

The Impact of Acute Bouts of Two Types of Physical Activity on Cognition in Elementary School-Aged Children

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Dedication

To my parents Laurie and Terry, and my little brother Andrew. Thank you so much for your
constant love and support in everything I do.

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Abstract

Purpose: To determine the effect of acute bouts of two types of physical activity on cognition in elementary school-aged children. **Methods:** Subjects were 21 6-11 year old children (8.8 ± 1.6 years) who were free of any cognitive or learning disabilities or delays. Children participated in three randomly ordered conditions. The control condition included watching 20 minutes of TV while seated, the cycle condition included 20 minutes of cycling on a pediatric cycle ergometer at 60% of estimated heart rate maximum, and the play condition include 20 minutes of semi-structured free play activity. After each condition, the children completed 2 trials of the modified Flanker test using the Psychology Experiment Building Language (PEBL) software.. Repeated measures ANOVAs were used to compare interactions between tests type (congruent, incongruent) and condition (TV, cycle, play) for Flanker test accuracy and reaction time. Paired samples t-tests were also used to look for differences in accuracy and reaction time between the congruent and incongruent trials as well as among conditions. **Results:** Significant differences were found between the congruent and incongruent trials for all conditions for both accuracy and reaction time ($p < 0.001$). However, no significant differences were found between conditions for both accuracy ($p = 0.20$) and reaction time ($p = 0.56$), though scores for both active conditions were higher than the control condition. No mean differences were found between the congruent and incongruent trials for each condition as well. **Conclusions:** It appears that the effects of cycling and play may be similar to those seen in the literature with acute bouts of structured cycling or treadmill walking at a moderate intensity. However, the results were not significant. More research is needed, along with a larger sample size, to make conclusions about semi-structured play and its effect on cognition in children.

Table of Contents

Chapter 1: Introduction	1
Chapter 2: Review of Literature	4
Introduction	4
What is Cognition?.....	4
How Cognitive Function is Measured.....	8
Physiological Changes to Cognition and Executive Function, Due toPhysical Activity.....	9
Chronic Physical Activity, Physical Fitness and Cognition.....	10
Academic Achievement and Cognition.....	12
Physical Activity Interventions	12
Cognition, Academic Achievement and Sports Participation	13
Cognition and Physical Education.....	15
Cognition and Fitness	16
Cognition, Academic Achievement and Physical Activity	18
Physical Activity, Academic Achievement, and Cognition.....	18
Acute Physical Activity and Cognition	19
How Do Children Participate in Physical Activity?.....	20
Chapter 3: Manuscript.....	22
Introduction	22
Methods	24

Participants	24
Protocol.....	24
Statistics.....	27
Results	27
<i>Accuracy</i>	28
<i>Reaction Time</i>	30
Discussion	33
Chapter 4: Summary	36
References	38
Appendices.....	47
Appendix A: Parental Consent.....	48
Appendix B: Child Assent	52
Vita.....	54

List of Figures

Figure 1: Definition of Cognition	5
Figure 2: Definition of Executive Function	7
Figure 3: Flanker Task Accuracy by Condition.....	29
Figure 4: Flanker Test Accuracy for Congruent vs. Incongruent Trials by Condition.....	30
Figure 5: Mean Reaction Time for Each Condition.....	31
Figure 6: Mean Reaction Time for Congruent vs Incongruent Trials by Condition	32

Chapter 1: Introduction

Regular physical activity is associated with many positive effects on health in children, including decreased adiposity, reduced triglycerides levels and decreased prevalence of metabolic syndrome (1). In this population, physical activity has also been shown to have positive mental health effects, with regular activity being associated with lower scores on scales of anxiety and depression, higher scores in self-concept, and positive gains in academic performance (1). Children's achievement in school is a crucial concern as it is tied to teacher evaluations, school funding, and the students' potential to continue and succeed in their academic careers. Current trends indicate that physical education classes and recess are being reduced or cut to make way for increased academic time during the school day in order to improve students' standardized test scores and overall academic achievement.

Academic achievement is a general term used to quantify a child's success in school and encompasses a large range of variables including grade point average, standardized test scores, and individual course grades (1). Academic achievement is also related to scores on tests of memory, concentration, classroom behavior (1), observation, problem solving, and decision making (2). These factors include behavioral and cognitive processes, which appear to mediate the relationship between physical activity and academic achievement. This proposed relationship indicates that physical activity may improve cognition, which then in turn causes improvement in behavioral mediators that lead to a direct increase in academic achievement (i.e. standardized test scores and classroom grades).

Cognition is general term used to define a number of mental processes including executive function, controlled processing, visuospatial processing, and speed processing (3). For the purpose of this study however, we will only focus on the executive function facet of

cognition. Executive function involves scheduling, response inhibition, planning and working memory (3). Executive function can further be divided into three variables: set-shifting, updating and inhibition (4). Set shifting requires individuals to disengage from an irrelevant task and refocus on a relevant task (4), while updating involves working memory and the monitoring of mental representations and inhibition requires the “deliberate suppression of prepotent responses” (4). When executive function is analyzed exclusively, physical activity is found to have an effect size of 0.68, which in some papers has led to a hypothesized causal relationship among physical activity, fitness levels and brain health (3).

Physical activity is thought to affect cognitive functioning through physiological and learning/developmental mechanisms. Physiological mechanisms include “increased brain cerebral blood flow, alterations to brain neurotransmitters, structural changes in the central nervous system, and modified arousal levels”(5) brought on by the body’s response to exercise and physical activity. The learning/developmental mechanisms are thought to work because movement and physical activity provide learning experiences that help develop proper cognitive development through experience and problem solving (5). This theory strongly supports the notion that the movement of physical activity is more important than the actual exertion of physical activity, allowing physical activity to possibly teach skills and relationships that can be carried over to the cognitive realm (5).

Currently, much of the research conducted on physical activity and cognition has involved structured exercise interventions, including resistance training, motor skill training, physical education interventions, and aerobic training programs (3). Aerobic training programs have often included bouts of walking or jogging on treadmills or over-ground or cycling at a moderate to vigorous intensity for periods of time from 5 minutes to almost an hour, with most studies having children on the treadmill or cycle for at least 20 minutes at a moderate intensity

($\geq 60\%$ of HR_{max} predicted) (6). Other interventions have also included physical education classes, calisthenics, and sports play. What is most interesting, however is that the type of physical activity did not appear to matter, with positive effects found in all types of interventions in relation to cognition (3). Unfortunately, the type of structured physical activity performed in previous studies is not indicative of how children typically move about or play. A study by Bailey et al. found that children typically engage in a play pattern composed of “very short bursts of intense physical activity interspersed with varying levels of activity of low and moderate intensity” (7). Examples of this type of play include games such as tag, kickball, and general playground play.

Since the findings of previous research in regard to physical activity do not reflect children’s normal play patterns, it is important to investigate whether unstructured physical activity has the same positive effects on cognition. In addition, most children have recess on a daily basis and not physical education classes. Therefore, if we attempt to simulate a semi-structured recess session, similar to what the children may experience at school, our findings may support the use of recess as a way to improve cognition and physical activity during the school day.

Therefore, the purpose of this study is to determine the effect of acute bouts of two types of physical activity on cognition in elementary school-aged children. We hypothesize that unstructured play will have the same positive effects on cognition as structured bouts of physical activity.

Chapter 2: Review of Literature

Introduction

According to the *Physical Activity Guidelines for Americans*, children should engage in at least 60 minutes of moderate to vigorous physical activity each day that is developmentally appropriate (8). Unfortunately, many elementary aged children do not meet these guidelines. According to Troiano et al. (2008) only 42% of 6 – 11 year olds are sufficiently active to meet the recommendations of 60 minutes of daily MVPA (9).

Physical activity is associated with reduced percent body fat and blood pressure, and improved bone health (10) as well as reduced triglycerides levels and fewer occurrences of metabolic syndrome (1). There is also strong evidence in the literature that indicates that physical activity may have a positive effect on the mental and emotional health of youth, with regular activity being associated with lower scores on scales of anxiety and depression, higher scores in self-concept, positive gains in academic performance, and improved cognitive processing. (10). . This thesis will focus on the effect of acute bouts of physical activity on cognitive processing in elementary school children.

What is Cognition?

Cognition is a term used to describe a number of underlying mental processes, including executive function, controlled processing, visuospatial processing, and speed processing (3). Together, these processes form an individual's cognitive control network, which allows for "the ability to orchestrate thought and action in accord with internal goals. (11)" Executive function involves scheduling, response inhibition, planning and working memory (3). Executive function works to exert executive control over a small group of goal directed processes that include the selection, scheduling and coordination of computational processes that are involved in

perception, memory and action (12, 13). Figure 1 depicts a visual representation of the cognitive and executive function processes. Das et al. further stated that executive functions are connected to planning and selecting strategies that establish and form goal orientated actions and are different from processes involved in basic information processing(3).

In addition to the previous definition, executive function can be further broken down into three parts, including: set-shifting, which requires a person to disengage from an irrelevant task and engage on a relevant task, updating, which uses working memory to monitor mental representations, and inhibition, which is the deliberate suppression of a dominant response (See Figure 2) (3). The other processes involved in cognition include controlled processing, which involves the automatization of response sequences, and visuospatial processing, which deals with perceptual learning, and speed processing which deals mainly with simple reaction time (3). While aerobic activity has been shown to have a moderate effect on overall cognitive performance ($ES=0.47$) the largest effects have been seen in executive function ($ES=0.68$), which will be the focus of our study (3).

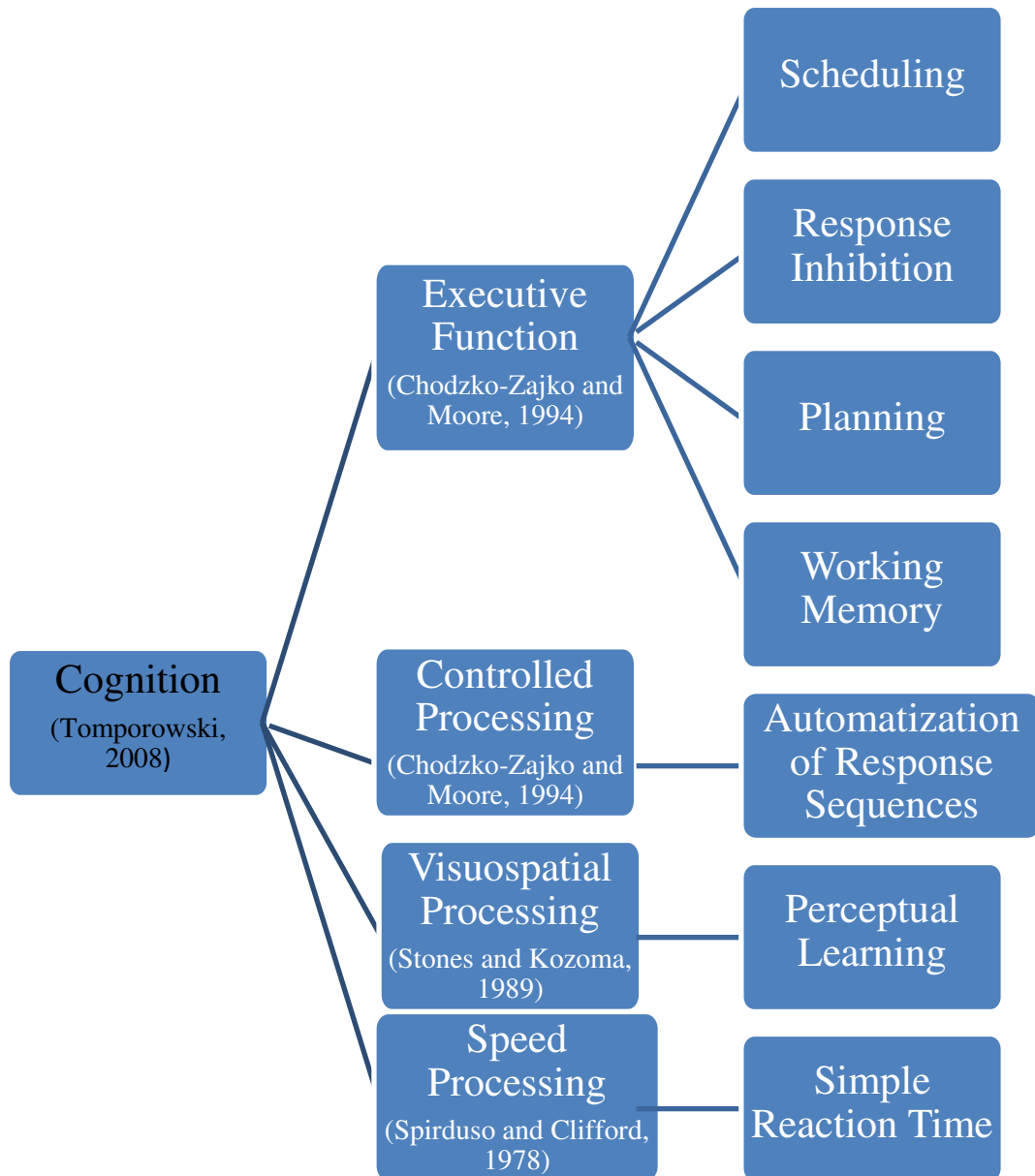


Figure 1: Definition of Cognition

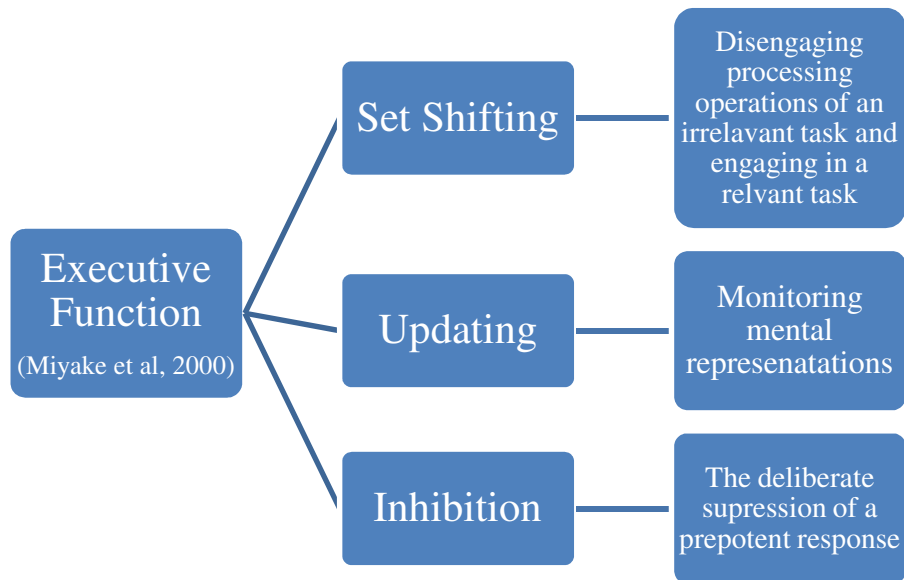


Figure 2: Definition of Executive Function

Executive function and executive control are thought to lie in the prefrontal regions of the frontal lobes of the brain. According to Hillman et al. (2009), children's executive function and control improves during the early stages of life. Significant changes typically occur between ages three and seven, with the most improvements being seen in tasks related to inhibition and cognitive flexibility (12). As children age and mature, the frontal lobes start to develop in a way that leads to improved performance on executive control tasks, especially in late childhood into early adolescence (12, 14, 15). Therefore, children who are younger or possess less developed frontal lobes can experience increased difficulty inhibiting irrelevant information and focusing cognitive attention on relevant information (12). This is important to note because executive function naturally improves with age and brain development, but other factors may have significant impact on a child's ability to exert executive control when given goal oriented tasks.

How Cognitive Function is Measured

There are several tests used to measure cognitive functioning. The Cognitive Assessment System is the most comprehensive test of cognitive testing. It measures a child's mental abilities defined on the basis of four interrelated cognitive processes: Planning, Attention, Simultaneous, and Successive. Each of the four scales is comprised of three subjects. Only the planning scale measures executive function (ie: strategy generation and application, self-regulation, intentionality, and utilization of knowledge). The remaining scales measure other aspects of cognitive performance (16), such as memory, concentration, and reaction time. Other tests that measure cognition and executive function include the Sternburg test, the Stroop Test, a visual oddball paradigm, and the Flanker test.

The Flanker Test is a standard test of conflict resolution that requires the successful inhibition of information that conflicts with the attended target (17) The Flanker test is the most commonly utilized test for executive function, and is often modified to fit the researchers' needs by either lengthening or shortening the exposure time to the stimulus or by modifying the time spent between each stimulus being presented. The Flanker test utilizes congruent (ie: >>>> or <<<<) and incongruent (ie: <<>< or >><>) trials to test response inhibition, which is a subdivision of executive control (18). Even though the test is simple in nature, the use of congruent and incongruent trials leads to conflicting demands in the cognitive processing centers of the brain, often leading to increased reaction time and decreased accuracy in the incongruent trials (19). This test provides an estimate of a person's cognitive functioning, specifically executive functioning. The Flanker task has been validated for both adults and children, and involves minimal equipment (19), which makes this the ideal test for executive functioning for our purposes.

Physiological Changes to Cognition and Executive Function, Due to Physical Activity

Reed et al. observed that the brain is activated during physical activity by increasing blood flow to essential areas that stimulate learning (20). Reed and his colleagues also noted strong associations between the function of the cerebellum and memory, indicating that physical activity has effects on spatial perception, language attention, emotion, nonverbal cues and the decision making ability of children (20). Additionally, Tomporowski et al, showed that exercise is known to effect several factors that influence neurological development (3). Tomporowski suggested that the reasons for this effect on neurological development could be physical activity's influence on the production of neurotrophins that regulate the survival, growth, and differentiation of neurons during development, and physical activity may affect synaptogenesis that happens together with myelination and angiogenesis, and influences glucose and oxygen distribution (3). Singh et al, stated that activity is beneficial for cognition, due to its effects on increased blood flow and oxygen to the brain, as well as movement and activity causing increased levels of norepinephrine and endorphins, which may result in a reduction of stress and improvement of mood (21). Activity may also lead to increased growth factors in the brain, which helps to generate new nerve cells and support synaptic plasticity (21). Basch et al. relate physical activity and exercise directly to executive functioning by saying that exercise may affect executive functioning by increasing oxygen saturation and angiogenesis, as well as increasing brain neurotransmitters and increasing brain-derived neurotrophins which support neuronal differentiation and survival in the growing brain (10). It has also been proposed that physical activity may increase the vasculature in the cerebral cortex and reduce vascular diffusion distances (22) which would in turn improve brain function.

Other relationships between physical activity and cognition include the fact that habitual physical activity is thought to promote structural changes in the hippocampus region of the brain,

which are important for memory (20). Habitual physical activity has also been found to increase neurons, dendrites, and synapses throughout the central and peripheral nervous system (20). Additionally, the act of movement itself has been recognized as a way to increase brain-derived neurotrophic factor (BDNF) which enhances learning and cognition through improving neuron communication and synaptogenesis. Additionally, BDNF is regulated by physical activity (20). With these potential mechanisms in mind, many researchers have identified a significant link between physical activity and improved cognition (20, 21), as well as relationships among physical activity and physical fitness and academic performance in youth (23).

Evidence that supports the notion that regular participation in physical activity may contribute to enhanced brain function and cognition (21). A meta-analysis performed by Sibley and Etnier found a positive correlation between all types of physical activity and cognitive function, with measures of cognitive functioning including perceptual skills, intelligence quotient, academic achievement, verbal tests, mathematics tests, developmental level, and academic readiness in children ages 4-18 years (24, 25).

Chronic Physical Activity, Physical Fitness and Cognition

In the literature, physical fitness is often used to analyze the effects of chronic physical activity on cognition. Physical fitness is most often used instead of physical activity because it is often easier to examine fitness levels in the laboratory setting than trying to examine physical activity levels. The relationship between fitness to cognition in children is measured in the laboratory setting using basic laboratory measures of cognitive performance (such as the Flanker test or Stroop protocol) (26). In children, there is only a weak relationship between physical fitness and habitual physical activity, the use of fitness as a proxy for chronic activity may not be appropriate. Previous studies have found significant associations between physical activity and cognition, however cardiovascular fitness is thought to have the strongest impact on changes

academic achievement (27) while physical activity practiced at vigorous to moderate intensity is thought to be related to better cognitive performance (28). Multiple studies have supported this hypothesis. Donnelly and Lambourne found that school-aged children who are more fit performed better on attentional tasks that require greater amounts of cognitive control than their less fit counterparts (24). More fit or more active individuals were also found to perform significantly better on the fluid intelligence tasks than untrained or inactive participants (29). Also chronic physical activity helped to improve concentration, along with reading and mathematics performance (29). What is most notable however, is that the largest improvements in cognition due to exercise and physical activity are typically found in an individual's ability to plan, initiate, and carry out activity sequences that make up goal directed behavior (29).

Higher fitness individuals also show physiological changes to the cognition process. Using event related potentials (ERPs), which are isolated events of brain wave activity recorded within an EEG, children who are highly fit performed executive functioning tasks much more rapidly and had larger P3 amplitudes that suggest enhanced executive functioning (20). P3 amplitudes are thought to reflect the allocation of attentional resources required for a task, with higher P3 amplitudes reflecting higher attentional focus (30). Van Dunsen et al. replicated these results stating that children with higher cardiovascular fitness processed higher P3 event-related brain potential (ERP) amplitude and lower P3 latency. P3 latency is reflective of a person's evaluation speed and stimulus classification skills, with lower P3 latency representing better evaluation and classification skills (30). These results suggest better attention span, working memory, reaction time and overall processing speed associated with improved cardiovascular fitness (27).

Although many studies have shown a positive association between fitness and cognition, some studies have yielded equivocal results. Tuckman (31) reviewed a number of studies

conducted in the school setting (unlike the previous studies discussed which were laboratory-based) and found that chronic exercise training programs had almost no impact on cognition, but did elicit various improvements in physiological functioning such as improved performance on tests of executive functioning. These results may have been mixed due to the real-world nature of the school setting and other studies doing all of the interventions and measurements in the laboratory setting.

Academic Achievement and Cognition

Academic achievement is a general term used to quantify a child's success in school and encompasses a large range of variables including grade point average, standardized test scores, and individual course grades (1). Academic achievement is also related to scores on tests of memory, concentration, classroom behavior (1), observation, problem solving, and decision making (2). These factors include behavioral and cognitive processes, which appear to mediate the relationship between physical activity and academic achievement. Because of this relationship, many researchers utilize measures of cognition to predict a child's academic achievement in the school setting. Most importantly, some studies have shown that time spent in physical activities does not detract from scholastic performance, even when less time is devoted to academics (32).

Physical Activity Interventions

Physical activity is positively associated with academic achievement and the academic learning process in school and previous research has found that time spent on nonacademic subjects, such as physical education classes, does not have a negative impact on academic performance (28). Some studies have found that physical activity has no effect on cognitive performance and only improves health outcomes (1, 28). Other studies have shown moderate but significant correlations between activity and academic performance, with some debates over

whether this relationship is linear or curvilinear in nature with a certain threshold of activity for impact on cognition to be seen (28). Despite these differing opinions, it is fairly well established that physical activity can lead to improvement in mental functioning and cognitive development (1, 28).

These differences in conclusions on how and how much physical activity may impact cognition may be due to the fact that physical activity is measured in many different ways from study to study. The most common methods of assessing physical activity include sports participation, physical activity questionnaire, physical education classes. Additionally, some assessments of fitness including the FITNESSGRAM or a VO₂ max test, which is sometimes used as a proxy for chronic physical activity. While each of these assessments have strength in their own right, each measures a slightly different facet of physical activity. Because of these differences, it makes it very hard to make accurate comparisons from study to study.

While most studies state that aerobic activity and fitness have the greatest impact on cognition and executive function, positive effects have been found in several different activity programs including resistance training, motor skills training, physical education interventions, and aerobic training programs (1). Overall, physical activity is thought to have a modest effect on cognition and executive function, with middle school and young elementary aged children reporting an effect size of ES=0.40 (1).

Cognition, Academic Achievement and Sports Participation

As stated earlier many studies have shown positive relationships between academic achievement and physical activity, however some have found positive influences with sports participation as well (33). Ruiz et al. found that Spanish adolescents who participated in more sports and activities during their leisure time performed significantly better on tests of cognitive

performance compared to youths who were not as active (34). Ruiz and his colleagues also found participation in athletics did not lead to reduced academic performance, despite a reduction in time devoted to class and other academic subjects (34).

In fact, despite speculation that sport participation could be detrimental to academic performance, children who participate in sport tend to have better academic outcomes than their non-athletic counterparts (35). There are many theories outside of the benefits of physical activity that could explain why athletes tend to perform better academically. Basch suggested that a feeling of connectedness with school by participating on a school sports team may improve academic performance, however this theory limits the benefits of sports participation to only the children with the greatest athletic ability (10). Other researchers suggest that the academic benefits of sports participation may be due to the team aspect of athletics (35). As a member of an athletic team, athletes are immersed in a culture where effort, persistence, and competitiveness are valued, which some researchers propose could be applied to the classroom (28). Additionally, improved self-esteem and socialization through sport combined with the benefits of physical fitness and physical activity acquired with sports participation may also be causes for improved cognitive abilities in children who participate in sports (28).

A study conducted by Fox et al. found that participation in athletic teams was linked to higher grade point averages (GPAs) for middle school boys and high school boys and girls, (35). Additionally, participating in more moderate to vigorous physical activity (MVPA) was associated with a higher GPA in girls and boys in middle school and high school (35). However, this finding may have been influenced by the fact that athletic participation requires students to maintain minimum GPA standards (35).

Cognition and Physical Education

Unlike sports participation, which is not available to all students, physical education classes are a way to reach the entire student body at any given school. Unfortunately, many physical education classes are being downsized or removed completely from public schools in favor of more time spent in the classroom working on more academic pursuits. However, contrary to this practice, the literature shows that increased time spent in physical education classes and other school-based physical activity programs is associated with positive or at worst neutral influences on academic outcomes (10, 33). Additionally, quasi-experimental interventions have found that taking time for physical education classes during the school day, even with reductions in classroom time, does not negatively impact academic performance, both for grades or for standardized test scores (22) This supports the notion that there is minimal to no evidence to support the argument that increasing time spent outside the classroom in physical activity during school hours leads to decreased academic performance (24).

Outside of there being no support for the reasoning behind reducing time spent in physical education, benefits have been found. Carlson et al (29) discovered that girls who were enrolled in greater amounts of physical education each week had a significant increase in academic achievement in math and reading (20).

Additionally, a study by Coe et al. used a 3-day physical activity recall and observed physical education classes to analyze the effects of physical activity on academic achievement. The measures of academic achievement used were grades in core classes (mathematics, science, English, and world studies) and standardized test scores. This study showed that students who performed vigorous physical activity at or above the Healthy People 2010 guidelines obtained higher academic scores compared to all other students throughout the year (33). However, they found that physical education classes had no effect on academic achievement. It was

hypothesized that during the physical education classes not enough time was spent being physically active, which may have influenced this finding (33). Additionally, the researchers concluded that the decreased classroom time that occurred due to physical education classes did not equate to lesser academic performance (33).

Cognition and Fitness

Fitness is often used to assess chronic physical activity and is commonly used a surrogate for physical activity in studies looking at activity and cognition due to the ability for fitness to be assessed not only in the lab but also in the field. Unfortunately, by using physical fitness instead of assessing physical activity, the timing, type, duration and intensity of physical activity cannot be determined, which limits our ability to evaluate physical activities true effect on cognition.

Overall, there have been positive associations found between cardiovascular fitness and cognition scores. The first study that supports this hypothesis is a study by Castelli et al (2007), which found a positive correlation between cardiovascular fitness, as measured by the FITNESSGRAM protocol, and standardized test scores overall and in math and reading in third and fifth grade students (22, 36).

Roberts, Freed, and McCarthy studied a group of students in California and analyzed their FITNESSGRAM assessments and standardized state test scores (37). They found that students who failed to run the mile in the time interval deemed as appropriate for age and sex scored significantly lower on the CAT6 and CST math, reading, and language California standards tests compared to those students who tested within the healthy fitness zone (37).

Additionally, a study by Hillman et al. looked at reaction time measures (a measure of executive function) and electroencephalography (EEG) in both low-fit and high-fit children (mean 9.6 years) and young adults (mean: 19.3 years). They found that although both groups of

children had slower reactions times than the young adults, the high fitness children performed better and had P3 latency measures that implied faster cognitive processing, compared to the low-fitness children (6). This study suggests that children who are more physically fit display more cortical activation and the corresponding cognitive processing than low-fit children (3).

Also, a study by Welk et al. looked at standardized test scores and the results of the FITNESSGRAM health related fitness battery for cardiovascular fitness and BMI for 6,222 Texas state schools ranging from elementary through high school. The results of this study showed a moderate correlation between cardiovascular fitness and standardized test scores ($r=0.41$), showing that students who tended to be more physically fit tended to perform better on the Texas state standardized tests (23).

Hillman et al. conducted a study using 48 children and divided them into low fitness and high fitness groups based on the results of the PACER test. Children were then asked to perform the Flanker Task while an EEG recording was done and to take the Kaufman Brief Intelligence Test. The researchers found that all participants had a longer response time to incongruent verse congruent trials. However, higher fit children responded more accurately to all conditions than their lower fit counterparts (12).

Additionally, Pontifex et al. conducted a very similar study where they took 65 children from the east-Illinois region and split them into high fitness and low fitness groups based on their $VO_2\text{max}$ and asked them to perform the Flanker Task while neuroelectric testing took place (38). Researchers found that children who had lower fitness levels had decreased response accuracy for both the congruent and incongruent conditions compared to the higher fit children. Additionally lower fit children were more accurate on the congruent verses incongruent trials while higher fit children showed about equal accuracy for both trials (38), which was different

compared to Hillman's study (12). Overall, the literature suggests that children who possess a higher level of fitness tend to score better on tests of executive function and cognition.

Cognition, Academic Achievement and Physical Activity

Overall, when it comes to physical activity, children who perform more hours of physical activity and participate in more vigorous activity tend to have better academic achievement than those who participate in less physical activity (35). Unfortunately, many studies do not focus strictly on physical activity measures or the type of physical activity, but instead use proxies or substitutes such physical activity, fitness, and sports participation as discussed above.

While studies that look at physical activity (acute or chronic) and cognition are difficult to find, a study by Kramer et al. examined the impact of six-months of aerobic exercise training on cognitive function in older individuals. Individuals who participated in aerobic exercise training performed tests involving executive function quicker and more efficiently than non-exercisers (39). While physical activity interventions have been shown to help improve cognition and executive functioning in older adults, it is important to investigate if this relationship holds true in children.

Physical Activity, Academic Achievement, and Cognition

While many studies have looked at physical activity and movement in relation to cognition, these studies have had inconsistent measures of activity and cognition, and often tended to focus on older adults. In terms of mental development, we know that executive function changes as a child matures, which may influence the development of a child's ability to understand when to apply acquired knowledge, and then realize how to act on this knowledge when it is appropriate to do so (3). This presents a complication to our analysis of cognition

when working with children because not only could natural growth and development cause changes in a child's natural cognitive ability, activity patterns and practices may as well.

Acute Physical Activity and Cognition

Unlike chronic physical activity, acute physical activity is a one-time bout of activity that occurs immediately before cognition testing. To be counted as an acute bout of activity, it should “employ aerobic exercise interventions of sufficient intensity and duration to promote the activation of the entire body and produce systemic changes in physiological functions and elevate energy expenditure above baseline, or homeostatic level” (40). Overall, acute bouts of physical activity have been found to improve reading comprehension, attention, and academic performance in children (28). These change are thought to occur due to short-term exercise-induced alterations in the neuroelectric system, which in turn causes changes in the cognitive control of attention and how attention relates to task performance (32).

Another study on acute physical activity was a study done by McNaughten and Gabbard looked at 120 sixth-grade children walking for separate bouts 20, 30 and 40 minutes at a heart rate range between 120-145 bpm and their ability to perform mathematical computation tests. They found subjects performed best with 30 and 40 minute bouts of activity, which was hypothesized to put the children in a “relaxation state”, allowing them to improve their arithmetic performance (41).

Additionally, a study by Caterino and Polak took second, third, and fourth grade children and had them perform either 15 minutes of aerobic walking and stretching or a classroom based activity. Afterwards, they were asked to perform the Woodcock Johnson Test to test their cognitive control. The researchers found that for fourth grade students, scores improved with physical activity. These results however did not hold true for the second and third graders (42).

More recently, Hillman et al. performed a study where 20 children were asked to complete a modified Flanker Task while fitted with EEG monitoring after performing 20 minutes of walking on a treadmill at 60% of their estimated heart rate maximum as well as performing the modified Flanker task after 20 minutes of rest. After the activity, the children had greater response accuracy and P3 amplitudes when compared to their resting values (18).

However, only one study has found no improvement between resting and active conditions when looking at cognitive functioning. Stroth et al. had 33 thirteen and fourteen year old children perform a modified Flanker Task and a Go-NoGo task while EEG was simultaneously monitored after 20 minutes of rest and 20 minutes of aerobic cycling. While the study did find that participants with higher fitness levels performed better on the various tasks, they did not find any differences based on acute levels of activity (43).

How Do Children Participate in Physical Activity?

Even though a relationship has been found between increasing levels of physical activity and physical fitness and improved cognition, many studies have had one major flaw in their methodology: long duration, steady state cardiovascular training is not a common or a familiar pattern of activity for children.

Bailey et al. performed a study in which he and his researchers observed children during their daily lives over the span of several days, both in the home and school setting. He found that children spent most of their time ($77.1 \pm 3.8\%$), engaged in low intensity activities like sitting, laying, or standing. Moderate intensity activity only accounted for $19.7 \pm 3.5\%$ of the children's time, while activities of high intensity activity only accounted for just $3.1 \pm 1.0\%$ of their time (7). In addition to the limited time spent in the preferred activity intensity of moderate to vigorous physical activity, children's play structure was highly transitory in nature, with short durations of

activity being the norm irrespective of intensity, with intervals of activity and rest being highly variable (7). This finding tends to give an overall picture of children's typical activity patterns, showing that children are naturally inclined to engage in very short bursts of intense physical activity combined with varying durations of rest interspersed with varying intervals of activity of low and moderate intensity (7).

Often when doing cognitive research, children are exposed to the same physical activity protocols as adults, often being asked to ride on a cycle or walk or run on a treadmill at a set intensity for extended periods of time (usually between 20-50 minutes). Since children are not naturally active in this way, it is important to see if it is possible to achieve the same cognitive benefits of activity that involves the typical play behavior of children. Therefore, the purpose of this study is to compare the effects of an acute bout of steady-state aerobic activity as well and a semi-structured play session, on children's cognitive performance, to determine if the play session will illicit similar cognitive effects as steady state, aerobic physical activity as seen in the literature.

Chapter 3: Manuscript

Introduction

According to the *Physical Activity Guidelines for Americans*, children should participate in at least 60 minutes of moderate to vigorous physical activity (MVPA) that is developmentally appropriate every day, (8). A study by Troiano et al. which gathered accelerometer data found that only 42% of 6 – 11 year olds are sufficiently active to meet the recommendations (9). The National Association for Sport and Physical Education reported that the prevalence of daily physical education classes dropped from 42% to 28% between 1991 and 2003 (27), Regular physical activity has numerous beneficial effects on the health of children, including decreased adiposity, lower triglycerides levels and lower rates of metabolic syndrome (1). In the pediatric population, physical activity has also been associated with lower severity of anxiety and depression, and higher scores in self-concept, as well as improvement in academic performance and cognitive processing (1).

Cognition encompasses the mental processes involved with gaining knowledge and understanding (40). Within cognitive development, executive function is the system responsible for controlling and regulating cognitive abilities and includes self-regulation, reaction time, attention, and response inhibition and control. There are a variety of assessments that have been used to assess executive function in children. One of the most widely used assessments is the Flanker Test. The modified Flanker Test assesses response inhibition (44, 45) by evaluation accuracy and reaction time for congruent and incongruent trials and has been validated for use in children (19).

Cognition is positively impacted by acute and habitual physical activity in youth (26). These studies focused mainly on physical activity on treadmill and cycle and cognitive response

immediately after the physical activity. Overall, these studies found that acute physical activity improved accuracy and decreased response time for tests of executive function, like the modified Flanker Task (18) and improved brain function related to both cognitive and computational tasks (18, 41, 42)

Additionally, prior research on physical activity and cognition has involved structured exercise interventions, including resistance training, motor skill training, physical education interventions, and aerobic training programs (3). Aerobic training programs have included structured bouts of walking or jogging on or off treadmills or cycling at a moderate to vigorous intensity for periods of time from 5 minutes to almost an hour, with most studies having children on the treadmill or cycle for at least 20 minutes at a moderate intensity ($\geq 60\%$ of predicted HR_{max}) (6). Other interventions have also included physical education classes, calisthenics, and sports play. Overall, all of these studies have found improvement in cognitive functioning, either by improving accuracy or reaction time in tasks involving executive functioning (3, 40, 46) or have shown improvements in other facets of cognition such as improving working memory (47, 48) and concentration (42).

Unfortunately, the type of structured physical activity performed in previous studies (i.e. treadmill walking, stationary cycling) is not indicative of how children typically move about or play. A study by Bailey et al. found that children typically engage in a play pattern composed of “very short bursts of intense physical activity interspersed with varying levels of activity of low and moderate intensity” (7). Examples of this type of play include games such as tag, kickball, and general playground play, which is typical in recess. Recess is one of many ways that children can accumulate physical activity that is semi structured or unstructured during the school day to meet recommendations (49). Approximately 60% of children participate in daily recess in the United States (50). Since this type of activity is common for children and the types of activities

used in previous research are not representative of children's normal play patterns it would be interesting to study if unstructured physical activity has the same positive effects on cognition as structured endurance bouts of activity. Therefore, the purpose of this study is to determine the effect of acute bouts of two types of physical activity on cognition in elementary school-aged children. We hypothesize that unstructured play will have the same positive effects on cognition as structured bouts of physical activity.

Methods

Participants

Participants were 21 6-11 year old children (15 boys) with no known learning disabilities or diagnosed cognitive development problems, who were able to participate in physical activity. They were recruited from the Knoxville, TN area using flyers, listserves, internet postings, and word of mouth. All participants' parent or legal guardian signed a parental permission form and each participant provided written assent prior to participation. This study was approved by the university's Institutional Review Board.

Protocol

Initial Visit

Children's height and weight were assessed using a portable stadiometer and digital scale (Seca; Birmingham, UK) (51). Anthropometric assessments were then used to calculate body mass index (BMI) and the Centers for Disease Control and Prevention (CDC) BMI age- and sex-specific growth charts were used to determine BMI percentile (52).

Each child's estimated maximum heart rate was calculated using the formula $[208 - (0.7 * \text{Age})]$, which has been validated for the pediatric population (53, 54). The target heart rate for exercise sessions was set at 60% (± 5 bpm) of estimated heart rate maximum. Once the target

heart rate zone was calculated, the child was fitted with a Polar heart rate monitor, which had a programmed target heart rate zone based on the previous calculation. The child then completed one of three randomly ordered conditions (control, cycle, or semi-structured play) on three separate visits, using a counterbalanced study design. Each study visit took between 45-60 minutes to complete, and was completed with at least a week between each visit.

Control Condition

Each participant was asked to view an episode of the television program, “The Magic School Bus” (“Works Out”; Season 3, Episode 9) for 20 minutes while seated. The heart rate monitor recorded average and peak heart rate, as well as the time in target heart rate zone. Heart rate was measured in order to ensure that the control trial condition was sedentary in nature.

Cycle Condition

Each participant was asked to perform an acute bout of moderate intensity activity on a pediatric cycle ergometer (Lode; Groningen, the Netherlands). After seat height was adjusted the participant was asked to ride on the cycle for 20 minutes between 50-60 rpm, set at a resistance that would place the participant in the target heart rate zone (60% of estimated maximal heart rate $\pm$ 5bpm). This protocol is similar in intensity and workload from previous research which found significant improvements in cognition after participating in a similar bout of activity (18). The heart rate monitor recorded average and peak heart rate and time spent in the target heart rate zone.

Semi-Structured Physical Activity Condition

Each participant was asked to participate in a semi-structured bout of physical activity, similar to a recess session at school in a gymnasium for 20 minutes. The researcher facilitated

the play session in order to ensure the participant was active during the 20-minute time frame. The children were allowed to self-select activities during their play session and could either engage in a solitary activity or play with the researcher. Some examples of activities included soccer, basketball, jump rope, tumbling, hula hooping and tag games, along with gross motor games such as tossing a football or baseball or running and jumping. Unlike the cycle condition, due to the sporadic nature of children at play, heart rate for the play condition was variable. The heart rate monitor recorded heart rate response during these activities and provided average and peak heart rate and time in the target heart rate zone.

Cognitive Testing

After each condition, the participant waited 10 minutes before completing two rounds of a modified Flanker task using the Psychology Experiment Building Language (PEBL) software (version 0.14, Houghton, MI), which is psychological testing battery that has been validated for use in cognitive testing (55). The modified Flanker task is used to assess response inhibition (44, 45), which tests the executive function, specifically inhibition, facet of cognition. This task required the participants to examine 40 trials of each series of arrows, with the arrangement being either congruent (>>>>), neutral (< or >) and non-congruent (<<><<) and select either the left or right shift key on a standard keyboard that corresponded to the direction the centrally located arrow was pointed. Each participant completed 10 practice trials, which provided feedback on reaction time and accuracy before each testing trial to minimize the learning effect and ensure proper understanding. During the practice trials of the modified Flanker task, there was a 500ms delay between each trial, with 800ms given to make a response, and 400ms were allotted for feedback. During the testing trials, participants were given 800ms to make a response, with a 500ms delay between each trial.

Statistics

Statistical analysis was carried out using SPSS software, Version 21.0 (SPSS, Inc., Chicago, IL, USA). Mean and standard deviation were calculated for demographic characteristics. Repeated measures ANOVAs (2x3) were used to compare interactions between tests type (congruent, incongruent) and condition (TV, cycle, play) for Flanker test accuracy and reaction time. A Bonferroni correction was used in the analysis. Paired samples t-tests were also used to look for differences in accuracy and reaction time between the congruent and incongruent trials as well as among conditions. Significance was set at $p \leq 0.05$.

Results

The children's age and demographic data are shown in Table 3.1. The children were 8.8 ± 1.6 years of age, with 15 being of normal weight status and six classified as either overweight or obese according to CDC height-to-weight growth charts. The control condition had an average heart rate of 85 ± 8.5 bpm, while the cycle trial had an average heart rate of 123 ± 8.1 bpm, with play having an average heart rate of 150 ± 20.1 bpm.

Table 1: Age and Demographic Data

Age (years)	8.8 ± 1.6
Height (m)	1.4 ± 0.12
Weight (kg)	32.8 ± 7.5
BMI (kg/m ²)	17.7 ± 2.4
Percentiles	61.2± 29.9

Accuracy

The repeated measures ANOVA for Flanker accuracy indicated a main effect of trial (congruent, incongruent). The congruent test scores were significantly higher than the incongruent test scores ($60.9 \pm 18\%$ vs. $71.5 \pm 16\%$; $p < 0.001$).

For mean accuracy there was not a main effect of condition ($p = 0.20$) (See Figure 3). There was no interaction effect between the trial and condition.

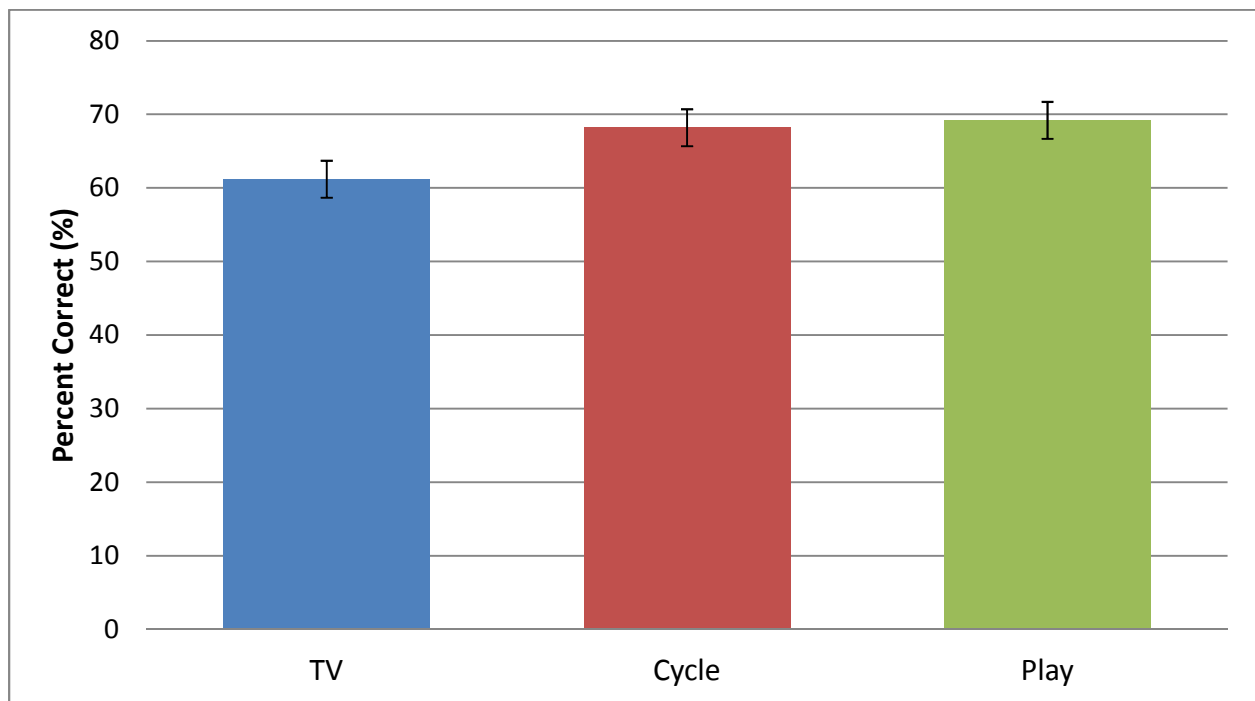


Figure 3: Flanker Task Accuracy by Condition

Finally, we then looked to see if there were any significant differences between means for each condition in relation to the congruent vs incongruent trials. We found that children were significantly more accurate on the congruent trial compared to the incongruent trial, and the cycle and play protocols appeared to illicit slightly higher accuracy scores compared to the control trial (see Figure 3).

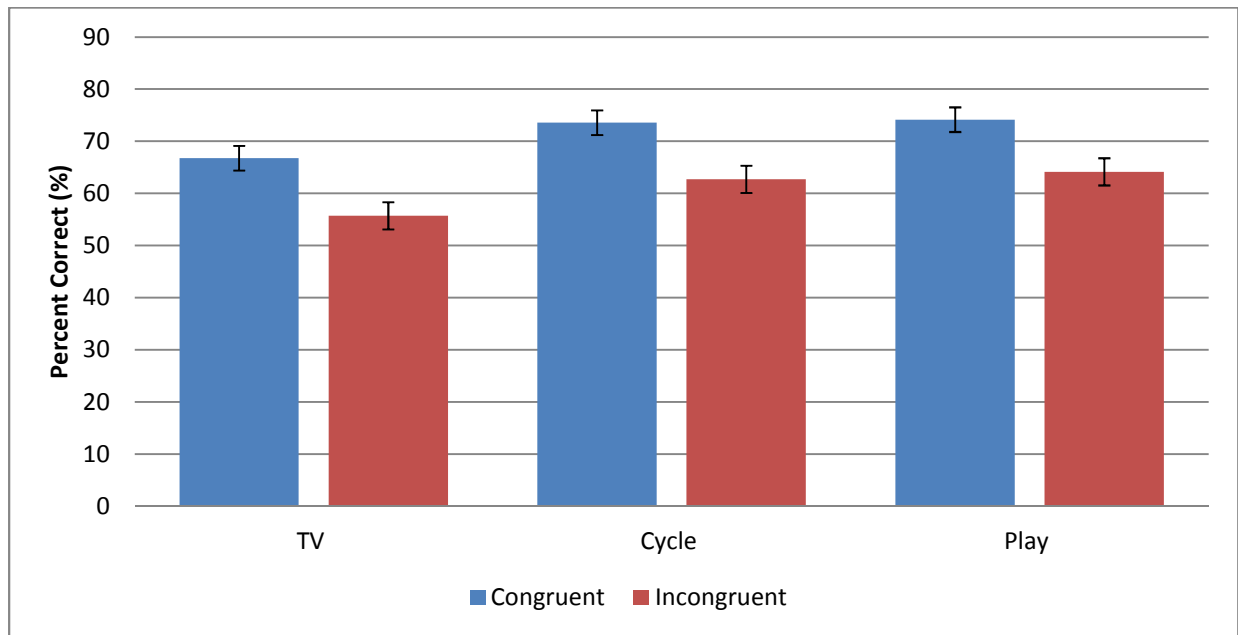


Figure 4: Flanker Test Accuracy for Congruent vs. Incongruent Trials by Condition

Reaction Time

The repeated measures ANOVA for Flanker reaction time indicated a main effect of trial type (congruent, incongruent). Results indicated that the incongruent trials required a significantly longer period of time to respond than congruent trials (598.2 ± 71.58 ms vs. 573.7 ± 66.86 ms; $p < 0.001$).

The main effect of condition (TV, Cycle, Play) was not significant ($p = 0.56$) for the reaction time. However, while not significant, reaction time was slowest with the TV condition (609.52 ± 88.14 ms) and the play condition had the fastest reaction time (583.76 ± 83.85 ms) (see Figure 5). There was not a significant interaction between condition and trial type for reaction time.

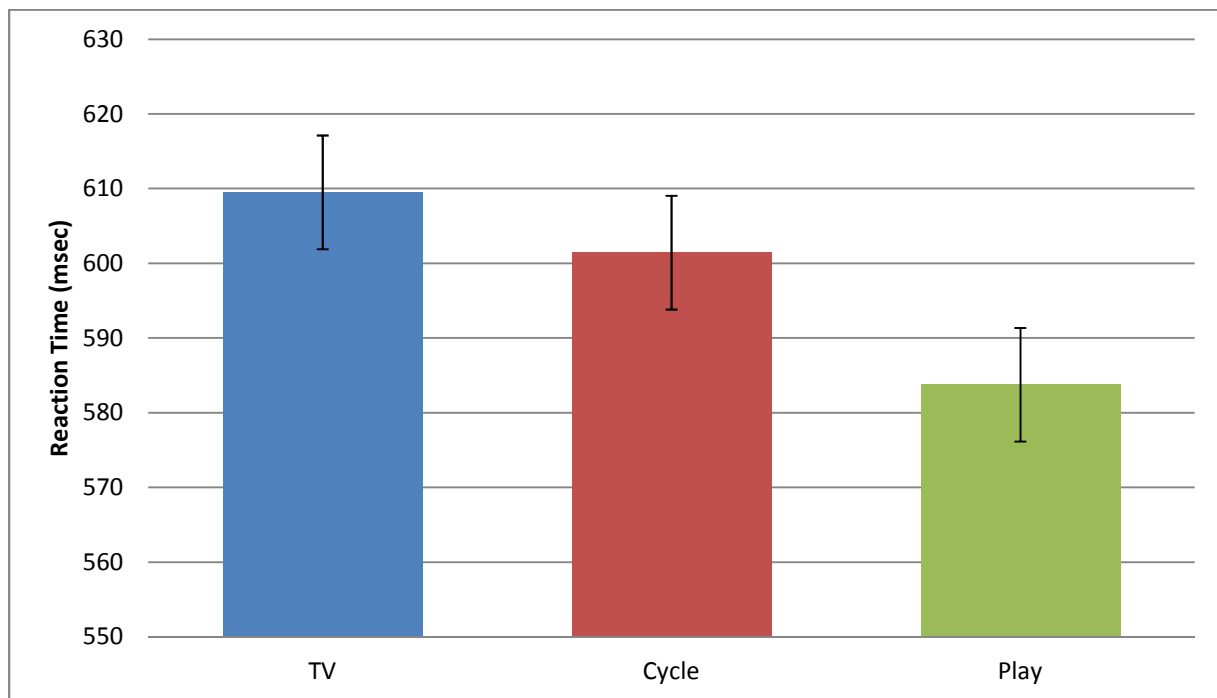


Figure 5: Mean Reaction Time for Each Condition

Finally, the data were analyzed to determine if there were any significant differences between means for each trial (congruent and incongruent) in relation to each testing condition. We found that children tended to complete the task significantly faster in the congruent trial compared to the incongruent trial, and the cycle and play protocols appeared to have faster reaction times compared to the control trial, although not significant (see Figure 6).

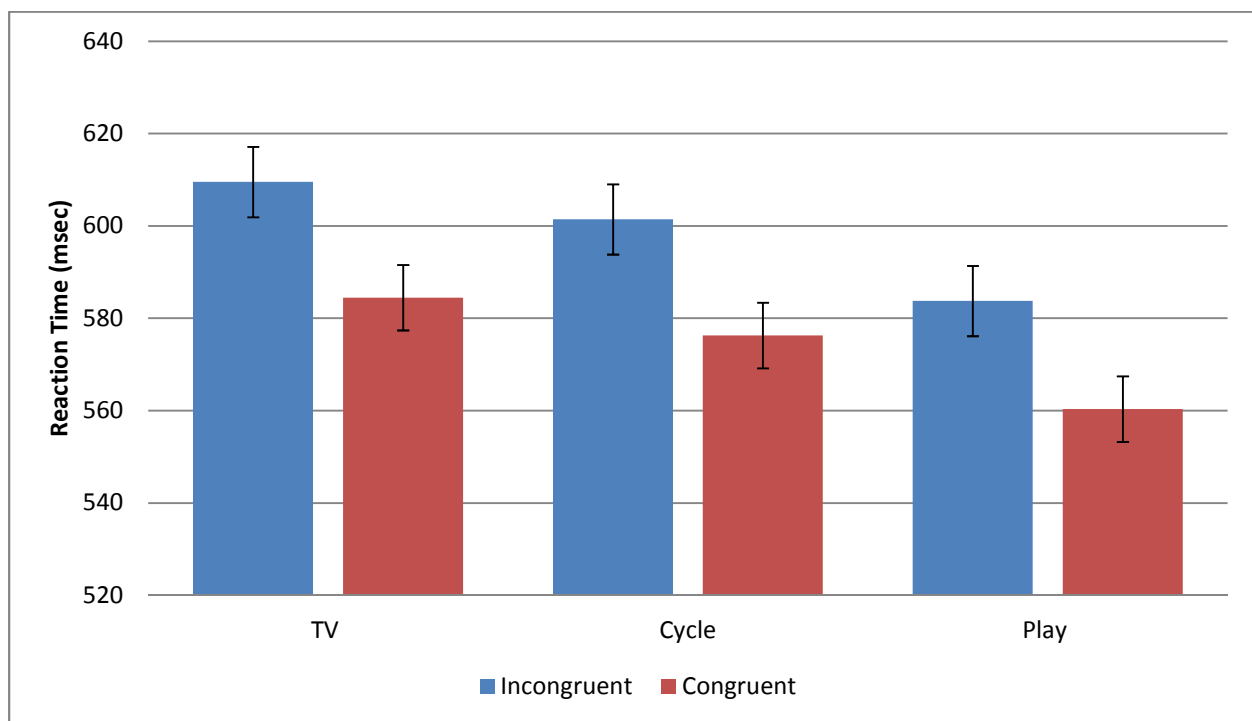


Figure 6: Mean Reaction Time for Congruent vs Incongruent Trials by Condition

Paired samples t-tests were run to analyze the mean differences between the congruent and incongruent trials for each condition. For accuracy, TV ($11.0 \pm 12.6 \%$) had the largest difference between the congruent and incongruent trials, followed closely by cycle ($10.8 \pm 14.1 \%$), and then play ($10.0 \pm 11.9 \%$). For reaction time, TV ($25.03 \pm 31.23 \text{ ms}$) and cycle ($25.14 \pm 30.92 \text{ ms}$) had almost identical mean differences between the congruent and incongruent trials, closely followed by play ($23.42 \pm 30.34 \text{ ms}$). No statistical difference was found across conditions.

Discussion

The purpose of our study was to compare the effects of acute bouts of stationary cycling and play on cognition in elementary school-aged children. We found that there were statistically significant differences between the congruent and incongruent tests ($p \leq .001$) for both accuracy and reaction time, supporting that our Flanker test accurately assessed the executive functioning component of cognition. However, we did not find any statistically significant differences between the three conditions for either accuracy or reaction time and there was no interaction between condition and trial type (congruent vs incongruent).

Accuracy was slightly higher for both the cycle and play conditions compared to the TV condition ($p=0.20$); however, these differences were not statistically significant. These results are similar to the study by Hillman et al., which found improvements in accuracy for the Flanker task after a 20-minute bout of treadmill walking when compared to a rest trial (18). These differences in accuracy may be due to the exercise related spike in neurotrophins and brain-derived neurotrophic factor (BDNF) which are known to occur during activity. These spikes in neurotrophins and BDNF are thought to help improve communication between the synapses, and over long term exposure, improve synaptogenesis, angiogenesis and myelination (3). However, due to our short duration of the activity (20 minutes), these levels may not have had the opportunity to increase to a sufficient level in the brain and bloodstream to elicit a statistically significant effect.

Our results for reaction time for the Flanker Task were also insignificant, but like the accuracy, there was a trend of faster reaction times with both the cycle and play trials. This finding is consistent with what has been shown in the literature (6, 18, 56). However since our results for reaction time were not significant ($p=0.56$), our results offer more support for the Stroth et al. study, which proposed that physical fitness may have a stronger impact in

decreasing reaction time than an acute bout of activity. It is also important to note that while the differences were insignificant, the cycle and play trials both elicited higher accuracy and faster reaction times than the TV trial. This is an important finding because it shows that sporadic, varied interval play typical of children (7) may elicit the same effects as moderate intensity controlled activity as seen in the literature. This has important implications for children's play at home and during the school day. This is supported by our heart rate data, which as stated earlier, our control condition had an average heart rate of 84.5 ± 8.5 bpm, while the cycle condition had an average heart rate of 123 ± 8.1 bpm, and play had an average heart rate of 150 ± 20.1 bpm. In our data, our cycle data falls into the heart rate range for moderate intensity activity, which is 120- 139 bpm, while our play data falls into the vigorous activity category, which is a heart rate over 140 bpm. These are two different types of intensity activity, however if there is a threshold effect as suggested by Coe et.al, play would be the most effective way to influence cognition (33), even though moderate intensity activity, such as cycling has still been found to have an effect.

For both the accuracy and reaction time components of the Flanker task, we found a significant difference between the congruent and incongruent trials ($p \leq 0.001$). These results are to be expected. One of the main qualifications for a proper administration of a modified Flanker task is that there is a difference found between the congruent and incongruent variables, with the incongruent variable having slower reaction speed and lower accuracy (19). This is due to the incongruent trial placing higher demands on a person's ability to ignore irrelevant information and seek out the appropriate target. A study by Pontifex et al. had similar findings in their study in regards to Flanker task response accuracy for children who were highly fit, finding that children who possessed high levels of fitness had greater response accuracy than their low fitness counterparts. An explanation for our findings may be that an acute bout of physical activity that

is at a high enough intensity may, for a short period of time, mimic the physiological changes that occur in a highly fit individual, which could in turn impact the results of the Flanker test.

However, an unexpected finding was that even though there was an overall difference between the congruent and incongruent variables, the mean difference between these variables did not change from trial to trial for both accuracy and reaction time. It is often observed that there is a narrowing in the difference between the congruent and incongruent trials when the activity condition is compared to the control condition (30, 46), however we did not see this in our data. This may have been due to lack of power from too few subjects or because our conditions were two different intensities.

By giving children the opportunity to play and be physically active in a way that is natural to them, we could not only encourage physical activity, but also facilitate it. The two most obvious times during the school day to implement these practices would be recess and physical education classes. While 60% of children have recess on a daily basis (9) even fewer have daily physical education classes. If policy is made to allow daily recess and physical education classes are brought to the forefront to facilitate activity, we present more opportunities during the school day to improve cognitive function and potentially academic performance through activity.

The biggest limitation of our study is the small sample size. Most studies use between 20-30 participants, however, most studies also only have two conditions, a control and activity. By only having 21 participants and three conditions we were unable to properly control for statistical errors and find significance (power=0.41), though our data showed trends toward our proposed hypothesis. Another limitation is that we used a software program called PEBL (version 0.14, Mueller) to run our modified Flanker task. This program did not allow us to modify exposure

time or the length of the test. In reality, our Flanker protocol may have been too fast for our age group, which may have led to slightly decreased accuracy and higher reaction times compared to other studies. However, despite our limitations with the PEBL software, the Flanker test did accurately analyze executive function and cognition.

A major strength of our study is that we had the children participate in the types of physical activity described in the literature such as moderate intensity cycling, in addition to the semi-structured play session. We also randomized the order of the trials to diminish the chance of an order effect and also allowed two trials of the Flanker task to be completed with each trial to minimize any learning effects of taking the multiple tests over time. We also utilized the best score out of the two attempts to represent the child's best effort for that condition.

In conclusion, we found that both cycling and semi-structured play may lead to better performance on the modified Flanker task in both accuracy and reaction time, although these results were not significant. Further research should attempt to replicate these results in the pre-elementary school age range as well as seeing if these effects carry into other age groups in the pediatric population. If a significant relationship is found, then it is worth investigating recess sessions during the school day as well as possibly physical education classes to see if further cognitive improvements can be found from acute activity, which will hopefully lead to improved academic achievement in children.

Chapter 4: Summary

The purpose of our study was to determine the effects of acute bouts of two types of physical activity on cognition in elementary school-aged children. We found that there was a statistically significant difference between the congruent and incongruent tests ($p \leq .001$) for both accuracy and reaction time. However, we did not find any statistically significant differences between the three trials for either accuracy or reaction time and did not observe any mean differences in either accuracy or reaction time. It would be beneficial to continue research on semi-structured play and its possible effects on cognition.

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Appendices

Appendix A: Parental Consent

Parental or Legal Guardian Permission for Child to Act as a Subject in a Research Study

The Impact of Acute Bouts of Two Types of Physical Activity on Cognition in Elementary School-Aged Children

Principal Investigator: Dawn P. Coe, Ph.D.
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University of Tennessee
Knoxville, TN 37996-2700
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1. INTRODUCTION:

Your child is being given the opportunity to participate in this study because s/he is in the age range of 6 – 10 years and is in grades 1 – 3. Your child will participate in some physical activity and resting trials to determine the impact of each on cognitive function. Your child's participation in this research study is voluntary. Please read this permission form carefully and take your time making your decision to allow your child to participate. As the study staff discusses this permission form with you and your child, please ask him/her to explain any words or information that you or your child do not clearly understand. We encourage your child to talk with your family and friends before s/he decides to take part in this research study. The nature of the study, risks, inconveniences, discomforts, and other important information about the study are listed below.

The purpose of this study is to determine the effect of two types of physical activity and a sedentary activity on cognition in elementary school-aged children. Your child will be asked to ride a stationary cycle for 20 minutes, play on a playground for 20 minutes, and sit and read for 20 minutes. After these activities, your child will complete cognition test on an iPad.

This is a single center study and approximately 30 subjects will be participating in this study.

The study will take place at the Applied Physiology Laboratory on the University of Tennessee campus. Each visit (three total) will last approximately 60 minutes. Total time for participation in the study is approximately 3 hours.

2. PROCEDURES TO BE FOLLOWED:

Height and Weight

Your child's standing and seated height and body weight will be assessed.

Activity and Sedentary Trials

Your child will engage in three randomly assigned activities. These activities include: 20 minutes of sitting and reading, 20 minutes of moderate intensity activity on the stationary cycle, or 20 minutes of semi-structured play on a playground similar to a recess session. Immediately after the sitting trial, the cognitive assessments will be completed on the iPad. Following the cycling and play trial, the cognitive assessments will be completed on the iPad after the recovery period.

_____ (Place initials here)

Following the completion of the third visit, your child will receive a small gift (valued at approximately \$6) from the University of Tennessee Applied Physiology Laboratory.

3. RISKS ASSOCIATED WITH PARTICIPATION:

Every effort will be made to minimize any discomforts or risks.

There are potential risks associated with physical activity in general. Potential risks to riding on a stationary cycle are minimal and include leg cramps, falling, and muscle sprain/strain. The researcher will be in close proximity to the participant during the entire cycling session to ensure the safety of the participant.

The semi-structured physical activity session also carries minimal risk. These risks are similar to those typically experienced during recess at school and include falling, musculoskeletal injury, and cuts and/or scrapes.

There is minimal risk associated with the heart rate monitors. The heart rate monitor is a cloth belt worn around the chest and is used to measure heart rate. The belt worn around the chest that contains the device may rub on the skin, causing irritation. The researcher will instruct the participant on how to adjust the belt to reduce irritation.

4. BENEFITS ASSOCIATED WITH PARTICIPATION:

There are no direct benefits to children who participate in this research study. However, information acquired may provide insight for parents/guardians and school administrators on the types of physical activity that may be beneficial to children's cognition and academic achievement.

5. CONFIDENTIALITY:

All of your child's paper research records will be stored in locked file cabinets and will be accessible only to research personnel. All of your child's electronic research records will be computer password protected and accessible only to research personnel.

Your child's research records will be located on the University of Tennessee, Knoxville campus and will be labeled with a code. A master key that links your child's name with the code on your research record will be maintained at the local investigative site.

Your child will not be identified in any presentations or publications based on the results of the research study.

6. COMPENSATION AND TREATMENT FOR INJURY:

Your child will receive a small gift (i.e. \$6 value) for participation in the study.

You and your child are not waiving any legal rights or releasing the University of Tennessee, or its agents, from liability for negligence. In the event of physical injury resulting from research procedures, the University of Tennessee has not budgeted funds for compensation either for lost wages or for medical treatment. Therefore, the University of Tennessee does not provide for treatment or reimbursement for such injuries. No compensation will be available for any ancillary expenses incurred as a result of research related physical injuries, additional hospital bills, lost wages, travel expenses, etc.

_____ (Place initials here)

If your child suffers a research-related injury, your study investigator will provide acute medical treatment and will provide your child with a subsequent referral to appropriate health care facilities.

You and/or your insurance carrier will be billed for the costs associated with the medical treatment of a research-related injury.

7. QUESTIONS:

If you have any questions about this study, you may contact Dawn P. Coe, Ph.D. at (865) 974-0294. You may contact the Office of Research Compliance Officer at 865-974-3466 if you have any questions about your child's rights as a participant in this study or your child's rights as a research subject.

8. VOLUNTARY PARTICIPATION:

Your child's participation in this research study is completely voluntary. Your child may choose not to participate or to drop out of the study without any penalty or loss of benefits to which your child is otherwise entitled.

9. PERMISSION OF SUBJECT:

You have read or have had read to you a description of the research study as outlined above. The investigator or his/her representative has explained the research study to you and has answered all the questions you have at this time. You knowingly and freely choose to allow your child to participate in the research study. A copy of this permission form will be given to you for your records.

_____	_____	_____
Signature of Parent/Guardian	Date	Time

Printed Name of Research Subject (Child)

_____	_____	_____
Signature of Person Obtaining Permission	Date	Time

Printed Name of Person Obtaining Permission

In my judgment, the subject or the legally authorized representative has voluntarily and knowingly given permission and possesses the legal capacity to give permission to participate in this research study.

Appendix B: Child Assent

Assent Form

The impact of acute bouts of two types of physical activity on cognition in elementary school-aged children

☐ The assent discussion was initiated on _____ (date) at _____ (time).

The information was presented in age-appropriate terms.

The minor: _____ (Subject's Name)

☐ Agreed to take part in the study on _____ (date) at _____ (time).

.....

☐ An assent discussion was not initiated with the minor for the following reason(s):

☐ Minor is under 8 years of age

☐ Minor is physically incapacitated

☐ Minor is cognitively or emotionally unable to participate in an assent discussion

☐ Minor refused to take part in the discussion

☐ Other _____

RESEARCHER/DESIGNEE STATEMENT: I hereby certify that I have discussed the research project with the research participant and/or his/her parent(s) or legal guardian(s). I have explained all the information contained in the permission document, including any risks that may be reasonably expected to occur. I further certify that the research participant was encouraged to ask questions and that all questions were answered.

Researcher/Designee Printed Name

Researcher/Designee Signature

Date

Time (AM/PM)

Minor Subject Printed Name

Minor Subject Signature (6 – 10 years)

Date

Time (AM/PM)

Vita

Aslynn Halvorson was born in Indianapolis, IN to her parents Terry and Laurie Halvorson. She has a younger brother named Andrew. She attended David W. Butler High School, where she graduated with honors as well as competing in track for all four years and earning an athletic scholarship for college. After graduation, she travelled to Knoxville, TN where she completed her Bachelors of Science in Education in Kinesiology (May 2012) while representing the University in athletics. Afterwards, she decided to continue her education and track career at the University of Tennessee, where she completed her Masters of Science in Kinesiology December of 2014. She hopes to continue her education by obtaining a PhD in the next few years. She currently resides in Knoxville, TN where she coaches shot-put and discus at a local high school.