DETERMINING THE DURATION OF EFFECTS ON BEHAVIOR AND ACADEMIC OUTCOMES FROM SINGLE AND MULTIPLE BOUTS OF MODERATE PHYSICAL ACTIVITY FOR STUDENTS WITH ADHD

A Dissertation in
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by
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ABSTRACT

The purpose of this study was to examine the effects of moderate to vigorous physical activity (MVPA) on the classroom behavior and academic engagement of early elementary children with ADHD. A key extension of the current study was examination of durability of effects of MVPA and implementation of a “Booster” session to increase effects over time. Results of this study indicate MVPA provided at the beginning of the school day can reduce classroom behaviors associated with ADHD. MVPA was shown to have a modest impact on academic engagement for some participants. These improvements, in both behavior and academic engagement, dissipated over time and were not present 90 minutes after participating in the MVPA intervention. In an effort to address the dissipation of effects of MVPA over time, a “booster” MVPA session was evaluated. Results showed that a 3-5 minute booster session of MVPA performed 90 minutes after the initial 15-minute bout of exercise both maintained benefits for all participants and improved behavioral benefits for some participants.
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ACKNOWLEDGEMENTS

I have been inculcated from an early age to appreciate learning. This is dedicated to those in my life who have helped me to stretch and achieve high aspirations.

My earliest memory of my grandfather, Dr. Edward LeRoy Hart, is visiting his office on campus. A narrow hallway in an old building gave way to his Sanctuary. Sun through the window catching dust in the air, old books, and a lifetime of curios collected from around the world. You are my real-life Indiana Jones. Sharing a treat from his secret stash, I knew I would someday follow his example. Thank you for always being there for me! Many of your curios are now in my office which I have made into my sanctuary.

Dad, I have not told you enough how much you inspire me to be a lifelong learner. Your intellect and accomplishments are staggering and I will forever be challenged in trying to make you proud. Thank you for instilling in me a deep-seated desire to know the world around me!

Mom, you have given me the passion I feel for life and discovery. You have helped me to be the free spirit that I am today and it is because of you that I never fear the future!

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Vita brevis. Vive ut vivas.
Chapter 1
INTRODUCTION

Recent data from the Centers for Disease Control and Prevention (CDC) provide evidence prevalence of Attention Deficit Hyperactivity Disorder (ADHD) is on the rise, impacts 11% of children in the United States (Visser et al., 2014). In school, children with ADHD are often unable to stay on task, do not complete assignments, or fail to turn them in on time (Denisco, Tiago, & Kravitz, 2005). Children with ADHD are more likely to experience school failure, have intellectual impairments, repeat grade levels and score lower on measures of intelligence as compared to typical children (Faraone et al., 1993; Kent et al., 2011). These issues often continue into adulthood, as half of children diagnosed in adolescence continue to meet criteria for ADHD as adults (Lara et al., 2009). Given these numbers, developing effective school-based interventions for this population of children that positively affects both academic performance and classroom behavior is very important.

ADHD is defined and diagnosed by presence of observable behaviors representing three areas: inattention, hyperactivity, and impulsivity. Research suggests executive functioning may underlie observed behavioral challenges for this group of children (Berlin, Bohlin, Nyberg, & Janols, 2004; Berlin, Bohlin, & Rydell, 2004; Weyandt, 2005). Executive function includes those capacities that allow a person to be purposeful, independent, self reliant and maintain an appropriate problem solving set to pursue future goals (Barkley, 2000; Welsh & Pennington, 1988). The term EF has been used to describe underlying cognitive processes that drive goal directed behavior and coordinate activity, such as reasoning, problem solving, and planning (Best & Miller, 2010).
Dopamine and EF

On a neurological level, there is evidence dopamine is related to attention and regulation in the prefrontal cortex (Glanzman & Sell, 2013). Dopamine is associated with reward and motivation behavior as well as self-control (Arias-Carrión & Pöppel, 2007; Robbins & Arnsten, 2009), all areas of concern for students with ADHD. Lower baseline levels of dopamine have been documented in children with ADHD (Levy, 1991). On a neurobiological level ADHD correlates with dysfunction of dopaminergic transmission, mainly in the striatum and frontal lobe (Grassmann, Alves, Santos-Galduróz, & Galduróz, 2014). A reduction in dopamine can lead to poor attention and focus (Tantillo, Hynd, Kesick, & Dishman, 2002). Thus, low levels of dopamine for children with ADHD may result in difficulties with self-regulation.

In an effort to increase dopamine levels of individuals with ADHD, stimulant medications (e.g., methylphenidate) are often prescribed. Methylphenidate is a dopamine agonist; it effectively inhibits reuptake of dopamine by neurons (Smith & Farah, 2011). Thus, stimulant medication has the effect of increasing the amount of dopamine in the synaptic cleft. Use of stimulant medication has been a common practice for children with ADHD for decades. In the United States roughly 1 in 25 children take medication for ADHD (Glanzman & Sell, 2013). Stimulant medication increases attention and motor control (Bush, Spencer, Holmes, & et al, 2008), leading to improved behavior (Glanzman & Sell, 2013). Additionally, children with ADHD have shown increases in the amount and accuracy of academic work completed while on stimulant medication (Prasad et al., 2012).

Although effective for some, stimulant medication is not a universal panacea. For example, research suggests that stimulant medication is ineffective at reducing ADHD symptoms for approximately 30% of users (Wigal, 2012). Some common adverse effects of medication include headaches, decreased appetite, low body weight, and sleep problems (Wigal, 2012).
Additionally, adherence can be an issue, especially in school settings where it may be difficult to manage the dosage protocol (Pelham et al., 2001). Lack of reliable, positive outcomes and negative side effects suggest a need to find and explore effective alternative treatments.

**Moderate-Vigorous Physical Activity**

Moderate-Vigorous Physical Activity (MVPA) has been suggested as a supplement, or alternative to, stimulant medication (Medina et al., 2010). MVPA is physical activity or movement that is aerobic in nature and typically entails an increase in heart rate of 50-85% of maximum through such activities as running, walking, or cycling (Nader, Bradley, Houts, McRitchie, & O’Brien, 2008). MVPA increases production of dopamine, that results in increased levels of the neurotransmitter delivered to synapses (McMorris, Collard, Corbett, Dicks, & Swain, 2008). In children with ADHD participation in MVPA, may lead to increased levels of dopamine leading to a more optimal state of functioning. Indeed, results of one study (Tantillo et al., 2002) suggest dopamine levels increased following a single session of MVPA. Thus, when a student returns to the classroom after MVPA she/he may be better able to attend to the task without exhibiting stimulation seeking behaviors that may be inappropriate for a given setting.

Recommendations suggest school-age youth engage in 60 minutes of MVPA per day for health benefits (Strong et al., 2005). Many physiological benefits result from regular exercise, including diabetes prevention, weight management, and cardiovascular health. In addition to effects of MVPA on physical measures, researchers have documented effects on attention to task, cognition, and brain function (Hillman, Erickson, & Kramer, 2008; Mahar, 2011), particularly for students with ADHD. These results have been demonstrated in a small number of single-case design studies (e.g. Allen, 1980; Azrin, Ehle, & Beaumont, 2006; Cannella-Malone, Tullis, & Kazee, 2011; Etscheidt & Ayllon, 1987; Evans, 1985). However, these results should be
replicated in studies with tighter controls (Hart & Lee, in preparation).

Little research on MVPA has been conducted directly with at risk or special needs populations. Although included within samples, data for individuals at risk for or already identified with disabilities were not disaggregated from typical performing students, the majority of which has been conducted using group designs (Archer & Kostrzewa, 2012; Best, 2010; Chang, Liu, Yu, & Lee, 2012; Etnier, Nowell, Landers, & Sibley, 2006; Gapin, Labban, & Etnier, 2011; Mahar, 2011; Taras, 2005; Tomporowski, 2003a, 2003b; Tomporowski, Davis, Miller, & Naglieri, 2008; Welsh & Labbé, 1994). Results of these group design studies tended to be positive suggesting MVPA may provide an effective method for enhancing executive function as a measure of children's mental functioning central to cognitive development (Tomporowski et al., 2008). Additionally, research suggests MVPA may lead to short-term academic improvements (Taras, 2005).

Similar to group design studies, single-case studies have documented positive effects. As one example, Canella-Malone et al. (2011) used a multiple baseline design to assess MVPAs effectiveness on reducing challenging behaviors of three boys, ages 8 to 11. Behavior was observed throughout the school day. Each participant engaged in eight sessions of exercise ranging from 46-70 minutes per day. Challenging behaviors for the three subjects decreased from a daily average of 5-9 occurrences before the intervention to 0-1 occurrences during the MVPA intervention.

Findings from single-case design studies summarized in a recent meta-analysis (Hart & Lee, in preparation) highlighted how MVPA has been shown to improve classroom behavior and academic engagement for children with ADHD, both on and off stimulant medication (Hart & Lee, in preparation). Hart and Lee highlight some variables that may be particularly important for developing a classroom intervention. First, exercise benefits can be seen with exercise episodes with durations as short as five minutes. For teachers with limited time and large demands to
increase time on task, short episodes of exercise may be more appealing. Time away from
academics while engaged in MVPA has not been shown to adversely affect academic
performance in other populations (Dwyer, Coonan, Leitch, Hetzel, & Baghurst, 1983; Sallis et al.,
1999). Second, exercise effects appear to be stronger for elementary age students. Third, robust
results were observed when using a variety of activities with varied intensity. Finally,
improvements in behavioral measures and academic engagement occurred with longer
interventions. Thus, to be more effective a program of MVPA should be sustained over time.

Hart and Lee also revealed potential shortcomings in the MVPA literature and
intervention. First, early elementary students were not included in this body of research. Most
studies evaluated effects of MVPA on students who where ages seven to thirteen. One question
remains as to whether MVPA will produce the same effects on academic performance and
behavior in elementary-age as observed in older students. Second, there is some evidence that
benefits are short-lived (Tomporowski, 2003b). For example, Allen (1980) provided evidence of
dissipating effects of MVPA over time. In this study, behavior was observed in one-hour intervals
for three hours post MVPA. Each successive hour showed an increase in the number of disruptive
behaviors leading to a return to baseline levels within three hours (Allen, 1980). In other
populations, a sharp reduction of behavior was observed shortly after MPVA, but after a 40
minute period effects gradually dissipated but did not reach baseline levels (Celiberti, Bobo,
Kelly, Harris, & Handleman, 1997). While this information is helpful it still leaves several
unanswered questions.

**Research Questions**

The purpose of this study was to address several of the limitations of the current MVPA
research base discussed earlier. More specifically, this study evaluated the effects of MVPA on
elementary-age children over time. The following questions were used to guide the experiment.

1. What are MVPA effects on classroom behavior of students with ADHD?
2. What are MVPA effects on the latency to respond to math problems for students with ADHD?
3. What are MVPA effects on accuracy in responding to math problems for students with ADHD?
4. What are the effects of a short MVPA booster session on classroom behavior of students with ADHD?
5. What are the effects of a short MVPA booster session on latency to respond to math problems for students with ADHD?
6. What are the effects of a short MVPA booster session on accuracy in responding to math problems for students with ADHD?
Chapter 2

METHOD

Participants

After obtaining IRB approval, the researcher provided recruitment materials to the superintendent of a charter school in a rural area of the Northeastern U.S. The superintendent sent an email containing the recruitment letter to all parents of students who attended the charter school. The letter included information regarding the study and target population. Recruitment materials indicated that the researcher was interested in recruiting students in grades K-4 diagnosed with ADHD or who exhibited ADHD-like behaviors, including students who demonstrated behavior problems and difficulties with academic engagement in a typical inclusive setting. Recruitment materials informed parents that participants taking stimulant medication should continue with medication, and not alter their current pattern of use during the study (to our knowledge, participants did not modify their medication schedule during the study). Eight parents returned signed consent forms with their child to the classroom teacher. However, two participants were dropped early in the study: one for an inability to complete the academic task, the second participant declined participation.

A total of six students participated in the study (see Table 2-1). Ernie was a 7-year-old Caucasian male with a formal diagnosis of ADHD. He was prescribed stimulant medication. His teacher described him as inattentive and easily distractible, but quiet and friendly. His teacher commented that Ernie often needed more time than peers to complete class work. Folk was a 9-year-old Caucasian female who engaged in ADHD-like behaviors, but did not have a formal diagnosis of ADHD. She was not taking stimulant medication at the time of the study. Her
teacher characterized her as a lovable individual who was always willing to try, but needed frequent redirection in order to complete tasks. George was a 9-year-old Caucasian male with a formal diagnosis of ADHD who was not taking stimulant medication. His teacher reported that George was easily distracted and often had a hard time sitting still unless he was immersed in a video game. Given the chance, he would turn any discussion to the topic of his favorite video game. Pieces was an 8-year-old Caucasian male who engaged in ADHD-like behaviors, but did not have a formal diagnosis. His teacher described him as being a good student when his behavior did not get in the way of academics. When he was focused on a task he performed well, but getting him to stay focused was a challenge. Road was a 6 year old Caucasian female in kindergarten who engaged in ADHD-like behaviors, but did not have a formal diagnosis of ADHD. She was very social and friendly, often at inappropriate times. Her teacher described having to redirect her from talking to her neighbors at inappropriate times. Any noise or movement in the classroom easily distracted her. Tesla was a 7-year-old Hispanic male with a formal diagnosis of ADHD. He was prescribed stimulant medication. His teacher described him as cheerful but easily distractible. His teacher further described Tesla as a social and outgoing individual who often used his gregarious nature as a distraction from work.

Table 2-1. Participant Demographics

<table>
<thead>
<tr>
<th>Name</th>
<th>Gender</th>
<th>Age</th>
<th>Grade</th>
<th>Diagnosis</th>
<th>Medication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ernie</td>
<td>Male</td>
<td>7</td>
<td>2</td>
<td>ADHD</td>
<td>Yes</td>
</tr>
<tr>
<td>Folk</td>
<td>Female</td>
<td>9</td>
<td>4</td>
<td>Behaviors</td>
<td>No</td>
</tr>
<tr>
<td>George</td>
<td>Male</td>
<td>9</td>
<td>3</td>
<td>ADHD</td>
<td>No</td>
</tr>
<tr>
<td>Pieces</td>
<td>Male</td>
<td>8</td>
<td>2</td>
<td>Behaviors</td>
<td>No</td>
</tr>
<tr>
<td>Road</td>
<td>Female</td>
<td>6</td>
<td>K</td>
<td>Behaviors</td>
<td>No</td>
</tr>
<tr>
<td>Tesla</td>
<td>Male</td>
<td>7</td>
<td>1</td>
<td>ADHD</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Setting

All sessions took place at the charter school, which serviced students from kindergarten through 8th grade. Sessions of MVPA were conducted outside on the playground and soccer fields adjacent to the school. The academic task (described below) was conducted in the learning support classroom. The classroom was thirty feet on a side and was set up for small group work, with eight student desks separated into two groups, a teacher desk, and several tables lining the walls. One table at the rear of the classroom was used for the academic task. Three computers were set up on this table. The classroom contained between one and 10 other students during baseline and intervention sessions.

Intervention

The independent variable for this study was MVPA. Specific elements of the intervention were based on results of meta-analytic findings (Hart & Lee, in preparation). More specifically, types, as well as intensity of exercises were varied and included exercises found to be successful in previous research (See Table 2-2 for list of exercises used during the 15-minute MVPA intervention). Participants were encouraged to stay in motion during MVPA, but intensity, speed, and overall effort were not monitored, as intensity was found not to be critical to the effectiveness of MVPA for children with ADHD (Hart & Lee, in preparation). That is, verbal encouragement was given when participants stopped moving completely. If they remained in motion no motivational encouragement was given.
Table 2-2. 15-min exercise routine

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3m walking/jogging</td>
<td>Brisk Walking or jogging Warm up- used to get to the soccer field.</td>
</tr>
<tr>
<td>12m cardiovascular activities</td>
<td>Participants played running games, Frisbee golf, soccer, and other running ball games with tennis balls and golf balls.</td>
</tr>
</tbody>
</table>

**Experimental Task**

During sessions participants completed a math task that assessed sustained attention. This task was chosen because it has been shown to be sensitive to intervention effects and could be simplified to meet the needs of early elementary age participants (Hemelryck, Rozloznik, Germonpre, Balestra, & Lafere, 2013; Perez, Masline, Ramsey, & Urban, 1987).

During the task, each participant sat at a computer separated from adjacent computers (approximately 1 m) using a partition. The experimental task software was loaded and running on the computer with written instructions displayed on the computer screen. Instructions were read verbally to participants before starting. A number between 1-4 and 6-9 appeared on the screen. Numbers were displayed using a font similar to 48 point Verdana on the computer screen. Participants were asked to indicate if the target number was "greater than" or "less than" the number 5 using the right and left shift keys, respectively. All other keys were disabled during the task. Allowing for greater-than/less-than answers, rather than locating individual keys, reduced potential for mixed results related to keyboarding experience. A new number appeared only after the student responded. The task was 5 minutes in duration and was administered using Psychology Experiment Building language (PEBL), which is an open source software system developed as a stimulus presentation package for research and education purposes (Mueller & Piper, 2014).
Procedures

Pre-baseline

Prior to starting baseline, there was a brief training session on the math task. During this training, participants were taught how to perform the task using a model, prompt, check sequence. During training the investigator first modeled problem completion. Next, the investigator verbally prompted the participant through the task. Finally, the participant was asked to complete the 5 min. task independently. During the check step scores ranged from 67-86% accuracy. Additionally, participants were asked to complete the math task 3 times over the course of three days in order to allow for habituation to task-related stimuli.

Baseline

Baseline sessions occurred after morning announcements. Participants were randomly selected in groups of three and brought to a quiet area of the classroom where three computer stations were set up. Participants were randomly assigned to computers. Upon arrival at their respective computer stations, participants were asked to read a book for 15 min. Books were selected by the classroom teacher. This reading period was instituted to equate time away from class and researcher attention between the baseline and intervention conditions.

Before starting the task each session, the researcher gave the following instructions to students:

This task is designed to show how quickly you can choose if the answer to a math problem is greater than or less than five. When the task begins, you will see a number. If you think that the number is less than five press the left shift key (researcher pointed to key. If you think that the number is more than five press the right shift key (researcher
pointed to key). *Getting the correct answer is just as important as going fast so give it your best effort. Get ready. Press either key now to begin.*

At the completion of the math task participants were escorted back to their classroom.

**MVPA Booster baseline**

In order to evaluate effects of a booster MVPA session, students were called out of class 90 min after the initial baseline. During these sessions participants were randomly selected to groups of three and brought to their respective task computer stations and asked to read a book for 5 min. This reading period was instituted to equate time away from class and researcher attention between the baseline and MVPA booster. During the 90 minutes in between the first and second task, teachers were asked to keep activity similar to that experienced during normal classroom routines. No extraneous bouts of MVPA were noted during this time period.

**MVPA**

The purpose of the first intervention phase was to determine effects of a single bout of MVPA on sustained attention and off task related behavior. This phase consisted of one, 15-minute bout of MVPA. During the first intervention phase, participants reported to the classroom as usual for the start of school. After morning announcements, the researcher met with the students to go outside. The 15-min exercise session began after meeting at the outside door. All six participants ran or walked to the athletic fields behind the school where the choice of activities was presented (see Tables 3-2). At the 12 min mark of MVPA sessions, equipment was collected, and as a group, participants ran to the front of the school. The last minute of the intervention was walking in the school and upstairs to the classroom where the experimental task was performed.
After arriving at the classroom, participants were asked to sit at a computer where the experimental task was administered. Because the availability of computers used to deliver the experimental task was limited to three, participants completed the academic task in two groups. Group order (first or second) was randomized across participants each day. That is, participants randomly had a 5 min lag before starting the task if they were assigned to the second group.

**MVPA + Booster**

The purpose of the second intervention phase was to determine the effects of a booster session of MVPA, administered 90 min after the initial bout, on sustained attention and off task related behaviors. The second intervention phase consisted of one 15-minute bout of MVPA identical to that in Phase 1, followed by a single 5 min bout of MVPA 90 min after the first bout. The procedures in Phase 2 were identical to those used in Phase 1 for the initial bout of MVPA. The only difference in the second intervention phase was the addition of a second bout, or booster session, of MVPA. For the 5 min booster session participants chose from a list of activities (See Table 2-3). The five minutes included the exercise time as well as transition time from meeting at the outside door to arriving at the learning support classroom. As in Phase 1, all activities were completed on the playground immediately outside the school. After an exercise was chosen, it was removed from the array for the remainder of the week. At the beginning of the following week, the list was reset to include all options again. Immediately following the booster session, participants completed the academic task using procedures identical to those used in baseline and Intervention Phase 1.
Table 2-3. 5-min varied exercise choices. 5-min includes time to move from seat to exercise areas.

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tag</td>
<td>Participants will play a game of tag on the playground equipment.</td>
</tr>
<tr>
<td>Jump rope</td>
<td>Students will pick up a jump rope and attempt to jump continuously for the entire time.</td>
</tr>
<tr>
<td>Jogging</td>
<td>Students will jog around the gym or outside dependent on the weather.</td>
</tr>
<tr>
<td>Tennis ball throws</td>
<td>Students will throw a tennis ball against a wall and catch it for 2 min.</td>
</tr>
<tr>
<td>Brisk walking</td>
<td>Students will walk briskly around the gym or outside dependent on the weather.</td>
</tr>
<tr>
<td>Crunches, pushups, jumping jacks</td>
<td>Students will do 12 crunches, 12 pushups and 25 jumping jacks.</td>
</tr>
<tr>
<td>Weights- Upper body</td>
<td>Curls, Triceps, shoulder: 12 each with 2-8 pound weights</td>
</tr>
<tr>
<td>Scooter board</td>
<td>Students will move scooter by shifting weight and remain in motion for the duration of the time.</td>
</tr>
<tr>
<td>Toe raises, squats, knee raises</td>
<td>Students will do 25 toe raises, 10 squats, and 25 knee raises.</td>
</tr>
<tr>
<td>Plank and/or Pushups</td>
<td>Participants will do a plank or pushups to try and beat previous amounts.</td>
</tr>
<tr>
<td>Arm Hang and/or Pull Ups</td>
<td>Participants will hang or do pull ups to try and beat previous amounts.</td>
</tr>
</tbody>
</table>

**Dependent Measures**

The lead author and four graduate assistants collected all data. All data collectors were trained by the lead author to independently record and collect behavioral data, and administer MVPA. During training sessions the lead author discussed and provided examples of the behavioral definitions and then modeled data collection procedures using videos of similar classroom situations. Data collectors were then provided an opportunity to practice data collection. Effectiveness of training was determined by scoring a practice video to 90% agreement. All data collectors for the study scored at least 90% on the practice video assessment.
**Behavioral**

The behavioral measures were similar to those used in previous research, found to be sensitive to changes in levels of activity in classroom settings (Evans, 1985; Lee & Zentall, 2002; Yell, 1988). Behavioral data were collected while participants performed the math task. *Looking away* from the computer was defined as any head movement not directed at the screen or keyboard, including turning the head more than 40 degrees from the screen. *Removing the hands* from the keyboard was defined as any time the fingers were moved farther than 3” from the shift keys. *Talking out* consisted of any verbalizations, including humming, singing, talking or mumbling. *Leg and torso movement* included any shifting in the seat, bending at the torso (leaning forwards and backwards from the waist), and any other leg movements including toe tapping, sitting on one leg, shuffling, and swinging legs.

A 10-s partial interval recording procedure was used to document behavior during the math task sessions. In order to allow researchers time to record each of the four behaviors a 5 second recording pause was included between each interval. With the pause between each interval, the final number of possible intervals was 20 for each 5 min math task.

**Attention to Task**

The sustained attention math task allowed researchers to collect data on three areas of academic performance. First, latency to respond to the target stimulus was used to assess sustained attention to the task (Lee & Zentall, 2002). Latency was defined as the time from presentation of a given math problem to initiation of a student response. Second, the number of problems attempted and accuracy (i.e., number incorrect) of documented. All academic performance data were collected via PEBL software (Mueller & Piper, 2014) and stored on a
Teacher Interviews

Shortly after the conclusion of the study, teachers were interviewed and asked three questions: (1) Did you notice any differences in your student's behavior and academic engagement during the intervention? (2) Have you seen any changes in your student since the completion of the study? (3) What are your general impressions of the intervention and its usefulness in the classroom? These responses were used as a measure of social validity and feasibility.

Research Design

The effects of MVPA were evaluated using an alternating treatments design (Johnston & Pennypacker, 1993; Kazdin, 2011). The alternating treatments design is uniquely suited to show the hypothesized short-term change in dependent measures across two or more interventions. The order of conditions was counterbalanced to control for possible order effects.

In single case design studies, certain characteristics of data are examined to evaluate effectiveness of the intervention. A plan of analysis was developed using five key areas outlined by Alberto and Troutman (2011). First, data were evaluated by mean differences among conditions. Within each phase, the mean of all data points may indicate meaningful changes in behavior. Second, data were evaluated by levels of performance within each phase relative to their respective baseline conditions. Identifying differences from one phase to another can help show a difference in performance. Additionally, the greater separation that occurs in the data in an alternating treatments design the stronger evidence of an effect. Third, analysis of data
included an evaluation of trend in performance. This focused on systematic and consistent increases or decreases in performance over time. The fourth analysis involved rapidity of change or length of time between onset or termination of change after initiating or ending a phase. Fifth, Alberto and Troutman (2011) suggest an analysis of the percentage of overlap in the data, or an effect size.

Tau-U was used because of its unique ability to handle small data sets and account for baseline trend (Vannest & Ninci, 2015), and is represented as a percentage of overlap between phases (Parker, Vannest, Davis, & Sauber, 2011). Vanest and Ninci (2015) offer the following tentative guidelines for interpreting Tau-U: Small effect = 0 - .20; moderate effect = .20 - .60; large effect = .60 - .80; very large effect = .80 – 1.0.

**Treatment Fidelity**

It is important to provide data ensuring accuracy and reliability of implementing the independent variable (Peterson, Homer, & Wonderlich, 1982). Treatment fidelity data provides a means for ensuring the independent variable is implemented in a manner consistent with the description in the method section. Treatment fidelity included data collected on participants’ completion of exercises and adherence to the exercise protocol and academic task. Graduate assistants helping collect IOA also collected treatment fidelity. A seven-step checklist was used to assess compliance (See Table 2-4).
<table>
<thead>
<tr>
<th>Steps</th>
<th>Participant 1</th>
<th>Participant 2</th>
<th>Participant 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Student reads for 15m</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Math task instructions are read to students</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Students complete math task</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. 70-90m break between first and second session</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Students read for 5m</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Math task instructions are read to students</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Students complete math task</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Chapter 3

RESULTS

The purpose of this study was to examine the effects of MVPA and MVPA plus a booster on attention (latency to response and off-task behavior) and academic productivity (problems completed and problems completed correctly) on a mathematics task. Results for each dependent variable for each participant are presented below.

Ernie

Attention to Task

Table 3-1 lists the means, and ranges of latency to respond to the math task for Ernie, as well as all other participants. Ernie’s mean baseline latency was 1381.93 ms. When the 15 min initial bout of MVPA was administered, his mean latency to respond decreased to 1123.59 ms, indicating an increase of attention to the task. The math task was again administered 90 min after the initial bout of MVPA. Ernie’s mean latency to respond during the 90 min baseline condition (booster baseline) was 1690.89 ms, which was greater than both the initial baseline and MVPA conditions. When the 5 min booster exercise condition (MVPA + booster) was administered, Ernie’s mean latency to respond was reduced by 26.1% (1250.83 ms), relative to the 90 min booster baseline. Both the booster baseline and MVPA + booster sessions resulted in latencies that were greater than the initial MVPA condition.

A visual analysis was conducted to examine relative changes across the various conditions (see Figure 3-1). Both of the MVPA conditions differed from their respective baselines.
only early in the experiment. The MVPA + booster data path showed a slight ascending trend. A Tau-U effect size confirmed visual analysis of latency for Ernie (Baseline to MVPA Tau-U = .41; Booster Baseline to MVPA + Booster Tau-U = .70; Intervention weighted mean Tau-U = .55).

Table 3-1. Mean Latencies (and Ranges) across Conditions in Milliseconds

<table>
<thead>
<tr>
<th>Student</th>
<th>Baseline</th>
<th>MVPA</th>
<th>Booster Baseline</th>
<th>MVPA + Booster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ernie</td>
<td>1381.93</td>
<td>1123.59</td>
<td>1690.89</td>
<td>1250.83</td>
</tr>
<tr>
<td></td>
<td>(1092.89-1788.67)</td>
<td>(791.98-1370.83)</td>
<td>(1358.86-1938.64)</td>
<td>(1028.16-1593.51)</td>
</tr>
<tr>
<td>Folk</td>
<td>747.01</td>
<td>736.93</td>
<td>796.56</td>
<td>716.63</td>
</tr>
<tr>
<td></td>
<td>(705.02-791.98)</td>
<td>(683-802.62)</td>
<td>(651.46-865.6)</td>
<td>(675.98-750.5)</td>
</tr>
<tr>
<td>George</td>
<td>1126.07</td>
<td>923.9</td>
<td>970.15</td>
<td>847.82</td>
</tr>
<tr>
<td></td>
<td>(950.18-1454.57)</td>
<td>(702.74-1302.61)</td>
<td>(789.27-1106.44)</td>
<td>(682.86-911.66)</td>
</tr>
<tr>
<td>Pieces</td>
<td>2999.75</td>
<td>1891.24</td>
<td>3443.82</td>
<td>1859.57</td>
</tr>
<tr>
<td></td>
<td>(2597.77-3666.86)</td>
<td>(1512.18-2357.71)</td>
<td>(2428.09-6108.5)</td>
<td>(1523-2078.18)</td>
</tr>
<tr>
<td>Road</td>
<td>2278.42</td>
<td>3113.98</td>
<td>2380.43</td>
<td>2828.12</td>
</tr>
<tr>
<td></td>
<td>(1835.57-2555.37)</td>
<td>(2272.41-4053.46)</td>
<td>(2040.94-2725.22)</td>
<td>(1719.49-3691.42)</td>
</tr>
<tr>
<td>Tesla</td>
<td>2295.48</td>
<td>1936.36</td>
<td>2779.51</td>
<td>2358</td>
</tr>
<tr>
<td></td>
<td>(2172.82-2371.97)</td>
<td>(1323.49-3125.44)</td>
<td>(2137.93-3610.28)</td>
<td>(1483.47-3153.66)</td>
</tr>
</tbody>
</table>

Figure 3-1. Mean Latency of Each Trial for Ernie.
Off Task Behaviors

Vocalizations, looking away from the computer, removing hands from the keyboard, and fidgeting were all considered off-task behaviors and were combined for final analysis. Data were collected on the total number of intervals scored with off task behaviors during the 5 min task. During baseline, Ernie averaged 14 scored intervals during the 5-minute math task. After a 15-minute bout of exercise his mean number of scored intervals was reduced by 51.3% (6.89 intervals). After 90 minutes without a booster (i.e., booster baseline), an average of 14.25 intervals were scored. In comparison, after 90 minutes with a 5-minute booster of MVPA (MVPA + booster) his mean number of scored intervals was reduced by 48.1% (7.4 intervals). Table 3-2 lists the means and ranges for all participants.

Table 3-2. Mean of Total Intervals Scored for All Behaviors (and Ranges) Across Conditions

<table>
<thead>
<tr>
<th>Student</th>
<th>Baseline</th>
<th>MVPA</th>
<th>Booster Baseline</th>
<th>MVPA + Booster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ernie</td>
<td>14.0</td>
<td>6.89</td>
<td>14.25</td>
<td>7.4</td>
</tr>
<tr>
<td></td>
<td>(10-17)</td>
<td>(5-11)</td>
<td>(13-15)</td>
<td>(7-9)</td>
</tr>
<tr>
<td>Folk</td>
<td>14.0</td>
<td>6.33</td>
<td>13.5</td>
<td>5.8</td>
</tr>
<tr>
<td></td>
<td>(12-15)</td>
<td>(4-9 )</td>
<td>(11-17)</td>
<td>(3-12)</td>
</tr>
<tr>
<td>George</td>
<td>17.33</td>
<td>8.9</td>
<td>16.25</td>
<td>6.4</td>
</tr>
<tr>
<td></td>
<td>(15-19)</td>
<td>(5-13)</td>
<td>(15-17)</td>
<td>(5-9)</td>
</tr>
<tr>
<td>Pieces</td>
<td>9.0</td>
<td>3.89</td>
<td>10.0</td>
<td>7.0</td>
</tr>
<tr>
<td></td>
<td>(6-12)</td>
<td>(2-7 )</td>
<td>(5-13)</td>
<td>(3-17)</td>
</tr>
<tr>
<td>Road</td>
<td>18.0</td>
<td>11.5</td>
<td>17.67</td>
<td>12.4</td>
</tr>
<tr>
<td></td>
<td>(16-20)</td>
<td>(7-16)</td>
<td>(16-19)</td>
<td>(10-15)</td>
</tr>
<tr>
<td>Tesla</td>
<td>19.33</td>
<td>11.22</td>
<td>19</td>
<td>13.2</td>
</tr>
<tr>
<td></td>
<td>(18-20)</td>
<td>(5-12)</td>
<td>(18-20)</td>
<td>(5-17)</td>
</tr>
</tbody>
</table>

Figure 3-2 represents data on behavior across time. Initial baseline data showed a slight ascending trend and were similar to intervention data. Non-MVPA data showed higher levels of scored intervals. Both interventions resulted in lower levels, relative to their respective comparison baselines, with little overlap (MVPA only). A Tau-U effect size confirmed visual
analysis of total intervals scored with all off-task behaviors for Ernie (Baseline to MVPA Tau-U = .93; Booster Baseline to MVPA + Booster Tau-U = 1.0; Intervention weighted mean Tau-U = .96).

![Figure 3-2. Total Number of Scored Intervals for all Behaviors Each Day for Ernie.](image)

**Problems Attempted and Accuracy**

Table 3-3 lists means and ranges of problems attempted for all participants. Table 3-4 lists the means and ranges of errors in responding for all participants. During baseline Ernie attempted, on average, 174 problems. In sessions where MVPA was administered the mean number of problems increased to 207. 56 (46.22 errors). During the booster baseline condition, Ernie completed a mean of 151.75 problems, with a mean of 22.5 errors. The MVPA + booster resulted in an increase of problems attempted relative to the booster baseline condition.

Visual analysis of Ernie’s math problems attempted (see Figure 3-3) showed differences in level between baseline and MVPA during the first 3 sessions of the experiment. This effect
was similar for the booster baseline and MVPA + booster comparison. Visual analysis of Ernie’s errors (see Figure 3-4) showed that error rates increased concomitant with increases in problems attempted. A Tau-U effect size confirmed visual analysis of the number of errors for Ernie (Baseline to MVPA Tau-U = .26; Booster Baseline to MVPA + Booster Tau-U = .70; Intervention weighted mean Tau-U = .48). A Tau-U effect size confirmed visual analysis of the number of trials completed for Ernie (Baseline to MVPA Tau-U = .33; Booster Baseline to MVPA + Booster Tau-U = .60; Intervention weighted mean Tau-U = .47).

Table 3-3. Mean Number of Problems Completed (and Ranges) across Conditions

<table>
<thead>
<tr>
<th>Student</th>
<th>Baseline</th>
<th>MVPA</th>
<th>Booster Baseline</th>
<th>MVPA + Booster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ernie</td>
<td>174.0 (136-207)</td>
<td>207.56 (169-256)</td>
<td>151.75 (122-174)</td>
<td>198.2 (146-252)</td>
</tr>
<tr>
<td>Folk</td>
<td>272.67 (257-290)</td>
<td>275.44 (258-290)</td>
<td>263.74 (245-298)</td>
<td>285.6 (272-296)</td>
</tr>
<tr>
<td>George</td>
<td>210.67 (164-241)</td>
<td>236.9 (175-281)</td>
<td>243.5 (213-271)</td>
<td>275.6 (238-300)</td>
</tr>
<tr>
<td>Pieces</td>
<td>85 (69-95)</td>
<td>137.56 (107-189)</td>
<td>122.75 (99-181)</td>
<td>120.5 (106-145)</td>
</tr>
<tr>
<td>Road</td>
<td>114.0 (94-145)</td>
<td>83.44 (64-108)</td>
<td>110.5 (89-137)</td>
<td>108.8 (69-145)</td>
</tr>
<tr>
<td>Tesla</td>
<td>105.33 (102-110)</td>
<td>129.33 (81-169)</td>
<td>95.0 (72-121)</td>
<td>108.6 (80-149)</td>
</tr>
</tbody>
</table>
Table 3-4. Mean Number of Errors (and Ranges) across Conditions with Ranges

<table>
<thead>
<tr>
<th>Student</th>
<th>Baseline</th>
<th>MVPA</th>
<th>Booster Baseline</th>
<th>MVPA + Booster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ernie</td>
<td>39.0</td>
<td>46.22</td>
<td>22.5</td>
<td>41.8</td>
</tr>
<tr>
<td></td>
<td>(17-71)</td>
<td>(24-114)</td>
<td>(19-26)</td>
<td>(22-61)</td>
</tr>
<tr>
<td>Folk</td>
<td>44.67</td>
<td>35.78</td>
<td>37.0</td>
<td>41.6</td>
</tr>
<tr>
<td></td>
<td>(38-48)</td>
<td>(32-40)</td>
<td>(29-46)</td>
<td>(38-47)</td>
</tr>
<tr>
<td>George</td>
<td>46.33</td>
<td>40.9</td>
<td>35.75</td>
<td>42.0</td>
</tr>
<tr>
<td></td>
<td>(26-70)</td>
<td>(25-74)</td>
<td>(32-41)</td>
<td>(35-53)</td>
</tr>
<tr>
<td>Pieces</td>
<td>18.67</td>
<td>17.67</td>
<td>22.5</td>
<td>19.0</td>
</tr>
<tr>
<td></td>
<td>(16-22)</td>
<td>(16-20)</td>
<td>(15-34)</td>
<td>(16-21)</td>
</tr>
<tr>
<td>Road</td>
<td>39.0</td>
<td>27.11</td>
<td>41.25</td>
<td>39.2</td>
</tr>
<tr>
<td></td>
<td>(15-82)</td>
<td>(19-59)</td>
<td>(20-61)</td>
<td>(15-74)</td>
</tr>
<tr>
<td>Tesla</td>
<td>20.67</td>
<td>21.11</td>
<td>18.25</td>
<td>17.8</td>
</tr>
</tbody>
</table>

Figure 3-3. Number of Problems Attempted Each Day by Ernie.
Figure 3-4. Number of Errors Each Day for Ernie.

Folk

Attention to Task

During initial baseline, Folk’s mean latency to respond to math problems 747.01 ms. When the 15 min bout of MVPA was administered, her mean latency decreased slightly to 736.93 ms. Folk's mean latency to respond during booster baseline was 796.56 ms, which was greater than the MVPA condition. Folk’s mean latency was lowest in the MVPA + booster condition (716.63 ms).

A visual analysis was conducted to examine relative changes across the various conditions (see Figure 3-5). The booster baseline showed variability, with Session 3 driving the effect. Other data paths were relatively stable. There were no discernible differences among conditions after the MVPA and MVPA + booster interventions were administered, relative to
their respective baselines. Data for MVPA + booster had a descending trend across time. A Tau-U effect size confirmed visual analysis of latency for Folk (Baseline to MVPA Tau-U = .18; Booster Baseline to MVPA + Booster Tau-U = .60; Intervention weighted mean Tau-U = .39).

Figure 3-5. Mean Latency of Each Trial for Folk.

**Off Task Behaviors**

During baseline, Folk averaged 14 scored intervals during the 5-minute math task. After a 15-minute bout of exercise her mean number of scored intervals was reduced by 54.8% (6.33 intervals). After 90 minutes without a booster (i.e., booster baseline), an average of 13.5 intervals were scored. In comparison, after 90 minutes with a 5-minute booster of MVPA her mean number of scored intervals was reduced by 57.8% (5.8 intervals).

Figure 3-6 represents data on behavior across time. Visual analysis shows a slight downward trend in all four conditions. However, non-MVPA data showed higher levels of scored
intervals. Both interventions resulted in lower levels, relative to their respective comparison baselines, with little overlap (MVPA + booster only). A Tau-U effect size confirmed visual analysis of total intervals scored with all off-task behaviors for Folk (Baseline to MVPA Tau-U = 1.0; Booster Baseline to MVPA + Booster Tau-U = .85; Intervention weighted mean Tau-U = .93).

![Graph showing intervals over days for different conditions](image)

Figure 3-6. Total Number of Scored Intervals for all Behaviors Each Day for Folk.

**Problems Attempted and Accuracy**

Folk’s baseline resulted in a mean of 272.67 problems completed with a mean of 44.67 errors. After a 15-minute bout of MVPA, her mean number of problems attempted increased slightly to 275.44. During the booster baseline condition Folk attempted a mean of 263.74 problems (37.0 errors). The MVPA + booster condition Folk completed 285.60 problems (41.60 errors) The MVPA + booster condition resulted in the highest number of problems completed.

Visual analysis of Folk’s math problems attempted (see Figure 3-7) showed no difference between baseline and MVPA. Data for booster baseline were variable, with Session 3 driving the
effect. The MVPA + booster showed an ascending trend over time. Differences between MVPA + booster and booster baseline were observed later in the experiment. The number of errors were similar across conditions, except that error rates during baseline trended higher later in the experiment, relative to MVPA. (see Figure 3-8). A Tau-U effect size confirmed visual analysis of the number of errors for Folk (Baseline to MVPA Tau-U = .45; Booster Baseline to MVPA + Booster Tau-U = .93; Intervention weighted mean Tau-U = .25). A Tau-U effect size confirmed visual analysis of the number of trials completed for Folk (Baseline to MVPA Tau-U = .07; Booster Baseline to MVPA + Booster Tau-U = .50; Intervention weighted mean Tau-U = .29).

Figure 3-7. Number of Problems Attempted Each Day by Folk.
George

Attention to Task

During baseline, George's mean latency to respond to math problems was 1126.07 ms. When the 15 min initial bout of MVPA was administered, George’s mean latency to respond decreased, relative to intervention baseline, to 923.90 ms, indicating an increase of attention to task. The math task was again administered 90 min after the initial bout of MVPA (e.g., booster baseline). George's mean latency to respond during this condition was 970.15 ms. When the 5 min MVPA + booster condition was administered, George's mean latency to respond decreased to 847.82 ms.

Visual analysis of relative changes across conditions (see Figure 3-9) showed differences between the intervention baseline and MVPA were yielded early in the experiment. Effects of the MVPA + booster are demonstrated by separation between those data and the booster baseline. A
Tau-U effect size confirmed visual analysis of latency for George (Baseline to MVPA Tau-U = .60; Booster Baseline to MVPA + Booster Tau-U = .80; Intervention weighted mean Tau-U = .70).

![Graph](image)

**Figure 3-9. Mean Latency of Each Trial for George.**

**Off Task Behaviors**

During baseline, George's averaged 17.33 scored intervals during the 5-minute math task. After a 15-minute bout of exercise his mean number of scored intervals was reduced by 48.7% (8.9 intervals). After 90 minutes without a booster (i.e., booster baseline), an average of 16.25 intervals were scored. In comparison, after 90 minutes with a 5-minute booster of MVPA (e.g., MVPA + booster) his mean number of scored intervals was reduced by 60.7% (6.4 intervals).

Figure 3-10 represents data on behavior across time. Visual analysis showed a clear separation between baseline and intervention conditions. Non-MVPA data showed higher levels of scored intervals. Both interventions resulted in lower levels, relative to their respective comparison baselines, with little no overlap. A Tau-U effect size confirmed visual analysis of
total intervals scored with all off-task behaviors for George (Baseline to MVPA Tau-U = 1.0; Booster Baseline to MVPA + Booster Tau-U = 1.0; Intervention weighted mean Tau-U = .1.0).

![Graph](image)

Figure 3-10. Total Number of Scored Intervals for all Behaviors Each Day for George.

**Problems Attempted and Accuracy**

During baseline, George's mean number of trials completed was 210.67 with a mean of 46.33 errors during the 5 min task. After a 15-minute bout of MVPA, his mean number of trials increased to 236.9. During the booster baseline George completed a mean of 243.5 trials and a mean of 35.75 errors. The number of problems attempted increased after implementation of MVPA + booster (275.60).

Visual analysis of George's math problems attempted (see Figure 3-11) showed little difference in problems completed across conditions. Similarly, visual analysis of George's errors (see Figure 3-12) showed considerable overlap in data and levels of errors. A Tau-U effect size confirmed visual analysis of the number of errors for Folk (Baseline to MVPA Tau-U = .10;
Booster Baseline to MVPA + Booster Tau-U = .80; Intervention weighted mean Tau-U = .34). A Tau-U effect size confirmed visual analysis of the number of trials completed for George (Baseline to MVPA Tau-U = .60; Booster Baseline to MVPA + Booster Tau-U = .80; Intervention weighted mean Tau-U = .70).

Figure 3-11. Number of Problems Attempted Each Day by George.

Figure 3-12. Number of Errors Each Day for George.
Attention to Task

During baseline, Pieces' mean latency to respond to math problems was 2999.75 ms. When the 15 min initial bout of MVPA was administered, his mean latency to respond was reduced by 37% (1891.24 ms), indicating an increase in attention to the task. The math task was again administered 90 min after the initial bout of MVPA. Pieces' mean latency to respond during this condition was 3443.82 ms. When the MVPA + booster exercise condition was administered, Pieces' mean latency to respond was reduced by 46.1% (1859.57 ms), relative to the booster baseline. Visual analysis of changes in latency (Figure 3-13) showed consistent separation of levels between both alternating treatments baseline and MVPA conditions. A Tau-U effect size confirmed visual analysis of latency for Pieces (Baseline to MVPA Tau-U = 1.0; Booster Baseline to MVPA + Booster Tau-U = 1.0; Intervention weighted mean Tau-U = 1.0).

Figure 3-13. Mean Latency of Each Trial for Pieces.
Off Task Behaviors

During baseline, Pieces averaged 9 scored intervals during the 5-minute math task. After a 15-minute bout of exercise his mean number of scored intervals was reduced by 56.7% (3.89 intervals). After 90 minutes without a booster (i.e., booster baseline), an average of 10 intervals were scored. In comparison, after 90 minutes with a 5-minute booster of MVPA (MVPA + booster) his mean number of scored intervals was reduced by 30% (7 intervals).

Visual analysis of data concerning total number of intervals scored for all behaviors (see figure 3-14) shows moderate overlap between non-MVPA and MVPA conditions, mostly due to one outlier in the MVPA + booster condition. Barring that outlier, levels in non-MVPA conditions showed higher variability and overall number of scored intervals. Data in the MVPA condition shows the lowest level of variability and a stable zero trend. A Tau-U effect size confirmed visual analysis of total intervals scored with all off-task behaviors for Pieces (Baseline to MVPA Tau-U = .93; Booster Baseline to MVPA + Booster Tau-U = .44; Intervention weighted mean Tau-U = .69).

Figure 3-14. Total Number of Scored Intervals for all Behaviors Each Day for Pieces.
**Problems Attempted and Accuracy**

During baseline, Pieces' mean number of problems attempted was 85 with a mean of 18.67 errors during the 5 min task. After a 15-minute bout of MVPA his number of problems attempted increased by 38.3% (137.56), relative to baseline. During the 90 min baseline (booster baseline) Pieces completed an average of 122.75 trials, which was slightly higher than the mean attempted after completing the MVPA + booster.

Visual analysis indicates a decrease in problems attempted across all conditions over time (see Figure 3-15). Given that trend, there was separation between both baselines and MVPA conditions. Conversely, little differences in errors were observed over time (see Figure 3-16). A Tau-U effect size confirmed visual analysis of the number of errors for Pieces (Baseline to MVPA Tau-U = .19; Booster Baseline to MVPA + Booster Tau-U = .30; Intervention weighted mean Tau-U = .24). A Tau-U effect size confirmed visual analysis of the number of trials completed for Pieces (Baseline to MVPA Tau-U = 1.0; Booster Baseline to MVPA + Booster Tau-U = .43; Intervention weighted mean Tau-U = .79).
Figure 3-15. Number of Problems Attempted Each Day by Pieces.

Figure 3-16. Number of Errors Each Day for Pieces.
Attention to Task

During baseline Road's latency to respond was 2278.42 ms. When the 15 min initial bout of MVPA was administered, her mean latency to respond increased (3113.98 ms). The math task was again administered 90 min after the initial bout of MVPA (e.g., booster baseline). Road's mean latency to respond during this condition was 2380.43 ms. When the 5 min booster exercise condition (MVPA + booster) was administered, Road's mean latency to respond again increased ($M = 2828.12$ ms), relative to the booster baseline.

Visual analysis of attention to task showed some overlap between all four conditions (see Figure 3-17). However, overall levels of non-MVPA conditions were lower and showed little to no variability with a slight upward trend. The majority of MVPA condition data points (MVPA and MVPA + booster) showed a higher level of latency to respond. These two conditions showed moderate to high variability. A Tau-U effect size confirmed visual analysis of latency for Road (Baseline to MVPA Tau-U = .63; Booster Baseline to MVPA + Booster Tau-U = .10; Intervention weighted mean Tau-U = .27).
Figure 3-17. Mean Latency of Each Trial for Road.

Off Task Behaviors

During baseline, Road averaged 18 scored intervals during the 5-minute math task. After a 15-minute bout of exercise her mean number of scored intervals was reduced by 36.2% (11.5 intervals). After 90 minutes without a booster (i.e., booster baseline), an average of 17.67 intervals were scored. In comparison, after 90 minutes with a 5-minute booster of MVPA her mean number of scored intervals was reduced by 29.9% (12.4 intervals).

Figure 3-18 represents data on behavior across time. Visual analysis of data showed non-MVPA conditions (baseline and booster baseline) to have a higher level of scored intervals. MVPA and MVPA + booster resulted in lower levels, relative to their respective comparison baselines, with only one MVPA condition data point overlapping baseline data. A Tau-U effect size confirmed visual analysis of total intervals scored with all off-task behaviors for Road (Baseline to MVPA Tau-U = .83; Booster Baseline to MVPA + Booster Tau-U = 1.0; Intervention weighted mean Tau-U = .91).
Problems Attempted and Accuracy

During baseline, Road's mean number of problems attempted was 114 with a mean of 39 errors during the 5 min task. After a 15-minute bout of MVPA, her mean number of trials decreased to 83.44 and the number of errors decreased to 27.11. During the booster baseline, Road attempted a mean of 110.5 problems with 41.25 errors. The number of problems attempted decreased during the MVPA + booster session.

Visual analysis of Road's math problems attempted (see Figure 3-19) showed some overlap in levels of data, with MVPA conditions being lower (MVPA) or similar (MVPA + booster) overall relative to non-MVPA conditions. There was an overall trend toward lower errors rates across conditions for Road. However, there were no differences among conditions for the error data (see Figure 3-20). A Tau-U effect size confirmed visual analysis of the number of errors for Road (Baseline to MVPA Tau-U = .22; Booster Baseline to MVPA + Booster Tau-U =
Intervention weighted mean Tau-U = .16. A Tau-U effect size confirmed visual analysis of the number of trials completed for Road (Baseline to MVPA Tau-U = .63; Booster Baseline to MVPA + Booster Tau-U = 0.0; Intervention weighted mean Tau-U = .32).

Figure 3-19. Number of Problems Attempted Each Day by Road.

Figure 3-20. Number of Errors Each Day for Road.
Attention to Task

During baseline, Tesla's mean latency to respond to math problems was 2295.48. When the 15 min initial bout of MVPA was administered, his mean latency to respond decreased by 15.7% (1936.36 ms). The math task was again administered 90 min after the initial bout of MVPA (e.g., booster baseline). Tesla's mean latency to respond during this condition was 2779.51 ms, which was greater than both the baseline and MVPA conditions. In comparison, when the MVPA + booster condition was administered, Tesla's mean latency to respond was reduced by 15.2% (2358 ms), relative to the 90 min baseline.

Visual analysis examining relative changes (see Figure 3-21) showed considerable overlap in all data. Data showed a slight ascending trend with little difference among conditions. A Tau-U effect size confirmed visual analysis of latency for Tesla (Baseline to MVPA Tau-U = .56; Booster Baseline to MVPA + Booster Tau-U = .20; Intervention weighted mean Tau-U = .38).

Figure 3-21. Mean Latency of Each Trial for Tesla.
Off Task Behaviors

During baseline, Tesla averaged 19.33 scored intervals during the 5-minute math task. After a 15-minute bout of exercise his mean number of scored intervals was reduced by 42% (11.22 intervals). After 90 minutes without a booster (i.e., booster baseline), an average of 19 intervals were scored. In comparison, after 90 minutes with a 5-minute booster of MVPA his mean number of scored intervals was reduced by 31.6% (13.2 intervals).

Visual analysis of scored intervals for all behaviors (see Figure 3-22) showed a consistently higher level in non-MVPA conditions. Intervention conditions started at a lower level, but increased midway through the intervention. However, the number of intervals scored remained lower relative to baseline conditions. A Tau-U effect size confirmed visual analysis of total intervals scored with all off-task behaviors for Tesla (Baseline to MVPA Tau-U = 1.0; Booster Baseline to MVPA + Booster Tau-U = 1.0; Intervention weighted mean Tau-U = 1.0).

Figure 3-22. Total Number of Scored Intervals for all Behaviors Each Day for Tesla.
Problems Attempted and Accuracy

During baseline, Tesla’s mean number of problems attempted was 105.33 with a mean of 20.67 errors. After a 15-minute bout of MVPA his mean number of problems attempted increased 18.6% (129.33). During the booster baseline Tesla attempted a mean of 95 problems, with a mean of 18.25 errors. The mean number of problems attempted increased after the MVPA + booster (108.6) with little change in the mean number of errors (17.8). Visual analysis of Tesla’s math problems attempted and errors showed little consistent difference among conditions (see Figures 3-23 and Figure 3-24). Problems attempted decreased overall over time regardless of conditions. A Tau-U effect size confirmed visual analysis of the number of errors for Tesla (Baseline to MVPA Tau-U = .15; Booster Baseline to MVPA + Booster Tau-U = .07; Intervention weighted mean Tau-U = .04). A Tau-U effect size confirmed visual analysis of the number of trials completed for Tesla (Baseline to MVPA Tau-U = .56; Booster Baseline to MVPA + Booster Tau-U = .30; Intervention weighted mean Tau-U = .43).

Figure 3-23. Number of Problems Attempted Each Day by Tesla.
Interobserver Agreement

Inter Observer Agreement (IOA) was calculated for point by point agreement, using the most stringent method based on the data (Cooper, Heron, & Heward, 2007). For behaviors that occurred at frequencies of 49% of intervals or fewer, a scored interval IOA was used. For behaviors that occurred at a relatively high rate, meaning 50% or more of intervals are scored, an unscored interval IOA was employed. This option provides a more conservative approach to agreement (Cooper et al., 2007). A disagreement was defined as any interval where total count across both observers did not match. Data for the All Behaviors measure used a frequency count as opposed to using an interval count. Table 3-5 displays the results of IOA as represented by means and ranges of agreement. A primary and secondary data collector collected live data for all sessions. Thus, agreement data were collected on 100% of sessions.
Table 3-5. Interobserver Agreement Results for Each Dependent Variable and Observer with Means

<table>
<thead>
<tr>
<th>Observer</th>
<th>Head</th>
<th>Hands</th>
<th>Voice</th>
<th>Torso*</th>
<th># Intervals*</th>
<th>All Behaviors*</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>89</td>
<td>94</td>
<td>96</td>
<td>87</td>
<td>89</td>
<td>86</td>
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<td>(74-86)</td>
<td>(100)</td>
<td>(80-91)</td>
<td>(78-91)</td>
<td>(74-90)</td>
</tr>
</tbody>
</table>

Mean by Variable | 87.3% | 88.5% | 98% | 86.6% | 87.3% | 86.3%
Overall IOA for all participants, behaviors, phases, and observations | 89%

* Indicates use of an un-scored interval IOA

Treatment Fidelity

Percentages of treatment integrity for each condition were calculated by dividing the number of steps completed correctly during each session by the total number of steps possible. Steps were followed 100% of the time in each of the four conditions (baseline, MVPA, booster baseline, and MVPA + booster, see Table 3-6). Treatment fidelity was collected for 12 of 15 sessions, including all sessions of the intervention and 50% of baseline sessions.
Table 3-6. Completed Treatment Fidelity Checklist

<table>
<thead>
<tr>
<th>Steps</th>
<th>Participant 1</th>
<th>Participant 2</th>
<th>Participant 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Student reads for 15m</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>2. Math task instructions are read to students</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>3. Students complete math task</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>4. 70-90m break between first and second session</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>5. Students read for 5m</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>6. Math task instructions are read to students</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>7. Students complete math task</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Chapter 4
DISCUSSION

The purpose of this study was to examine the effects of moderate to vigorous physical activity on the classroom behavior and academic engagement of early elementary children with ADHD. More specifically, the study was designed to build from prior work in this area (Bass, 1985; Cannella-Malone et al., 2011; Evans, 1985; Yell, 1988) that has demonstrated that MVPA can reduce inappropriate behavior in an academic setting and improve attention to academic tasks. A key extension of the current study was the examination of durability of effects of MVPA and the implementation of a “Booster” session to increase effects over time.

Results of this study indicate MVPA provided at the beginning of the school day may reduce classroom behaviors associated with ADHD. MVPA was shown to have a modest impact on academic engagement for some participants. These improvements, in both behavior and academic engagement, dissipated over time and were not present 90 minutes after participating in the MVPA intervention. In an effort to address the dissipation of effects of MVPA over time, a “booster” MVPA session was evaluated. Results showed that a short 3-5 minute booster session of MVPA performed 90 minutes after the initial 15-minute bout of exercise not only maintained benefits for all participants but also improved upon behavioral benefits for some participants. Although no data was collected on dopamine increases, it has been suggested as one possible mechanism for changes seen.

Proposed Mechanism for Behavior Change

The results of the present study are in line with prior research that has demonstrated the
role of dopamine on behavior (Levy, 1991; Tantillo et al., 2002) and the effects of MVPA on dopamine production (McMorris et al., 2008; Tantillo et al., 2002). Similar to earlier research, the effects of exercise appear to be temporary and short-lived. Children with ADHD exhibit deficits in dopamine production (Grassmann et al., 2014), and that deficit is related to attentional difficulties (Glanzman & Sell, 2013). MVPA increases production of dopamine and other neurotransmitters, leading to an increase of attentional resources in the brain (McMorris et al., 2008). Although not measured directly in this study, the results are in line with this prior research.

**Behavioral Effects of MVPA**

The first guiding question of this study involved identifying the benefits of MVPA on behavior. Previous research has indicated that MVPA can improve classroom behavior for children with ADHD (Azrin, Vinas, & Ehle, 2007; Bass, 1985; Cannella-Malone et al., 2011; Etscheidt & Ayllon, 1987; Evans, 1985; Morand, 2004; Yell, 1988). The results of the present study suggest that the intervention components, as designed, were effective at reducing off-task behavior observed in many classrooms (e.g., fidgeting, talking out, looking away from the task, and extraneous movements).

Five of six participants showed a clear separation between MVPA and baseline conditions suggestive of a strong functional relation between MVPA and task-related behaviors. One participant had a single overlapping data point, suggesting a moderate functional relation. All participants showed considerably more stable levels of responding during intervention conditions. In this study, the majority of off task behaviors involved fidgeting in seats and looking away from the computer, such as staring out the window or at wall hangings, which are characteristic of students with ADHD (Glanzman & Sell, 2013). Non-task related behaviors were reduced by 30 - 60% for all participants.
The second guiding question asked in this study involved the use of booster sessions. Only one study employed multiple bouts of MVPA to alter inappropriate behavior (Cannella-Malone et al., 2011), but gave no rationale for having participants exercise once an hour. Prior research indicates that benefits of MVPA on the behavior of children with autism may dissipate within at little as 90 minutes (Celiberti et al., 1997; Kern, Koegel, Dyer, Blew, & Fenton, 1982). Based on the 60-90 minute window used in these studies, it was hypothesized that a short booster of MVPA given approximately 90 minutes after the main bout would help maintain the behavioral benefits observed after an initial, more substantial 15-minute bout of exercise.

Results of the current study provide support for the use of a booster MVPA to help maintain behavioral gains. A short 3-5 minute booster of MVPA maintained, and in some cases, improved upon behavioral benefits observed after the initial 15-minute bout of exercise. Particularly robust effects were observed for five of the six participants. One participant had an outlier that resulted in an overlap between the booster baseline and MVPA + booster (see Figure 4-14). All six participants showed a clear reduction in mean number of off-task behaviors during the MVPA + booster condition compared to booster baseline condition, with reductions in the 30 - 60% range.

**Attention to Task and MVPA**

The third guiding question involved assessing the effects of MVPA on sustained attention. Previous research indicates MVPA can improve sustained attention (Gawrilow, Stadler, Langguth, Naumann, & Boeck, 2013), visual searching (Verret, Guay, Berthiaume, Gardiner, & Béliveau, 2010), and latency (Medina et al., 2010). Further, research suggests MVPA can improve the ability to inhibit distracting stimuli (Chang et al., 2012; Chang, Hung, Huang, Hatfield, & Hung, 2014; Gawrilow et al., 2013; Smith et al., 2013), improve information
processing (Verret et al., 2010), and improve planning (Gapin & Etnier, 2010). For the current study, it was hypothesized MVPA would lead to increased attention to task as measured by latency to respond to visual stimuli. Increased attention to task has the potential to lead to increased opportunities, or an overall increase in number of learning trials completed during classroom-based tasks. Five of six participants showed differences in mean latency across baseline and MVPA conditions. However, visual analysis of graphs showed few patterns and a large amount of overlap in data. In this study, the effects of MVPA on sustained attention during a simple math task were highly variable across days and participants.

The fourth question asked in this study involved assessing sustained attention after a booster session of MVPA. Results of the booster baseline demonstrated changes in behavior 90 minutes after initial bouts of MVPA, indicating that effects dissipate over time. These results are similar to those found elsewhere (Celiberti et al., 1997; Kern et al., 1982). When the short 3-5 minute session booster of MVPA was administered, five of six participants showed a mean reduction in latency relative to booster baseline. The graphs of the booster baseline to the MVPA + booster conditions revealed a strong functional relation between exercise administered at the 90 min mark of sessions for two participants (Ernie and Folk) and a moderate functional relation for an additional two (George and Pieces).

**Math Problems Attempted and Accuracy**

The final two guiding questions were concerned with problems attempted and accuracy of responding and MVPA. Previous single-case design research suggests MVPA can improve measures of academic engagement (Etscheidt & Ayllon, 1987; Evans, 1985; Morand, 2004). These studies showed increased rates of homework completion, work output, and percent correct of completed work after participating in MVPA. Results of the current study only partially
support prior research.

Visual analysis of the number of problems attempted suggest that MVPA increased the number of problems attempted for only Ernie and Pieces and did not seem to change the percentage of errors across students. These findings were similar to those observed during the booster sessions. The tasks used in previous studies were longer and provided students with internal breaks. For example, Morand (2004) assessed the effects of MVPA on homework completion. Homework is comprised of cycles of on and off task behavior, which may provide students an opportunity to interact with external sources of stimulation and/or movement in order to self-regulate behavior (Zentall & Goldstein, 1999). The current task did not provide students with an opportunity to obtain stimulation from external sources. Future research should investigate the differential effects of MVPA across various types of tasks.

Social Validity

Readers of published studies should judge social importance and significance of results (Cooper et al., 2007; Wolf, 1978). The most widely used method for assessing social validity is through subjective evaluations (O’Neill & McDonnell, 2011). In the case of the current study, the key group is teachers of the students. They appear to be in the best position to evaluate outcomes of the intervention as it relates to effectiveness in the classroom. Teachers were asked two questions 10 days after completion of data collection. The first question asked if teachers noticed a difference in student's behavior or academic engagement during the intervention? One teacher responded that during the intervention she noticed her student was more focused on some days rather than others. She added that she did not know which days we had exercised but could figure it out judging from the focus and behavior of the student's behavior. Another teacher responded that her student was "more alert, actively engaged, and enthusiastic," during the intervention.
Another teacher commented that her student was "more inclined to volunteer" while participating in the MVPA intervention. The second question asked if teachers had seen any changes in the two weeks since completion of the intervention. One teacher commented that her student needed more redirection and was not as alert after the intervention ended. Another mentioned her student "appears to have more behavioral issues now that the study is over."

Kazdin (2011) outlines three questions for guiding social validation. First, are goals of the intervention relevant to everyday life? In the case of the current study, the answer is yes. Not only can reduction of disruptive behaviors along with improved academics help students with ADHD but additional health and wellness benefits are advantageous for a population that tends to have weight and health issues (Glanzman & Sell, 2013). Second, are intervention procedures acceptable to the consumer and community? More than one teacher commented on how quickly we were able to perform the exercise, especially in the booster phase. Third, do the outcomes of the intervention make a difference in the lives of the individuals? As results show, MVPA can reduce inappropriate behavior and increase academic engagement, which will influence the individual profoundly during their time in school.

At completion of the study, participants were asked if they noticed any change in their behavior on days when they exercised. Tesla said he thought the math task was shorter on days he exercised, and was surprised to find out it was 5 minutes long regardless. George felt he was calmer and more focused on days he exercised. Folk felt she paid better attention in class on days she exercised and it was even better on days when she exercised twice. All participants became more willing and eager to exercise as the intervention progressed, often expressing disappointment when a baseline day occurred. This was especially apparent in Road who started out very apprehensive and almost unwilling to engage in physical activity. However, by the end she was one of the most engaged members of the study.
Recommendations for Practitioners

The current study was designed with the typical classroom in mind. The goal was to help identify a practical, efficient, and effective protocol for implementing MVPA to help children with ADHD improve both academic engagement and classroom behavior. Based on visual analysis and social validity results, teachers may see benefits in behavior and potentially academic engagement using MVPA. The protocol was designed to be the most effective for children with ADHD according to previous research (Hart & Lee, in preparation). Although, this protocol was designed to meet the needs of children with ADHD, research suggests all children can benefit from the effects of MVPA (Hillman et al., 2008; Hillman, Kamijo, & Scudder, 2011; Tomporowski, 2003a; Tomporowski et al., 2008).

Teachers have a dilemma in finding effective and efficient ways to deal with behavior problems, particularly given the large numbers of children with ADHD (Visser et al., 2014). Lost potential of students in need of behavioral support increases the need for effective ways to improve classroom behavior and academic engagement. The potential benefits of MVPA could justify the minimal time spent away from academics; in this study students spent about 20 min per intervention day engaging in MVPA. Time away from academics while engaged in MVPA has been shown to not adversely affected academic performance in other populations (Dwyer et al., 1983; Sallis et al., 1999). Rather, MVPA has been associated with better grades (Taras, 2005). This study also highlights several key suggestions for implementing a MVPA program for students with ADHD. First, short bouts of MVPA can be effective. This study showed positive results with an initial bout of 15 minutes and the addition of a short 3-5 minute booster for a daily maximum of 20 minutes of MVPA. For teachers with limited time and pressure to increase time on task, short episodes of exercise may be more appealing.

Second, effects of MVPA appear to be short lived. Benefits observed in this study
dissipated within 90 minutes. To compensate for the return to baseline, a 3-5 minute booster session 90 minutes after the first bout was added. Keeping this timing in mind, teachers should consider short active breaks allowing students to get their heart rate and exertion levels briefly "revved" up every 60-90 minutes throughout the day.

Third, MVPA interventions should use a variety of activities. Repetitive activities, such as running laps on the track, particularly with children with ADHD may be less effective than introducing a variety of tasks (Hart & Lee, in preparation). A variety of activities were used in this study and were chosen based on their effectiveness in previous research (Hart & Lee, in preparation). The students in the present study were given a choice of activities. Although not assessed directly, choice of activities may help produce positive intervention outcomes. Positive effects of student selection have been documented elsewhere (Cannella-Malone et al., 2011; Hart & Lee, in preparation).

Finally, consideration should be given to creating a program that can be sustained over time. The longer the intervention is implemented the more MVPA appears to prolong behavioral improvements and increase academic engagement (Hart & Lee, in preparation; Hillman et al., 2011). One explanation for the weak academic engagement results observed in this study may be the short nature of the program. Studies that had students exercise for more than two months showed improvements in class work production and homework completion (Etscheidt & Ayllon, 1987; Morand, 2004).

Limitations

Overall, the effects of MVPA were positive, but should be viewed within the context of the limitations of the current study. First, mandated state testing was occurring during the study, which limited contact with participants. This limited contact resulted in a fewer than optimal
number of data points, particularly during baseline. Second, participants had a lack of uniformity in their diagnosis, differences in gender, and a wide range of developmental differences based on the K-4 grade range. Parents reported three participants had a formal diagnosis of ADHD. The other three participants were reported as exhibiting ADHD-like behaviors, but not a formal diagnosis of ADHD. It is possible those participants without a formal diagnosis did not represent students who have been diagnosed with ADHD and may have impacted the findings. Similarly, differences in age and medication use may have effected engagement and behavior.

**Risks and Benefits**

As with any physical activity, there is a potential for risk. However, this research posed minimal risk in the daily lives of children with ADHD and was well within recommended levels of physical activity for children (Strong et al., 2005). Physical activities are those that represent activities encountered on a daily basis during recess and PE classes by children in public education and charter school settings. Throughout the exercises, investigators encouraged participants to continue but at an effort level that would not be aversive. There were unforeseeable risks of injury, similar to those expected from participating in a PE class or recess. Equipment use was monitored closely to ensure it was used appropriately and did not pose additional risk to participants or other individuals. Because of the limited number of participants, investigators were able to monitor each participant with more focus than that obtained in most PE or recess class settings. There were no injuries reported or visually observed by investigators.

This research presents prospects of direct benefit to individual subjects in the form of improved physical fitness. This includes improved musculature, cardiovascular function, fine and gross motor function, and pulmonary health. Additional benefits may include encouraging promotion of physical activity in a typical school setting during a time when non-academic
activities are being cut. Early promotion of physical activity may instill a value for healthy living that goes beyond that of a school setting. Students, parents, and administration can help promote a development of the whole student, rather than just the academic abilities. Finding a potential alternative treatment for the adverse effects of ADHD is a possible benefit of this study.

**Future Directions**

Previous research has used multiple bouts of exercise throughout the school day (Cannella-Malone et al., 2011). Behavioral effects were sustained throughout the day, but the authors admit timing of these bouts was not predicated on any empirical research. The current study suggests a short booster session of MVPA sustained behavioral benefits over a 90-minute period. Use of a short booster session of MVPA maintained lower levels of inappropriate behavior and in some cases improved upon them. These data provide an initial starting point for fine-tuning the timing of MVPA for children with ADHD. Perhaps using higher frequencies of implementation could maintain improved levels of behavior for the duration of the school day.

Future research should attempt to replicate findings from this study with the addition of a booster session every 60-90 minutes for the entire school day to determine if this dosage will maintain effects throughout the day. Based on current findings, speculation exists that multiple booster sessions every 60-90 minutes could maintain behavioral benefits and possibly academic benefits for the duration of the school day.

Past research suggests chronic exercise (consistently reoccurring over the course of many days) has a cumulative effect on behavior, academic engagement, and cognition of all children (Hillman et al., 2008, 2011; Sattelmair & Ratey, 2009). Future studies may see more profound improvements in academic engagement with studies that have participants exercise multiple times per day consistently over the course of many weeks.
More than one data collector noticed more profound changes in behavior occurred with George, the participant who appeared to put the most effort into the exercise intervention. Future research should consider the use of a heart rate monitor or 3-axis accelerometer (e.g. Fitbit) to help identify levels of engagement while participating in MVPA. This would add a level of engagement variable to results. While intensity is not critical for children with ADHD participating in MVPA (Hart & Lee, in preparation), the inclusion of data on level of engagement adds an additional variable in the effectiveness of MVPA.

Conclusions

Results of this study indicate MVPA can reduce distracted and off-task behaviors associated with ADHD. Behaviors of interest included, looking away from the academic task, talking out, extraneous hand movement, and general torso and leg fidgeting. In all cases, participants showed a marked reduction in off task behaviors. Behaviors were reduced often by more than 50%.

Results suggest MVPA has potential to improve academic engagement for most participants; however, limitations in the design preclude an outright endorsement of changes seen in academic engagement. Keeping limitations in mind, results indicated after MVPA five of six participants improved in accuracy of answering math problems. It appears MVPA may have an effect on latency to respond to visual stimuli. However, counter to the hypothesis not all participants reduced latency. One participant increased latency leading to improvements in accuracy. Results are in line with previous research showing MVPA increases allocation of attentional resources (Hillman et al., 2008; Mahar, 2011).

This study adds a key extension to current literature concerning the timing and frequency of implementing MVPA for children with ADHD. Specifically, improvements seen after MVPA
dissipate over time, disappearing after 90 minutes. This finding supports previous research with other populations that showed a similar return to baseline levels of behavior (out of seat, self stimulatory behavior, and appropriate play) within 90 minutes (Celiberti et al., 1997; Kern et al., 1982). A key finding here suggests a short booster session of MVPA can sustain behavioral benefits beyond 90 minutes. A short 3-5 minute booster of MVPA 90 minutes after the 15-minute bout, not only maintained, but even improved behavioral benefits for most participants. This study supports previous research suggesting MVPA can improve behavior and potentially academic engagement for children with ADHD. Additionally, this study adds to the literature by suggesting a frequency and schedule of implementation.
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Appendix

Literature Review

The purpose of this study was to examine the effects of moderate to vigorous physical activity on the classroom behavior and academic engagement of early elementary children with ADHD. In addition, the intent is to determine if a short booster session of MVPA after 90 minutes could help sustain the effects over time. The following review of the literature provides the context for the population, intervention, and methodology used in the study.

Children with ADHD

Definition. Dealing with behavior problems in the classroom is a concern for every teacher. Along with unidentified children who may be at risk for behavior problems are children who receive special education services and are identified as having behavioral or emotional disabilities. ADHD is one such disability and is defined and diagnosed by presence of observable behaviors representing three areas: inattention, hyperactivity, and impulsivity. The CDC indicates prevalence of ADHD is on the rise, suggesting 11% of children in the United States are diagnosed with the disorder (Visser et al., 2014). That number has increased from the previous year, where students with ADHD comprised 7-10% of children in the United States (Glanzman & Sell, 2013).

In school, children with ADHD are often unable to stay on task, do not complete assignments, or fail to turn them in (Denisco et al., 2005). Children with ADHD are more likely to fail out of school, suffer from intellectual impairments, repeat grades and score significantly lower on measures of intelligence as compared to control children without ADHD (Faraone et al., 1993).

Students with or at risk for behavior problems including those with ADHD represent a sizable portion of students who cause behavioral issues in the classroom (Forness & Kavale,
2001; Forness, Kim, & Walker, 2012). With more than one in ten children identified as having ADHD, teachers can expect to deal with inappropriate behavior in every class they teach, and each class is likely to have more than one student exhibiting ADHD-like behaviors. This, along with unidentified children who exhibit similar behaviors, represents a sizable percentage of students in classrooms who struggle with inappropriate behaviors. In addition to behavioral problems, youth with ADHD are more likely to experience obesity, inactivity, and sedentary behavior early in life (Cook, Li, & Heinrich, 2014).

**Deficits in Executive Function.** Related to core behavioral deficits such as inattention, hyperactivity, and impulsivity, children with ADHD exhibit multiple deficits in executive function (EF), such as impairments in updating of working memory, inhibition, and processing speeds (Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005; Pennington & Ozonoff, 1996; Weyandt, 2005). Using meta-analytic techniques Willcutt et al., (2005) examined 83 studies that utilized measures of EF to assess deficits in individuals with ADHD. Their analysis similarly showed individuals with ADHD presented with deficits in all areas of EF, with the strongest effect sizes coming from measures of inhibition, updating, vigilance, and planning, which are all hallmarks of diagnostic criteria of the disorder. These areas align with those proposed by Miyake (2000) with vigilance and planning falling under larger constructs of inhibition and updating respectively. In synthesizing these deficits, two become particularly clear in students with ADHD: inhibition (Barkley, 2000; Pennington & Ozonoff, 1996; Weyandt, 2005; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005) and updating (Barkley, 2000; Martinussen et al., 2005; Pennington & Ozonoff, 1996; Schreiber, Possin, Girard, & Rey-Casserly, 2014; Willcutt et al., 2005). Although there is some overlap in underlying processes, inhibition and updating are distinct and employed differently based on the required task (Best, 2010).

Inhibition, or an inability to interrupt an ongoing response, is a key characteristic of ADHD (Doyle, 2006). For example, while taking a test, a child with ADHD may not be able to
refrain from calling out to a friend. Deficits in inhibition can lead to problems listening to instructions, compliance, task completion and socialization with peers and adults, even more serious or life threatening problems can occur (Glanzman & Sell, 2013). Deferred gratification, and resistance to temptation (i.e., self-control) are elements of inhibition children with ADHD lack (Barkley, 1997). This deficit in self-control may suggest a cause for elevated risk of accidents and driving infractions for adolescents and adults diagnosed with childhood ADHD (Thompson, Molina, Pelham, & Gnagy, 2007).

Updating is a second major deficit implicated in ADHD. Updating is emerging as one of the primary deficits in children with ADHD and could potentially help explain academic problems observed in this population (Schreiber et al., 2014). Updating is a limited capacity system (i.e., short-term memory) for holding information in mind and manipulating it to help guide complex behavior without external aids (Barkley, 2000; Best & Miller, 2010; Schreiber et al., 2014). Tasks that necessitate maintaining and manipulating information, such as remembering and completing multiple steps of a task, rely on pre-frontal cortex control and executive involvement (Best & Miller, 2010). Children with ADHD have deficits in the pre-frontal regions of the brain (Prince, 2008). Research suggests executive functioning may underlie observed behavioral challenges for children with ADHD (Berlin, Bohlin, Nyberg, et al., 2004; Berlin, Bohlin, & Rydell, 2004; Weyandt, 2005).

**Life outcomes.** Negative effects of emotional and behavioral problems can be a lifelong burden and take an enormous toll on finances, academic pursuits, vocation and family (Biederman, 2005; Spencer, Biederman, & Wilens, 1999). On average, half of children diagnosed in adolescence continue to meet criteria for ADHD as adults (Lara et al., 2009). Given these numbers, developing effective school-based interventions that positively affect academic performance and classroom behavior early and prevent future problems from occurring is very important. Given the deficits experienced by this group of individuals, several categories
of interventions exist to treat the disorder.

**Types of Interventions available**

**Behavioral Intervention.** Currently, there are two main interventions used to help this population: behavioral supports and stimulant medication (Glanzman & Sell, 2013; Homer et al., 2000). Behavioral supports consist of teaching adaptive, alternative, or replacement behaviors. Classroom-based interventions tend to rely on manipulations of consequence-based events (i.e., reinforcers and punishers). Behavioral supports rely on altering antecedents or consequences of behavior to help reduce a child's unwanted behaviors. While this type of intervention has been proven repeatedly to be effective, it can be costly and time consuming (Carlson, Pelham, Milich, & Dixon, 1992; Fabiano, Pelham, Gnagy, Burrows-MacLean, & al, 2007; Glanzman & Sell, 2013). It is also difficult in educational settings to ensure procedures are followed in all settings. These limitations support a desire for finding further interventions that may benefit children with behavioral concerns, particularly interventions that prevent problems before they occur.

**Medical Intervention.** Use of stimulant medication has been a common practice for children with ADHD for decades. Stimulant medications used for this population include, but are not limited to, methylphenidate (Ritalin), dextroamphetamine (Dexadrine), and amphetamines (Adderall). Some risks of taking medication include addiction, decreased appetite, and insomnia (Glanzman & Sell, 2013). Additionally, long term effects of stimulant medication use are not well known (Glanzman & Sell, 2013).

Methylphenidate, the most commonly prescribed medication, has a short half life, necessitating frequent dosing (Pelham et al., 2001). This creates problems in a school setting were laws and regulations make it difficult for school personnel to administer medications. A typical dose lasts four hours, and takes 30 minutes before effects are seen (Pelham et al., 1999). This can lead to frequent peaks and valleys in the effectiveness of medication use, particularly in afternoon hours, where it may be difficult to receive additional doses due to legal issues with staff.
administration of medication. There are long lasting release options for methylphenidate (Concerta) that can be an effective, one dose, stimulant medication for children with ADHD (Pelham et al., 2001). However, stimulant medication, while widely used, is only effective for roughly 70% of children with ADHD and positive effects disappear when medication is not taken (Glanzman & Sell, 2013). In addition, stimulant medication can be costly, and includes a long list of potential side effects (Glanzman & Sell, 2013).

**Combined Behavioral and Medical Interventions.** Both stimulant medication and behavioral therapy have been shown to be effective at improving behavior. However, researchers have pointed out 32-64% of children who receive stimulant medication and/or behavioral supports continue to exhibit clinically significant levels of ADHD behaviors (Swanson et al., 2001).

In some instances use of stimulant medication in conjunction with behavioral supports allows for a reduction in dosage of medication while maintaining maximum behavioral benefits (Carlson et al., 1992; Fabiano et al., 2007). If elimination of medication is not possible, perhaps the addition of moderate to vigorous physical activity (MVPA) may support a reduction in stimulant medication dosage while maintaining behavioral benefits.

**Define MVPA**

Moderate to vigorous physical activity (MVPA) is physical activity or movement that is aerobic in nature and typically entails an increase in heart rate of 50-85% of maximum through such activities as running, walking or cycling (Nader et al., 2008). Intensity, duration, intent (e.g. type of exercise), and frequency are components often used to define and measure MVPA. MVPA could be defined as an increase in heart rate or intensity (Hillman et al., 2008; Silverstein & Allison, 1994; Verret et al., 2010), lasting for a predetermined duration (Bass, 1985; Cannella-Malone et al., 2011; Evans, 1985; Yell, 1988), with focused intent (Bass, 1985; Evans, 1985; Jensen & Kenny, 2004; Lufi & Parish-Plass, 2011; Molloy, 1989; Verret et al., 2010; Yell, 1988),
and with a consistent and frequent implementation (Bass, 1985; Cannella-Malone et al., 2011; Evans, 1985; Parish-Plass & Lufi, 1997; Silverstein & Allison, 1994; Verret et al., 2010; Yell, 1988).

Recommendations suggest school-age youth receive 60 minutes of MVPA for health benefits (Strong et al., 2005). Many physiological benefits result from regular MVPA, including diabetes prevention, weight management and cardiovascular health. MVPA has been suggested as an antecedent strategy that may decrease problematic behavior and increase academic engagement (Allison, Faith, & Franklin, 1995).

Studies examining physiological effects of MVPA with children can be separated into two groups: acute and chronic (Best, 2010). Short term or acute effects are represented by studies that examined single bouts of MVPA. Acute or short-term benefits of MVPA have been positive and observed in a variety of studies conducted with adults and children (Chang et al., 2012; Tomporowski, 2003a, 2003b).

Chronic MVPA is exercise continued over longer periods of time, such as several days or weeks. Researchers studying exercise suggest chronic MVPA has produced improvements in cognition, executive function, academic engagement, and blood flow to the brain (Hillman et al., 2008; Sattelmair & Ratey, 2009). In a large-scale study, the California Board of Education examined the relationship between fitness level and academic achievement on the Stanford Achievement Test-9 and found a strong positive correlation (California Department of Education, 2005). While only suggestive of a relation, this result adds evidence MVPA and academic achievement may be related.

Little research on MVPA has been conducted with at risk or special needs populations directly. Although included within samples, data for individuals at risk for or already identified with disabilities were not disaggregated from typical performing students, the majority of which has been conducted using group designs (Archer & Kostrzewa, 2012; Best, 2010; Chang et al.,
2012; Etnier et al., 2006; Gapin et al., 2011; Mahar, 2011; Taras, 2005; Tomporowski, 2003a, 2003b; Tomporowski et al., 2008; Welsh & Labbé, 1994).

**Physical Benefits of MVPA.** An understanding of the physiology of MVPA and behavior, especially in adolescent children, remains largely unclear (Tomporowski, 2003a). MVPA, on a physiological level, creates elevated changes in cardio-respiration, endocrine function and body temperature (Tomporowski, 2003b). That is, MVPA can improve cardio-respiratory function, hormone regulation, metabolism, sleep, mood, muscle function and muscle growth. The list of physical benefits is long and far out stretches the focus of this review.

**Neurological benefits of MVPA.** MVPA has been shown to improve cognition, executive function, and blood flow to the brain (Hillman et al., 2008; Hillman, Snook, & Jerome, 2003; Sattelmair & Ratey, 2009). These improvements have led to short-term improvements of learning after intense exercise (Medina et al., 2010).

MVPA may cause changes in behavior, cognition and executive function in three unique ways (Ploughman, 2008). MVPA appears to increase oxygen saturation in the brain, increase neurotransmitters such as dopamine and norepinephrine, and lastly it appears MVPA up-regulates neurotrophins such as brain derived neurotrophic factor which promotes neuroplasticity and neurogenesis (Ploughman, 2008). All of which can have short and long term affects on the brain.

MVPA causes an increase in blood flow throughout the body. This increase in blood flow includes the pre-frontal cortex (Schneider et al., 1998). With prolonged increases in blood flow, the body responds with the creation of capillaries (Crisman, Rittman, & Tomanek, 1985), increasing the efficiency of brain function (Smith, Paulson, Cook, Verber, & Tian, 2010). These studies have shown that increases in capillary growth produce blood flow to deeper regions of the pre-frontal cortex (Crisman et al., 1985), and can lead to improvements in cognition and executive function (Hillman et al., 2003).

The idea of neurogenesis later in life is a recent discovery. Until the last few decades, it
was believed after pre-adolescence no new neurons formed. Recent advances in neuroscience have shown this is not the case. One discovery fueling this new look at neuron growth is brain derived neurotrophic factor (BDNF). BDNF is a growth protein that encourages growth of new neurons, and helped to support our modern understanding of a continual growth of neurons throughout life. BDNF has been called "miracle grow" for the brain (Ratey & Hagerman, 2008), and leads to an increase in neurogenesis.

MVPA has been shown to increase BDNF synthesis (threefold) in humans, and indicated in growth of new neurons and improvements in cognitive function (Szuhany, Bugatti, & Otto, 2015). This meta-analysis reported that a single bout of MVPA returned a moderate effect size on BDNF production and a regular routine of MVPA intensified that effect even further. An increase in physical activity leads to increases in BDNF production resulting in an increase in neuronal growth (Szuhany et al., 2015). Increases in BDNF through exercise have lead researchers to suggest it is a key element in improvements of cognitive ability for participants of all ages.

However, the research base is strongest for adult populations. But, there is a growing base of research looking at MVPA and cognition providing strong evidence MVPA has a positive effect on cognitive performance (Buck, Hillman, & Castelli, 2005; Etnier, Nowell, Landers, & Sibley, 2006; Tomporowski, Davis, Miller, & Naglieri, 2008). This body of research examining MVPA and brain function has provided some evidence, particularly for adults (Hillman, Erickson, & Kramer, 2008), that exercise has a positive impact on cognitive performance and behavior (Davis et al., 2011; Hillman et al., 2005; Tomporowski et al., 2008). While this research base is strong for adult populations (Hillman et al., 2008), an understanding of effects of MVPA on cognition and behavior of adolescents, particularly those with or at risk for disabilities remains largely unclear (Allison et al., 1995; Allison & Keays, 1995; Tomporowski, 2003a).

**Behavioral Benefits of MVPA.** There has been little effort to investigate MVPA as it relates to behavior in an systematic fashion, and little discussion of underlying theoretical
mechanisms (Allison, Faith, & Franklin, 1995; Lufi & Parish-Plass, 2011). Without an organized foundation of research to build upon, studies lack support from earlier research and theory (Grimshaw et al., 2006). Only a limited number of studies were conducted on effects of MVPA on behavior in the classroom, primarily looking at typically functioning youth (Tomporowski et al., 2008). Studies highlighted below, go into detail on behavioral benefits of MVPA for the limited studies that used behavior as a variable of interest for children with ADHD. In spite of a limited number of studies, it has been suggested physical activity can potentially improve behavior, and is underestimated for its academic benefits (Sattelmair & Ratey, 2009).

**MVPA and Other benefits.** A recent study demonstrated children with lower inhibitory control, such as children with ADHD, benefit more from exercise (Drollette et al., 2014). Additionally, time away from academics while engaged in MVPA has been shown to not adversely affected academic performance (Dwyer et al., 1983; Sallis et al., 1999). In fact, MVPA has been associated with better grades (Taras, 2005).

MVPA can be implemented in two fundamentally different ways. First, MVPA can be used as a consequence for inappropriate behavior. Consequence-based interventions may not be effective in every instance (Cannella-Malone et al., 2011). This type of intervention may require increased training (Rosenthal-Malek & Mitchell, 1997), a short-term increase in behavior, and added time to implement (Cannella-Malone et al., 2011). An alternative to interventions based on consequences is use of an antecedent approach. Antecedent MVPA involves participants following a program of effortful activities, independent of occurrences of inappropriate classroom behavior (Fisher, Piazza, & Roane, 2011). Some have found this approach takes less time and training to implement (Rosenthal-Malek & Mitchell, 1997). Antecedent MVPA may reduce challenging behaviors, thereby increasing academic engagement time. However, it is important to keep in mind behavioral supports suggest replacing inappropriate behaviors with more appropriate ones and not leave a behavioral void. Behavior and learning are intertwined and
increased learning can result from reductions in inappropriate behavior.

Considering the link between improved cognition and MVPA, some would consider it a worthy endeavor to study learners who are defined by their learning and behavior problems (e.g. ADHD) and how MVPA might affect those behaviors. However, a reduction in inappropriate behavior may not lead to an increase in better classroom engagement and improved academic achievement. It could create a behavioral void that should be replaced with an appropriate behavior. Looking at behavior may include looking at disruptive behavior, attention to task, and work output. These outcomes have potential for observing any improvements that may occur after implementing MVPA as an intervention.

**Theory**

To date there has been little effort to investigate how MVPA relates to behavior and academic achievement of children with special needs in classroom settings, and little discussion of underlying theoretical mechanisms (Lufi & Parish-Plass, 2011). Following is a brief description of two theoretical perspectives that together may provide one coherent perspective on how MVPA alters behavior.

**Optimal Stimulation Theory.** Optimal stimulation theory (OST) has been suggested as a theoretical framework for examination of MVPA for students with ADHD (Allison et al., 1995; Lufi & Parish-Plass, 2011). According to OST, individuals engage in operant responses in order to regulate incoming stimulation (Leuba, 1955). Much like a thermostat regulates temperature in a home, individuals engage in behavior to self-regulate levels of stimulation. When stimulation levels are low, an individual engages in behavior until an optimal level of stimulation has been reached.

Zentall (1975, 2005) has proposed, individuals with ADHD require higher levels of stimulation and habituate to stimulation more quickly than typical individuals. Relatively high levels of behavior observed in individuals with ADHD may function to increase the amount of
stimulation and move the student into a homeostatic state of arousal. Students with ADHD who are asked to perform tasks that require little movement and high levels of sustained attention, such as those experienced in many classrooms, may act out/act inappropriately to increase their stimulation to a level allowing them to function optimally (Zentall, 2005, 1975; Zentall & Zentall, 1983). The positive effects observed in this population after MVPA may be a more appropriate means of increasing the level of stimulation to an optimal point. Thus, when a student returns to the classroom after MVPA she/he is better able to attend to the task without exhibiting stimulation seeking behaviors that may be inappropriate for a given setting.

OST suggests typically functioning students are nearer the optimal range and will therefore exhibit smaller benefits concerning behavior. Research has shown effects of MVPA are stronger for students who are on task the least and exhibit more inappropriate behavior in the classroom (Drollette et al., 2014; Mahar, 2011). These findings could explain consistently positive effects seen in studies that examined children with ADHD compared with typical children.

**Neurochemical Theory.** Similarly, in support of OST, on a neurochemical level dopamine may provide an explanation for effects of MVPA for children with ADHD. There is evidence dopamine is related to attention and regulation in the prefrontal cortex (Glanzman & Sell, 2013). Dopamine is associated with reward and motivation behavior as well as self-control (Arias-Carrión & Pöppel, 2007; Robbins & Arnsten, 2009), all areas of concern for students with ADHD. Children with ADHD exhibit lower baseline levels of dopamine (Levy, 1991). Thus, low levels of dopamine for children with ADHD may correlate with their limited self-control and inappropriate behavior. MVPA increases production of dopamine, which results in increased levels of dopamine delivered to synapses (McMorris et al., 2008).

Dopamine and other neurotransmitters cycle through a closed system connecting adjoining neurons. In the space between the two neurons call the synapse neurotransmitters are
produced and released by a sender neuron. They are pumped into the synapse between the neurons where they can be picked up by the receiving neuron. In this way, messages are sent from one neuron to the other. The sender neuron releases dopamine into the synapse, while receptors on the receiving neuron uptake dopamine to read the message. The receiving neuron then releases the dopamine so the sender can reuptake the neurotransmitter for future messages.

Stimulant medication, such as methylphenidate, block the sender neuron from the reuptake of dopamine and other neurotransmitters (Smith & Farah, 2011). Much like a sink stopper plugging the drain, stimulant medication causes the dopamine to remain in the synapse. This causes an increase in the amount of dopamine and other neurotransmitters for future communication. The increased dopamine in the synapse is believed to be related to the increases in attention, focus, and academic engagement for children with ADHD (Bush et al., 2008; Glanzman & Sell, 2013; Prasad et al., 2012).

Children with ADHD have been shown to have lower levels of dopamine (Grassmann et al., 2014) compared with typical children. This deficit in dopamine may explain the differential effects of stimulant medication on children with ADHD as compared to neuro-typical peers. While both groups may see improvements in attention, the children with ADHD show a differentially greater effect from the use of stimulant medication as a result of the lower dopamine levels (Andersen, 2005).

It is possible these same differential effects could be seen after MVPA. MVPA has been shown to increase (up-regulate) the production of dopamine in the synapse (Tantillo et al., 2002). Going back to the analogy of the sink, rather than plugging the drain, MVPA appears to turn up the faucet and produces more dopamine. Increases in dopamine may suggest a theoretical hypothesis for explaining increases in attention seen in children with ADHD after MVPA. As children with ADHD participate in MVPA, their levels of dopamine may increase leading to a more optimal state of functioning as OST suggests.
Adding to the theory, animal studies suggest after MVPA, dopamine levels will dissipate over time. Some research involving other human populations suggests the benefits of an increase in dopamine diminish within 90 minutes (Celiberti et al., 1997; Kern et al., 1982). This may suggest that the academic and behavioral benefits of MVPA may diminish over time.

**MVPA and Executive Functioning of Students with ADHD**

As stated earlier, children with ADHD exhibit multiple deficits in EF. These deficits fall into two main areas: inhibition and updating. One means of determining if MVPA can improve EF processes is through research examining event related potential (ERP) data. ERP research involves presenting a stimulus to a participant while wearing an array of electrodes on the head and recording electric impulses that occur. Electric impulses produce waves with peaks and troughs that are graphically displayed and compared.

Research has identified one element, the P3 waveform, as a possible indicator of attentional, inhibitory and updating processes (Polich, 2007; Polich & Lardon, 1997). It has been theorized P3 amplitude is sensitive to the amount of attentional resources utilized during task performance (Polich, 2007). That is, the stronger the amplitude of the P3 waveform, the more attentional resources are brought to bear on a given task. Thus, increases in magnitude are indicative of increased attention and inhibition (Higashiura et al., 2006; Polich, 2007; Yagi, Coburn, Estes, & Arruda, 1999). ERP research with typical students has shown differences in P3 amplitude after college age students perform MVPA, suggestive of an increase in attentional resources (Hillman et al., 2003; Kamijo et al., 2004; Magnié et al., 2000). Past research suggests reductions in P3 latency represent mental function speed: shorter latencies are related to superior cognitive performance, or improvements in updating (Polich, 2007; Yagi et al., 1999). Again, college age participants demonstrated reductions in P3 latency, suggesting improved mental processing speed (Magnié et al., 2000). These changes in amplitude and latency are seen at all recording sites along the scalp, suggesting a global arousal response not focused on one area of
Recent studies have examined the effects of MVPA on the P3 waveform. The first study examined magnitude and latency of P3 to assess changes in EF for participants with ADHD. Twenty children ages 8 - 10 ran on an indoor treadmill at a moderate pace (65-75% maximum heart rate) for 20 minutes (Hillman et al., 2003). Participants then performed an Eriksen Flanker task to measure changes in P3 magnitude and latency. The Eriksen Flanker task is a response inhibition test assessing one's ability to suppress a dominant response in favor of a target response (Eriksen & Eriksen, 1974). After exercise, there was an increase in P3 amplitude and a decrease in P3 latency at all recording sites, again suggesting a global increase in arousal. Results support previous research, and extend it to an ADHD population suggesting a single bout of MVPA has an enhancing effect on allocation of attentional resources (P3 amplitude) and improved processing speed (P3 latency). Results across all recording sites suggest exercise increases arousal levels across the brain and not limited to one region.

Using a within-participants design, a recent study showed a single bout of MVPA had positive effects on neurocognitive and inhibitory control using a modified Eriksen Flanker task for students with ADHD (Pontifex, Saliba, Raine, Picchietti, & Hillman, 2013). After a single 20 minute bout of MVPA children with ADHD showed increased P3 amplitude and reduced P3 latency, which resulted in improvements in reading comprehension and math. Recently, in a 9 month randomized controlled physical activity intervention, 222 seven to nine year old children showed only the intervention group (n=109) increased P3 amplitude and decreased P3 latency (Hillman et al., 2014). This study did not control for ADHD. However, 43% of the intervention group consisted of children with ADHD.

Taken as a whole for both typical children as well as child with ADHD, data looking at the P3 waveform suggest MVPA increases allocation of attention resources (magnitude) and increases mental functioning (latency) related to superior cognitive abilities, which results in
improvements in classroom academics.

In addition to neuroscience studies, there are several classroom intervention studies conducted with children with ADHD showing changes in EF. These studies have examined variables such as duration of MVPA, age of participants, type of MVPA and types of tasks used to measure two key variables related to EF, inhibition and updating.

Exercise produces effects that are robust across many variables. Ages in studies ranged from 5-15 years, and all demonstrated a positive shift in elements of EF. Also noteworthy is the finding that effects of MVPA are independent of effects of stimulant medication. In a clinical setting, 25 children diagnosed with ADHD participated in a single episode of MVPA and demonstrated significant improvements in response time and on measures of shifting and inhibition.(Medina et al., 2010). Participants in this study taking stimulant medication had similar results to those who were not taking medication. Furthering the role of stimulant medication, a randomized controlled trial involving 28 children with ADHD had all medication naive participants start taking stimulant medication at the onset of the study (Kang, Choi, Kang, & Han, 2011). Results showed only the MVPA intervention group improved on measures of shifting and updating. These results suggest the benefits of MVPA can be adjunctive to those of stimulant medication.

Various tasks were used to assess changes in EF, most tended to be clinical research tools. However, a recent study used a unique task that may benefit classroom teachers in quickly assessing changes in EF, specifically inhibition. This research had young children with ADHD in grades K-3 participate in an eight-week intervention (Smith et al., 2013). In each session, children completed 26 minutes of aerobic games (e.g. tag). To assess changes in EF researchers had children play a recess game of Red light/Green light. This task showed measurable improvements in response inhibition. For teachers, this is particularly noteworthy as a task to observe, in their own classroom, the effectiveness of MVPA for students with ADHD.
Inhibition. Six of eight studies used tasks related to inhibition. For example, Chang and colleagues (2012) asked children with ADHD ages 8-13 years to participate in treadmill running for 30 minutes. These researchers found children had an improved allocation of attentional resources as assessed by measures of inhibition after exercise (Chang et al., 2012). Perhaps the most significant applied finding from this study is a single 5-min bout of MVPA can improve EF. In a similar study, children with ADHD jumped on a mini-trampoline for 5 minutes at a vigorous rate (Gawrilow et al., 2013). This single 5 min bout of MVPA resulted in improved response inhibition and fewer errors on a sustained attention task. In a descriptive study, Gapin and Etnier (2010) found overall activity levels predicted children's planning (a sub-component of updating) and response inhibition. This study did not alter activity levels but used accelerometer data from 18 children ages 8-12 to determine if MVPA could be a predictor of improvements in EF. Results suggested improvements in EF were of the same magnitude as differences between ADHD and non-ADHD children. Other measures of updating and inhibition showed improvements after MVPA, but did not reach statistical significance (Gapin & Etnier, 2010).

Updating. Improvement in updating was demonstrated in three studies (Chang et al., 2012; Kang et al., 2011; Verret et al., 2010). In one study, children diagnosed with ADHD participated in a 10 week MVPA program, and showed improvements in updating including improved information processing and faster visual search, leading to improvements in sustaining attention (Verret et al., 2010). Significant to educators, both parents and teachers reported improved behavior after the physical activity intervention. Similarly, latency of responding was reduced on an updating task compared to the non-MVPA control group in two additional studies (Chang et al., 2012; Kang et al., 2011).

Conclusions of Executive Function on MVPA

Using measures of EF, research suggests that MVPA can serve independently or in conjunction with other interventions to improve classroom behavior and academic performance
for children with ADHD. Students with ADHD appear to show an increase in attentional resources after participating in MVPA. Results of this review suggest physical activity may be one possible solution for improving EF deficits in children with ADHD. In summary, there is evidence MVPA can be effective at improving EF resulting in improved inhibition, updating and shifting; leading to improvements in behavior and academic engagement for children with ADHD.

**SCD Studies on MVPA**

Results of SCD studies suggest MVPA has potential for curtailing inappropriate classroom behaviors and increasing academic engagement for students at risk for or diagnosed with behavioral and emotional disturbances (Azrin et al., 2006, 2007; Bass, 1985; Cannella-Malone et al., 2011; Etscheidt & Ayllon, 1987; Morand, 2004; Yell, 1988). However, consideration of group design studies adds weight to findings of SCD studies. When considering the level of evidence from reviews of group design studies and comparing it to those found in SCD studies there is a chorus of agreement in effectiveness of MVPA as an intervention for children with ADHD.

Studies were analyzed to determine if they contained elements that have been deemed critical for creating a quality body of research. Kratochwill and colleagues (2010) developed a list of five quality indicators necessary for a study to be deemed "high quality". Canella-Malone (2011) alone contained all elements. With the inclusion of a measure of IOA three more studies would have joined the "meets evidence standards" group ($n = 24$).

Guidelines for determining a body of research to be an evidence based practice require a minimum of five studies meeting acceptable methodological criteria, by at least three different researchers, with at least 20 participants (Horner, Carr, Halle, & McGee, 2005). With only one study meeting acceptable methodological criteria, there is not enough evidence to support use of MVPA as an evidence-based practice, based on SCD studies alone. However, intent of the current
section on SCD is to situate findings within context of existing group design studies. These reviews show positive benefits for behavior and academic engagement for students with ADHD and other behavioral difficulties (Allison et al., 1995; Chang et al., 2012; Medcalf, Marshall, & Rhoden, 2006; Medina et al., 2010; Mehta et al., 2011; Verret et al., 2010).

**Overall Conclusions**

For teachers, exercise may help to alleviate problem behaviors of students in the classroom. Current research highlights some variables that may be particularly important for developing an intervention in the classroom. First, benefits of exercise can be seen with even short episodes of exercise. Positive results were observed with durations as short as five minutes. For teachers with limited time and large demands to increase time on task, short episodes of exercise may be more appealing. MVPA has been associated with better grades (Taras, 2005). Time away from academics while engaged in MVPA has been shown to not adversely affected academic performance in other populations (Dwyer et al., 1983; Sallis et al., 1999). Second, analysis suggests effects of exercise appear to be stronger for elementary age students, suggesting interventions be started early. Third, analysis revealed stronger results may be seen when using a variety of activities with varied intensity. Finally, consideration should be given to creating a program that is sustained over time. This appears to prolong behavioral improvements while increasing academic engagement.

Teachers have a dilemma in finding effective and efficient ways to deal with behavior problems. Lost potential of students with behavior issues increases need for an effective way to improve classroom behavior. SCD and group design studies in EF indicate exercise may improve behavior for students diagnosed with ADHD and those who exhibit ADHD-like behavior. Potential benefits of this intervention could justify potential time spent away from academics, through increases in engagement and decreases in problem behavior.

Given that we know little about the effects of MVPA on early elementary age children
with ADHD, how that MVPA should occur over time, and the duration of effects from MVPA, the purpose of this study is to examine the effects of MVPA on academic performance and classroom behavior for this group of students.
EDUCATION

PhD 2015  Special Education  Pennsylvania State University
Cert 2010  Special Education Certification  University of New Hampshire
MEd 1999  Instructional Technology  Utah State University
BS 1994  Elementary Education  Brigham Young University

SELECTED PUBLICATIONS


SELECTED PRESENTATIONS

Hart, J. L. (2015, May) Exercise in schools and how it can benefit children with ADHD. Invited presentation. Department of Educational Psychology, Counseling, and Special Education Graduate Exhibition of Research; College of Education, Pennsylvania State University.
Hart, J. L. (2014, May) Variables of importance in creating an exercise program for improving behavior in ADHD and EBD students. Accepted presentation, Behavior Analysis Research Colloquium, Mercyhurst University.

AWARDS/HONORS

2014  3rd Place award in university wide Graduate Student Research Contest. Presentation of results: Exercise and children with or at risk for behavior problems: A meta-analysis of single subject studies.
2010  ETS Recognition of Excellence award for outstanding score on Praxis II: Elementary Education: Content Knowledge.
2009  Awarded Annie Fords Up Syndrome Scholarship. $1,500 support for continued education at the University of New Hampshire in Special Education.