1996). Physical activity and health: a report of the Surgeon General. Atlanta: U.S. Department of health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion.

Van Boxtel, M.P.J., Paas, F.G.W.C., Houx, P.J., Adam, J.J., Teeken, J.C., Jolles, J. (1997). Aerobic capacity and cognitive performance in a cross-sectional aging study. Medicine and Science in Sports and Exercise, 29(10), 1357-1365.

van Praag., H., Christie, B.R., Sejnowski, T.J., and Gage, F.H. (1999). Running enhances neurogenesis, learning, and long-term potentiation in mice. Proceeding of the National Academy of Sciences of the United States of America, 96, 13427-13431.

Walker, E.L. (1959). Action decrement and its relation to learning. Psychological Review, 65, 129-142.

Weuve, J., Kang, J.H., Manson, J.E., Breteler, M.A.B., Ware, J.H., Grodstein, F. (2004).Physical activity, including walking, and cognitive function in older women. Journal of the American Medical Association. Vol. 292 12; 1454-1461.

Wickens, C.D. (1991). Processing resources and attention. In Multiple Task Performance (Ed. D.L. Damos), 3-34, Taler and Francis, Ltd. Bristol.

Wilkins, J.L.M., Graham, G., Parker, S., Westgall, S., Fraser, R.G., and Tembo, M. (2003). Time in the arts and physical education and school achievement. Journal of Curriculum Studies, 35, 721-734.

Zervas, Y., Apostolos, D., and Klissouras, V. (1991). Influence of physical exertion on mental performance with reference to training. Perceptual and Motor Skills, 73, 1215-1221.